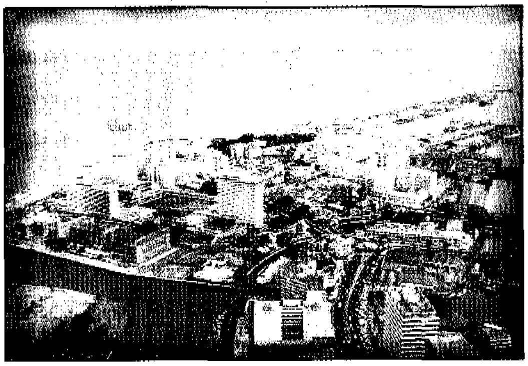
NATURAL RESOURCES OF SRI LANKA

Conditions and Trends



A REPORT PREPARED FOR THE NATURAL RESOURCES, ENERGY AND SCIENCE AUTHO

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A REPORT PREPARED FOR THE NATURAL RESOURCES, ENERGY AND SCIENCE AUTHORITY OF SRI LANKA. 1991

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1 INTRODUCTION

Can Sri Lanka achieve a future of environmentally sustainable development? What, in fact, constitutes "sustainable" development, and what are the environmental conditions essential to achieve it? Should present policies and programs change? Answers depend on how well we understand the conditions of Sri Lanka's natural resources and the dynamic changes that affect them.

This profile describes these conditions and trends at a critical time. A tropical island in the Indian Ocean, smaller than Scotland or Tasmania and half the size of the State of New York, Sri Lanka nonetheless possesses infinite variety, rich scenic beauty, unusual water, mineral, and biotic resources, and an ancient cultural heritage. These attributes exist today with a population of some 17 million people, which places Sri Lanka second after Bangladesh in population density among developing countries.

Unmistakable signs of environmental stress in Sri Lanka are now cause for serious concern. They include loss of natural forest cover, contamination of waters, degradation of rural lands, and rising levels of air, water, and solid waste pollution. A projected population of 25 million by 2040 will create unprecedented demands for food, fiber, energy, developable land and other natural resources. Without prompt management actions, these demands will aggravate the negative trends.

Sri Lanka might respond by enhancing the social benefits that can be sustained from natural systems of land, water, wetlands, and their biological resources. It can increase its wealth by avoiding costly environmental abuse. Significant new laws and programs have begun to shift in this direction. Actual results will depend in part on how well planners, decision makers, and citizens apply what they know about Sri Lanka's natural resources.

This profile will provide concerned citizens in and out of government with the best available information on significant natural resource conditions and trends in Sri Lanka. It builds on findings of the *National Conservation Strategy* and fills gaps in other recent studies on the environmental and economic dimensions of development. It should help government and private sector institutions identify and rank national priorities for action when they face a dauntingly vast number of environmental problems, demands, and choices.

For practical reasons this conditions and trends assessment is considered in discrete pieces, but true perspective and sound policy also require understanding of complex interactions among ecological, and social systems over time and space. This introduction follows with an overview of Sri Lanka's setting and the relationships of her resources to her people. The subsequent chapters, with their tables and graphics, describe important conditions and trends in detail. Chapter 2 describes the ancient heritage of Sri Lanka -- a history of irrigated agriculture and forest use that strongly affects Sri Lankans' present political, social, and environmental perspectives. Three subsequent chapters describe the dynamic factors of population, economics, and energy use that most strongly affect natural resources. Subsequent chapters then focus on natural resource conditions and trends affecting physical and biological resources, and the environmental pollutants that threaten productive and sustainable resource use. Each chapter addresses institutional responses and experiences. The concluding chapter describes the environmental stresses likely to affect Sri Lanka in the future and the opportunities and paths for achieving sustainable development.

To supplement these chapters, topical "boxes" interspersed throughout the profile give readers a more integrated perspective on many significant conditions and trends discussed in the chapters.

This profile is only a beginning. The contributions of more than a score of Sri Lanka's best scientists and experts to this profile indicate deficiencies in information and analysis that need prompt attention. Wise economic, social, and environmental decisions will require long-term efforts to refine and enlarge Sri Lanka's body of practical environmental information and analysis. Fortunately Sri Lanka's growing community of environmentally concerned citizens and professionals have the capacity to fill these gaps.

NATURAL RESOURCES AND THE HUMAN ENVIRONMENT OF SRI LANKA

Geographical Setting

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

From the middle of the first millennium B.C. to well after the first millennium A.D. Sri Lanka sustained an advanced hydraulic civilization centered around village tanks and irrigation schemes, described in Chapter 2. The island was dominated by successive European sea powers beginning with Portugal from the early sixteenth century to the mid-seventeenth, followed by the Netherlands until the end of the eighteenth century, and finally Britain until Independence. The last Sinhalese king reigned until 1815, and Sri Lanka was not independent again until 1948.

Physical Features

Sri Lanka's development has been largely determined by the natural and economic attributes of its physical features. Based on elevation and nature of the terrain five geomorphic regions can be identified: the coastal fringe, the central highlands, the southwest country, the east and southeast, and the north central lowlands.

The chapter on coastal resources describes a coastal fringe consisting of estuaries, peninsulas, beaches, and offshore islands that support 90 percent of the fisheries, most of the tourism and industry, agriculture, and human settlements. The length of the coastline open to the sea, including that of the bays and the shores of the offshore islands, is about 1,600 kilometers. Koddiyar Bay (Trincomalee) is one of the finest natural harbors in the world, but Colombo itself has become an important commercial port. The continental shelf skirting the island forms a narrow ledge of approximately 20 kilometers along the western, southern and eastern coasts, while to the northwest it is continuous with that of peninsular India.

The central massif from which headwaters of all Sri Lanka's major rivers originate, as described in the chapter on water resources, is a compact physiographic unit bounded on the south by a high mountain wall with precipices offering magnificent views toward the sea from World's End. Sri Lanka's highest point is over 2,524 meters at Piduruthalagala Peak. The Horton Plains, now an important national park, is the best known of several high-plain surfaces in the island. Until the coming of nineteenth century plantation agriculture, natural forests and grasslands covered this region. Today these areas are covered largely by rubber, eucalyptus, or pine; natural forests are small and scattered. Evidence of upland soil erosion and overuse of pesticides and fertilizers creates potentially serious but still poorly understood problems for downstream land and water use, including water for drinking, irrigation, and hydroelectric generation. Major aspects of these conditions and trends are described in chapters on land, water, forestry, and inland aquatic resources.

Topography of the southwest -- the other part of Sri Lanka's Wet Zone -- is characterized by long parallel ridges cut by the rivers beginning in the hill country. This is the most densely populated region. The Forest Resources chapter describes its rapid deforestation; natural forests now cover only 8 percent of the wet, intermediate and montane zones. The 47,370-hectare group of Sinharaja forests is the last remnant of the once-vast southwestern rain forests. The chapter on biological diversity describes the rich flora and fauna of this region.

Rolling hills, undulating plains, and isolated residual hills characterize Sri Lanka's eastern and southeastern lowlands. The coastal fringe has important fisheries and the region contains large parks and wildlife refuges that are home for wild elephants. Together with the north central lowlands it contains an estimated 2.5 million hectares of land that are considered capable of development for forestry, agriculture or human settlement.

The north central lowlands are somewhat similar to those in the east, with massive residual rocks such as Sigiriya, adorned by its monuments of fifth century civilization. Here Sri Lanka's hydraulic civilization flourished, and continues to be a center of archaeological and tourist interest. The Mahaweli Ganga, which drains about 16 percent of the island, has its floodplain in this region, one of Sri Lanka's most important wildlife and agricultural attributes.

Sri Lanka is endowed with lands that can be highly productive so long as they have adequate water. Over two-thirds of the land area is flat or undulating with gentle slopes; extremely steep lands with slopes over 60 degrees gradient comprise only 1 percent of the land. About one-third of Sri Lanka is put to agricultural use. Forests and wildlife use another third, and the rest is under transportation, human settlements, and a variety of other uses.

Most gently sloping lands are within the agriculturally rich areas of the Dry Zone, but agriculture is also important in the central hill country where slopes range from 30-60 percent. Plantation agriculture has flourished there since the beginning of the British colonial era. Sections of the Land Resources chapter focus particularly on rice paddy and tea plantation agriculture in these two regions; the Economics chapter describes their importance to the nation's economy. Impacts of Sri Lanka's oldest form of agriculture -- shifting *(chena)* cultivation -- are also significant, however. About 18 percent of the island, including lands on steep slopes, is devoted to *chena* cultivation, which, as now practised, contributes to significant soil erosion and most of the apparently increasing symptoms of land degradation. *Chena* problems and prospects are described in the chapter on land and in several topical boxes.

Geology

Beneath Sri Lanka's landscape lie some important minerals, most notably its world-famous gems, and other minerals as yet only modestly exploited. No oil or coal can be found under the land mass, although petroleum may exist offshore.

Sri Lanka, like the Indian peninsula and Antarctica, formed part of Gondwanaland in the distant geological past, and it was never fully submerged by the sea. The only major marine transgression was in Tertiary times when Miocene sediments were laid down in the northwestern belt of the island, including the Jaffna Peninsula. As a result, nearly 90 percent of the area of the island is not covered by any sedimentary rocks. Precambrian rocks consist predominantly of a sedimentary succession of a variety of metamorphosed sedimentary rocks that are conventionally divided into two groups on the basis of their lithology and structure -- the Highland Series and the Vijayan Series. Miocene formations cover large areas in the northwest and in the Jaffna Peninsula. They are important aquifers used extensively in the north for irrigation.

Among the superficial deposits of recent origin in many parts of the country are alluvium on the river floodplains and loose unconsolidated sands in the coastal belt. As the Mineral Resources chapter describes, these superficial deposits are economically important not only as grass lands and agricultural lands but as sources of gems, heavy mineral sands, and industrial clays.

Climate

As tourists come to know, Sri Lanka's tropical location ensures uniformly high temperatures throughout the year, but influence of the sea makes the island free from the temperature extremes experienced by continental interiors. Although mean annual temperatures in the lowlands are around 27°C, with a mean daily range of about 6°C, ground frost can sometimes appear in Nuwara Eliya in the central highlands, where the mean annual temperature is 15°C. In most parts of the country daily temperature ranges are more significant than the seasonal change.

Unlike conditions in mid-latitudes of the globe, seasons in Sri Lanka bring almost unnoticeable temperature fluctuations. Seasonality primarily results from variations in the rainfall rhythm, but because Sri Lanka is a predominantly agricultural country rainfall distribution over time and space is of great concern.

Climatologists divide Sri Lanka's climatic year into five seasons:

- *The convectional-convergence period* (March to mid-April), when the island comes under the influence of the Inter-Tropical Convergence Zone. This is a constant daily weather sequence with bright clear mornings that induce convectional activity leading to the formation of rain clouds by early afternoon and thunderstorms in the late afternoon.

- *The pre-monsoonal period* (mid-April to late May), has transitional weather patterns. During this time convectional weather is gradually suppressed by surges of the southwest monsoon.

- *The southwest monsoon period* (late May to late September), which brings the largest amount of rainfall to the southwestern lowlands and

- windward slopes of the central highlands, where some places receive over 5,000 millimeters annually. The southwestern monsoon blows across the northern, north central, and southeastern lowlands as a dry, desiccating wind.

- *The convectional cyclonic period* (late September to late November), which begins to appear with the weakening of the southwest monsoon. Unlike the convectional weather in March-April, this period can include cyclones. When combined with convectional weather, cyclones occasionally produce periods of heavy rainfall causing widespread floods and landslides.

- *The northeast monsoon* (November to February), has a weak and dry wind compared with that of the southwest monsoon. However, the northeast monsoon brings agriculturally significant rainfall to the northern and eastern parts of the country.

Conventionally Sri Lanka recognizes two distinct climatic regions -- the Wet and Dry Zones -- although precise demarcation is subject to academic debate. Application of the term "Dry Zone" to an area that receives over 1,000 millimeters of rainfall can be misleading, however, and tends to create a psychological barrier to the human settlement and development of its resources. In addition some have identified an "Intermediate Zone" between the 'Wet' and 'Dry' zones, while others have chosen to depict the coastal areas of the northwest and those in the southeast as "arid zones."

Hydrology

Sri Lanka's rains feed a radial network of rivers that begins in the central highlands. Some 103 distinct river basins cover 59,217 square kilometers. The rest of the land is practically devoid of surface water basins of any significance (Arumugam, 1969). Most identifiable stream basins are less than 100 square kilometers and many carry water only during the rainy season.

The chapter on water resources describes the critical factors that determine how much surface water is actually or potentially available to Sri Lankans before it evaporates or reaches the sea, and how much can be obtained from the ground water recharged by the rains. Sri Lanka receives about 12 million hectare meters of water annually from rainfall, of which more than 50 percent is lost through evapotranspiration. Another 20 percent seeps down to replenish ground water. Only 30 percent, or about 3.5 million hectare meters, is available as stream flow for irrigation or other purposes.

A substantial proportion of surface water is already used for irrigation and hydropower generation. The chapter on inland aquatic systems describes how many of these uses have already affected the fishing and wildlife productivity of inland marshes, tanks and other waters that constitute an unusually high proportion of Sri Lanka's surface area. Land use in catchment areas affects the quality of these waters. Sedimentation may ultimately reduce original estimates of the lifetimes of dams and irrigation systems. Although water shortages constrain developments in the Dry Zone, excessive water flow in the Wet Zone often poses serious problems of flooding and inundation, aggravated by floodplain settlement and misuse of uplands.

Use and development of water resources has been an integral part of Sri Lanka's heritage, as described in the Inland Aquatic Resources chapter. About 12,000 small village tanks now irrigate some 269,000 hectares mainly in the Dry Zone. Since ancient times they have been recognized as valuable sources of fish. Inland reservoirs now provide about 20 percent of Sri Lanka's fish production.

Large-scale development of water resources for irrigation and hydro-power progressed rapidly during the last fifty years. Today largely because of dams on the Mahaweli, hydro-power provides 90 percent of Sri Lanka's electric energy. The large reservoirs irrigate over 500,000 hectares of land, and have an aggregate installed capacity of 938 Megawatts (1988). But opportunities for projects of large-scale water resource development, with a few limited exceptions, have been exhausted with the Mahaweli Development Programme. Now attention must focus largely on opportunities for small hydro-generation and more efficient use and distribution of existing water resources and developments.

Pollution of Sri Lanka's waters, described in the section on water degradation, occurs throughout the island from domestic, industrial, and agricultural sources. Problems appear to be increasing. Health impacts are a basic indicator of this problem, but comprehensive data are inadequate. Less than 25 percent of Sri Lankan households have access to pipe-borne water. The large majority still depend on water from wells, while about 7 percent draw water from rivers and reservoirs for domestic use. Industrial waste is in most cases untreated. Sri Lanka's only sewers exist in Colombo, serving about 20 percent of the larger Colombo metropolitan region of 1.8 million, but none of the discharge is treated.

Ground water provides an increasingly important source of water for irrigation and domestic use. Contamination of wells from improper waste disposal is a rising concern in rural and urban areas. In the north central region investments in tube wells have substantially increased in recent years, but data and analysis of ground water conditions and trends indicate serious deficiencies. In Jaffna, however, symptoms of over-exploitation as well as contamination of well water from urban discharges and agro-chemical use threaten populations and economic development. These impacts are described in a topical box.

People

At the last census (1981) Sri Lanka had a population of 14.9 million and at present it is estimated to be nearing the 17 million mark. The great majority (75 percent) of the people are Sinhalese. The Tamil population accounts for 18 percent including those in the estate sector, who are descendants of the workers from India brought to Sri Lanka by the British in the nineteenth century to work on plantations. The Moors, mostly Tamil-speaking, form the next largest minority comprising 7 percent of the population. All other minorities, including Burghers (descendants of Dutch and other Europeans), Eurasians, and Chinese, account for less than one percent, but remain as distinct ethnic groups.

The growth and distribution patterns of Sri Lanka's population are described in detail in the chapter on population. Population has increased from 2.76 million in 1881 to the present 17 million, recording a sharp increase particularly after Independence. It is projected to reach about 20 million by the end of the century and to level off at about 25 million by 2046.

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 per square kilometer, it varies considerably from 50-3,000 between the areas of lowest and highest densities.

Most Sri Lankans live in villages. Despite a steady flow of migration from rural to urban areas, the urban component of the population has remained virtually static at about 22 percent during the past decade. These trends have been expected to change with industrialization and scarcity of available rural land, and may reach 30 percent by the end of the century, which translates into an 88 percent increase in Sri Lanka's urban population over its present urban component. Most of this increase will occur in the urban fringes, where public services are already under stress.

The spoken language of the large majority of the people in Sri Lanka is Sinhala, while Tamil is the dominant language in the north and to some extent in the eastern and central regions. Use of English is most widespread among urban and educated classes, while it serves as a link language between different linguistic groups. Nearly 70 percent of the people are Buddhists, 15 percent are Hindus, and the balance is equally divided between Muslims and Christians.

Civil disturbances since 1983 in the north and east, and from 1987-1989 in other parts of the country, have affected natural resources and their management in many ways. One consequence has been an inability to carry out essential data gathering and field studies, including analyses of coastal, wildlife, forestry, and water resources. Other impacts include significant restrictions on resource management and enforcement. Profile chapters allude to many of these constraints.

The Economy

Since Independence Sri Lanka has achieved a high level of literacy (85 percent), a low rate of infant mortality and a high level of life expectancy at birth. Sri Lanka's economic performance until recently has been characterized by low output and poor employment growth in contrast to other countries that have grown rapidly; in 1960 Sri Lanka was more prosperous than South Korea and in 1970 more prosperous than Taiwan. As described in the chapter on the economy, real Gross Domestic Product (GDP) grew at 2.9 percent per year from 1971-1977. From 1978-1986, however, it grew at 5.6 percent per year under a more liberalized economy and with substantial new foreign assistance and investment, including support for the Accelerated Mahaweli Development Project. Civil disturbances brought sharp declines from 1987-1989, when GDP grew at 2.2 percent per year.

In spite of changes since the late 1970s Sri Lanka remains primarily an agricultural country. Agriculture accounts for over 25 percent of the total GDP, nearly half the total employment and export earnings, and about 40 percent of government revenues. Over 90 percent of the rural population directly or indirectly depends on agriculture. Traditionally agriculture has consisted of the export-oriented plantation sector -- primarily tea, rubber and coconut -- and the household farmer sector, growing mainly paddy and subsidiary food crops for domestic consumption. Many varieties of fruits, vegetables and potatoes are grown in the hill country areas. A highly productive home garden system based on traditional land use patterns remains important and can be replicable in many parts of the island.

Available information indicates that 27 percent of rural households are landless, 42 percent of the holdings are less than half a hectare. These statistics paint a distressing picture of the rural scene, and indicate some of the pressures that are exerted on the natural resource base.

Plantation crops spread over about 800,000 hectares, particularly in the hill country and the wet and intermediate climatic zones. Although areas under all plantation crops, particularly rubber, have declined significantly over the last three decades, they remain important sources of export earnings. Several other perennial crops such as cocoa, coffee, cinnamon, cardamom, pepper, nutmeg and cloves, often referred to as "minor export crops," have recently become significant exports.

The industrial base is narrow. Major manufacturing industries, still primarily operated by the government, include cement, steel, paper, tires and ceramics. With the launching of the Free Trade Zone, the garment industry has gained prominence through private investment. Although foreign investment and external collaboration have given Sri Lanka access to important export markets, particularly for garments, other industries have not yet expanded sufficiently to provide solutions to the twin problems of poverty and unemployment. Yet, as the chapters on population and the economy make clear, Sri Lanka needs to create two million new jobs over the next decade to match population increases and relieve pressures on the land.

Constitutional and Administrative Structure

Management of natural resources has increasingly depended on national administrative and legal structures. The Democratic Socialist Republic of Sri Lanka is a unitary state whose legal and administrative structure is based on its republican constitution. The national Constitution (1978) forms the supreme law under an Executive Presidency and a single house of Parliament.

Sri Lanka consists of 25 administrative districts and nine provinces. The hierarchy of regional administrative divisions that supports the central government now consists of Provinces, Districts, Divisions and Grama Niladhari units, in descending administrative order and area.

The Thirteenth Amendment to the Constitution in 1987 provided for devolution of power to the provinces, and this process, potentially significant for natural resource management, is still underway. Provinces are now the fundamental administrative units of regional governance, and they have concurrent jurisdiction with the central government over the protection of the environment, soils, coastal fisheries, and wildlife, among other resources. Districts still form the basic units in the parliamentary election process, but they have lost much of their traditional local authority. The Kachcheries that once formed the hub of district administration may continue to function as administrative arms of the Central Government with a reduced staff and resources.

At the village administrative level significant changes are also taking place. The former Grama Seva Niladhari Divisions have been made smaller, and a unified village-level administrative service has been introduced by bringing together the former Grama Seva Niladhari, Vaga Niladhari (Cultivation Officer) and Visesa Seva Niladhari (Special Services Officers) into one rank, renamed as Grama Niladhari.

The authorities in the Central Government executive structure rank from the President to the Cabinet of Ministers, Project Ministers and State Ministers, and from Governors to Chief Ministers and their Cabinets at the provincial level. The elected government officers in Sri Lanka are the President, Members of Parliament, and Members of the Provincial Councils. In the hierarchy of administrative officials, Secretaries to the Cabinet, Project and State Ministers, Heads of Departments and Corporations function at the central government level. Chief Secretaries and Secretaries to provincial ministries operate in the provinces. The Divisional Secretaries (former Assistant Government Agents) and the Grama Niladhari carry out vital functions at the divisional levels.

Translation of government policy into action is often entrusted to the bureaucracy, which has established its own norms for administrative and financial procedures. No cadre of environmental professionals exists, however, within the Sri Lanka Administrative Service.

Legal Structure Affecting Natural Resource Management

Article 28 of the Constitution states that "it is the duty of every person in Sri Lanka to protect nature and conserve its riches." To help implement this goal Sri Lanka has over 100 statutes directly or indirectly important to natural resource management and environmental protection.

Compared with most developing countries, Sri Lanka has a long history of natural resource legislation. Laws supplement village traditions of resource use that operate in many parts of the island and may be most significant in coastal fisheries. Some of the statutes date back to the middle of the last century, including the Crown Lands Encroachment Ordinance of 1840, Irrigation Ordinance of 1856 and the Thoroughfares Ordinance of 1861. Among the more prominent pieces of legislation related to natural resources are the Forest Ordinance of 1907, the Land Development Ordinance of 1935, Fauna and Flora Protection Ordinance of 1937, Mines, Quarries and Minerals Ordinance of 1947, Crown Lands Ordinance of 1947, and the Soil Conservation Act of 1951. More recently, Parliament enacted the Coast Conservation Act of 1981, the National Aquatic Resources Act of 1981, the National Heritage and Wilderness Act of 1987, and the National Environmental Act of 1980, which was amended in 1988 to require environmental impact assessments and licenses for industries potentially producing air, water, and land pollution.

The large numbers of government entities responsible for implementing environmental laws, and the gaps, overlaps and needs for cooperation and coordination that make this task difficult, are noted in each chapter.

Key Issues in Natural Resource Management

Each chapter that follows raises major challenges that confront Sri Lanka as it grapples with environmental stress caused by rising population and increased demands on natural resource systems. Underlying these challenges are several key issues and questions that run through the text, and these are also addressed in the final chapter.

One issue concerns how to obtain and use information on environmental conditions and trends in the most cost-effective manner possible. Whether the topics concern causes and effects of land, water, air, or biological resource degradation or other topics, they give rise to difficult but important practical questions. These include: who should gather and analyze the information, how should it be made available to all who need it, and how can it best be used for making decisions?

A second issue concerns how to obtain informed public debate about the nature and direction of environmentally sustainable development in Sri Lanka. What are the essential elements of environmental conservation around which different interest groups can agree? Should, for example, development projects and investments focus most strongly on creating new employment that is environmentally sustainable, or on ways to maximize environmental benefits or agricultural productivity? Where should industrial growth occur -- in Colombo, in smaller cities, in villages? How should concerns for decentralization of authority or distributive justice affect the components of sustainable development?

A third basic issue concerns needs for effective implementation of environmental objectives by governmental and non-governmental entities. Nearly every chapter of this profile highlights the proliferation of agencies and other institutions involved in some aspect of land, water, or other natural resource. How can these resources be managed more effectively -- more efficiently -- given increased threats of environmental degradation, and needs for productivity? How can information on environmental costs and benefits be integrated into government and private sector economic decisions? What greater roles are possible by citizens, villages, businesses, and others? How should and could government change its role *vis a vis* the environment?

We can be sure of one thing. Responses to these issues and questions will unfold over the next decade. By the turn of this century Sri Lanka will have made significant, in some cases irrevocable, environmental decisions affecting its future development.

Among the many ancient monuments of Sri Lanka's hydraulic civilization are these ruins at Yapahuwa

2 Heritage in Natural Resource Management

Sri Lanka's history of natural resources management and conservation has few parallels even among countries with old civilizations. Until the arrival of settlers around the fifth century BC, Sri Lanka was affected only by prehistoric man. The few studies of its primeval landscape (Noon & Noon, 1941; Perera, 1975) suggest that the prehistoric Bandarawelian community used stone implements capable of clearing the forests and practicing a form of *chena* cultivation, possibly leading to the creation of some *patana* grasslands. Nevertheless, impacts on prehistoric man on the landscape and natural resources appear insignificant.

The legendary story of civilization in Sri Lanka begins when the island was inhabited by people of the original tribes Yakka, Raksa, and Naga. These early people gradually developed systems of sedentary agriculture based on irrigation, and folklore maintains that the Yakkas built some ancient irrigation tanks. By the arrival of Vijaya, a prince from North India, around 500 BC, small-scale irrigation systems were already operational (Figure 2.1).

The early Vijayan settlers probably harnessed the skills of local inhabitants, predominantly Yakkas, to construct irrigation works and clear forests. In time these Yakkas merged with the Sinhalese to form a single community; those who resisted assimilation probably retreated to the interior forest and rock fastness, where jungles sustained them. The Nagas also integrated with the Sinhalese, but the Naga culture left a lasting imprint, particularly on water resources development. Some believe that the multi-headed cobra symbol often discovered at the sites of ancient irrigation structures and other water works, was the insignia of a Naga line of royalty well versed in hydraulic engineering.

Hydraulic Civilization

The early hydraulic societies thrived on small irrigation systems with unique assemblages of land uses and agricultural attributes (Leach, 1959). Possibly these systems evolved from early rain-fed shifting agriculture into small-scale irrigation that, in turn, led to major systems. The sedentary way of life facilitated by this hydraulic base led to land tenure, property inheritance, and social organizations that persisted for centuries. Community leadership patterns had to be strong and effective with increasing size and complexity of irrigation systems. These conditions eventually led to centralized authority representing a form of "oriental despotism" (Witfogel, 1959).

Conveyance of irrigation water over long distances needed efficient control over distribution and allocation between the top- and tail-ends of the system. Smooth functioning of all hydraulic structures required efficient maintenance. Irrigation depending on micro-catchments required careful watershed management to reduce siltation and ensure catchment water yields. The land and water use system that developed over centuries to satisfy these requirements has been described as a "cascading system" (Madduma Bandara, 1985).

Organization of small tanks into a cascading sequence within micro-catchments allowed greater efficiencies in water use (see Figure 2.2). Drainage from the paddy fields in the upper part of the cascade flowed into a downstream tank for reuse in the paddy fields below. The system fully expressed the well known dictum by the King Parakramabahu (AD 1153) that "not a single drop of water received from rain should be allowed to escape into the sea without being utilized for human benefit."

System management required community effort and coordination. A breach in the upper-most tank bund through neglect or excess water would threaten the collapse of the entire sequence of tanks below. Similarly, if the capacity of a tank was increased ar-

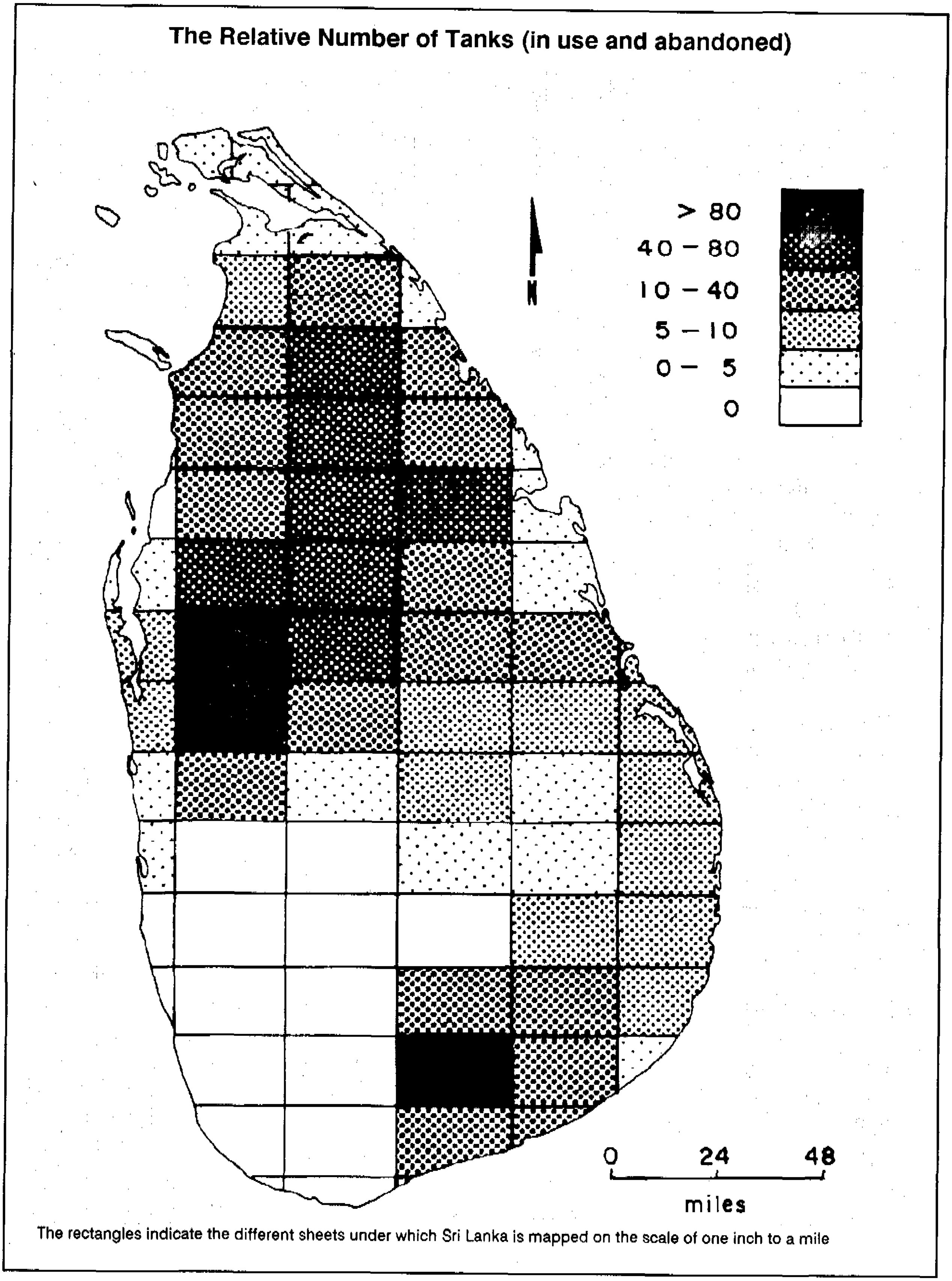
The Relative Number of Tanks (in use and abandoned)
N
> 80
40 – 80
10 – 40
5 – 10
0 – 5
0
0 24 48
miles
The rectangles indicate the different sheets under which Sri Lanka is mapped on the scale of one inch to a mile

Figure 2.1

bitrarily by one village raising the bund or the spillway, it could inundate the lowermost paddy fields in an upstream village. Interdependency between villages in a cascade required well-coordinated management of land and water resources.

The land use 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. The tanks and the paddy fields occupied the valleys where Low-Humic-Gley soils with poor drainage had limited use other than for bunded paddy cultivation. Ridge summits, often strewn with rock 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 (de Alwis, 1969) and the enduring protection of wildlife unusual in many parts of the world (Kablishingh, 1988).

The middle part of the catena between the ridge tops and valley bottoms was used for rain fed *chena* farming where Reddish Brown Earths proved ideal for many subsidiary seasonal food crops. Although in the modern context, *chena* wastes resources in Sri Lanka's early history long fallow periods allowed vegetative regeneration, and use was sufficiently infrequent to avoid serious soil erosion and environmental damage. Moreover village farmers spared large trees to provide shade and places for watch-huts. Small trees were lopped at breast height to enable them to sprout again at the end of the rainy season. Even during the Dutch period, introduction of cinnamon in *chena* lands was apparently done to enrich forest with cinnamon rather than to grow it as a monoculture (Abeywickrema, 1990).

The ancient village with its typical threefold land use system -- paddy field, home garden, and *chena* was self-sufficient and provided a stable base for long-term use. As Brohier (1934) noted, "tank" would appear to be synonymous with "village," implying that each agricultural settlement had a tank and paddy field below it.

The remainder of the ancient population lived in the larger irrigation areas that developed subsequently, or in cities like Anuradhapura in the Dry Zone lowlands. The hill country and the Wet Zone attracted only a few settlements.

The skills in irrigation technology possessed by the ancients were unique for a small country like Sri Lanka. As Needham noted "[a]lready in the first century AC, they understood the principle of the oblique weir .... the height of dam spillways were adjusted by removable pillar sluices were well understood, ... the inside surfaces of reservoir abutments were faced with 'ripple bands'... which acted as wave-breaking groynes ... the most striking invention was the intake-towers or valve towers (*bisokotuwa*)." They developed the knowledge 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 kilometers long (Figure 2.3). This *yoda ela*, which had a gradient of less than 10 cm per kilometer within its first 27 kilometers, continued to maintain itself as a natural stream. Some of the major ancient tanks, such as Yodawewa in Mannar district, were constructed to feed a large number of small tanks .

The establishment of forests and construction of ponds, reservoirs and irrigation systems were considered great meritorious acts in accordance with popular Buddhism, the faith of the leaders and the large majority of the people. 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 field in the Dry Zone. Construction and upkeep of these irrigation systems became massive undertakings. An indigenous expertise developed over the centuries which appears to have been called upon by other countries of South Asia.

Not all irrigation systems remained operational throughout this history (Figure 2.1). Their numbers and command areas expanded and contracted with population changes. Nevertheless, up to the twelfth century AD the ancient Dry Zone supported a dense

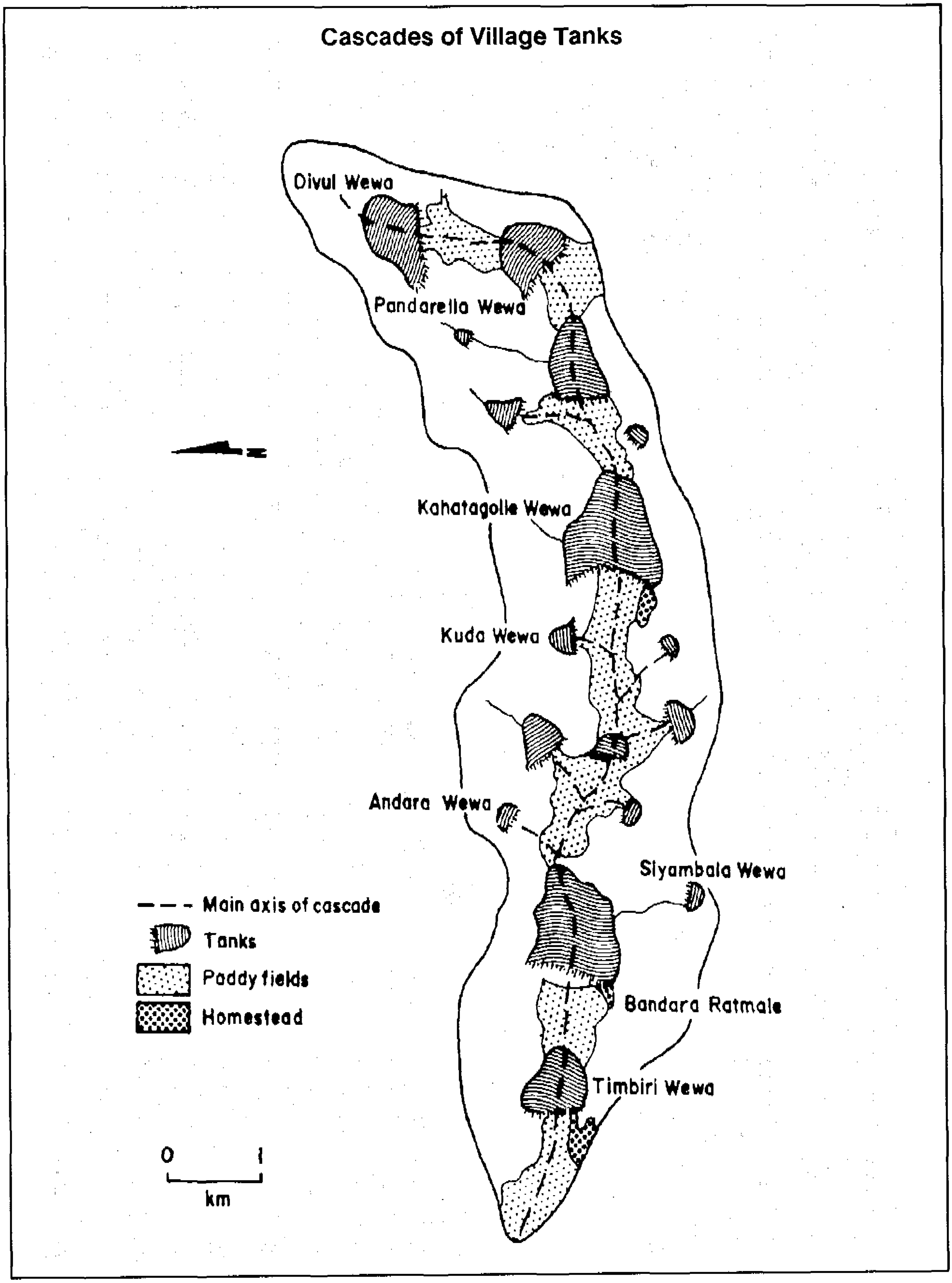
Cascades of Village Tanks
Divul Wewa
Pandarella Wewa
Kahatagolle Wewa
Kuda Wewa
Andara Wewa
Siyambala Wewa
Bandara Ratmale
Timbiri Wewa
Main axis of cascade
Tanks
Paddy fields
Homestead
0
1
km

Figure 2.2

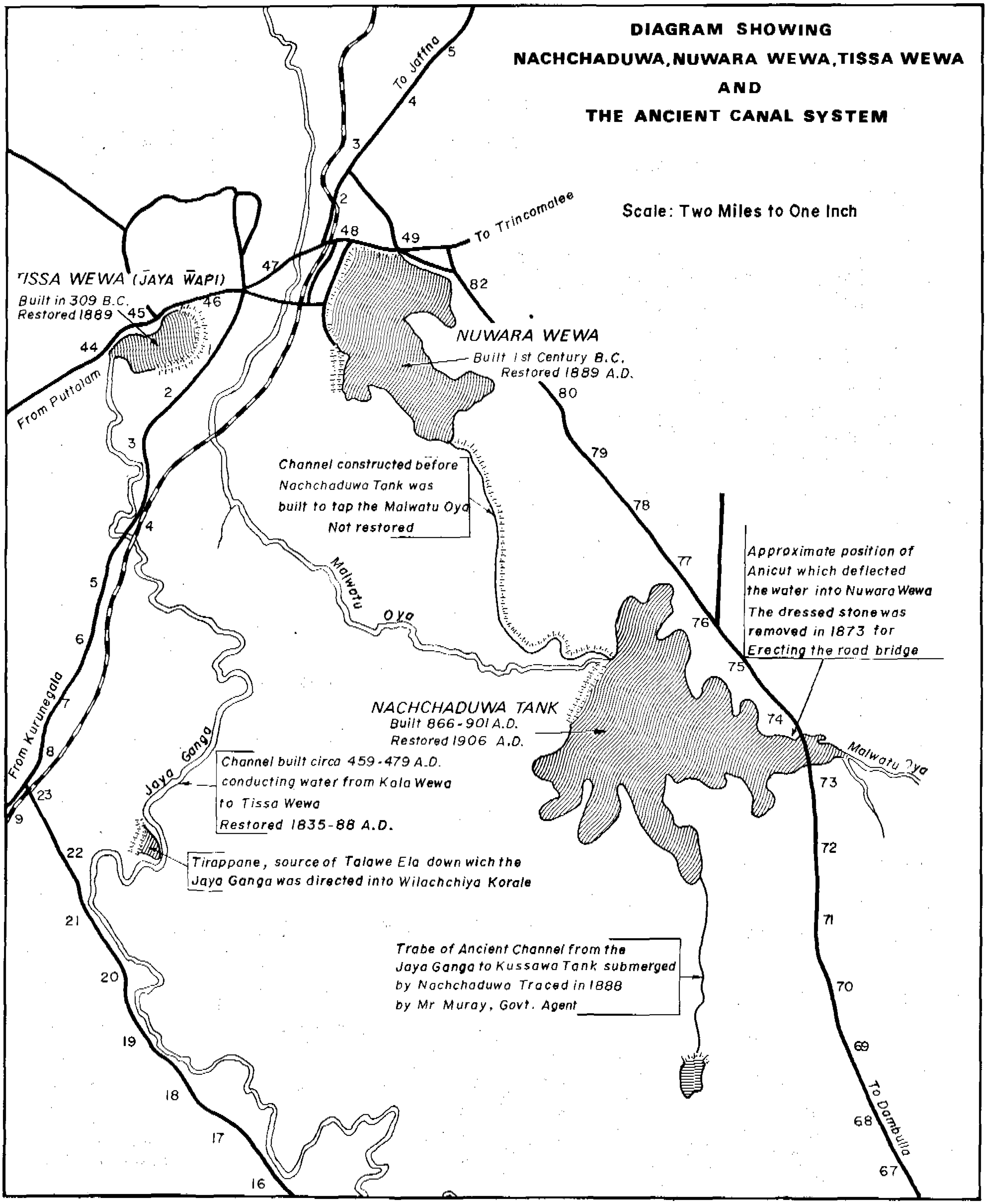
DIAGRAM SHOWING
NACHCHADUWA, NUWARA WEWA, TISSA WEWA
AND
THE ANCIENT CANAL SYSTEM
Scale: Two Miles to One Inch
To Jaffna
To Trincomalee
TISSA WEWA (JAYA WAPI)
Built in 309 B.C.
Restored 1889
From Puttalam
NUWARA WEWA
Built 1st Century B.C.
Restored 1889 A.D.
Channel constructed before
Nachchaduwa Tank was
built to tap the Malwatu Oya
Not restored
Malwatu Oya
Approximate position of
Anicut which deflected
the water into Nuwara Wewa
The dressed stone was
removed in 1873 for
Erecting the road bridge
NACHCHADUWA TANK
Built 866-901 A.D.
Restored 1906 A.D.
Malwatu Oya
From Kurunegala
Jaya Ganga
Channel built circa 459-479 A.D.
conducting water from Kala Wewa
to Tissa Wewa
Restored 1835-88 A.D.
Tirappane, source of Talawe Ela down wich the
Jaya Ganga was directed into Wilachchiya Korale
Trabe of Ancient Channel from the
Jaya Ganga to Kussawa Tank submerged
by Nachchaduwa Traced in 1888
by Mr Muray, Govt. Agent
To Dambulla

Figure 2.3

population. Folklore maintains that the density of houses allowed a fowl to move continuously from Anuradhapura to Polonnaruwa by hopping over the roof tops! Attempts to estimate the ancient population on the basis of tank densities, without considering their temporal changes, have led to gross over-estimations which exceeded even the present population. However, the population in the capital city appears to have been high, as reflected by the urban limits of Anuradhapura, which encompassed an area the size of Greater London today.

Collapse of the Rajarata Civilization

The ancient hydraulic civilization of the Dry Zone disappeared after the twelfth century. Climatic change, malaria, depletion of soil fertility, foreign invasions and famine are some of the reasons cited. The breakdown of the efficient irrigation management system may have resulted from annihilation of the *kulinas* -- the Dry Zone nobility who possessed irrigation expertise -- by invading South Indian forces (Paranavitana, 1960). Some scholars (Farmer, 1957) cite a combination of factors, including a push-pull effect that led to demographic shifts from the Dry Zone to the Wet Zone (Roberts, 1971). Whatever the reasons for collapse, the outcome indicates the ecological and social fragility of a human settlement pattern based on surface irrigation systems.

The Kandyan Kingdom

With the decline of the hydraulic civilization Sri Lanka's capital began to shift from the Dry to the Wet Zone and to the hill country, which eventually became the stronghold of the Sinhalese people against invading forces. First Anuradhapura, capital of Sri Lanka for over a millenium, yielded its status to Polonnaruwa. Then after brief spells in Dambadeniya, Kotte, Gampola and Sitavaka, the capital was finally established in Kandy until the British conquest. Population shifts across different ecological zones, from the Dry Zone, to the Wet Zone, and to the hill country, required an agrarian society to adjust to new environments and try new ways of managing land and water.

In the hill country the people modified their life to suit the wetter and more rugged terrain. The paddy cultivation in the *deniyas* (valley bottoms) was irrigated during the drier periods through canals that collected water from springs in the hill slopes. Hills performed the function of reservoirs, and the management of watersheds necessarily formed an integral component of the agricultural enterprise. Different ecological segments of the slopes were recognized, as reflected in village names such as Ovita, Ovilla and Ovilikanda according to their location. Valley bottoms around which settlements arose were named after the valley with the suffix of *deniya* (e.g. Gurudeniya, Aideniya, Peradeniya). At the lower segment of the catena, forest gardens were developed in the homesteads. Farther up, *chena* cultivation was practiced occasionally on a largely sustainable basis. Hilltops were permanently kept under a thick forest cover, which helped control soil erosion and regulate water flow.

The Kandyan Forest Garden became a man-made forest consisting of various fruits and other economically useful tree species, such as nutmeg and cloves. It essentially copied the diversity and intricate interrelationships of the natural forest. Kandyan Forest Gardens are located between the valley bottoms and high slopes to avoid damp conditions and benefit from a deep soil cover and seepage of moisture from the upper regions. Aerial photographs can distinguish Kandyan homesteads from the natural forests by the sand-strewn compounds in front of the houses, which brought much fresh air and sunshine. The micro- environment of a Kandyan homestead provided a suitable base for the continuity of human settlements in a wet montane setting.

The Colonial Period

The Portuguese, and then the Dutch, ruled the maritime areas of the island after the beginning of the sixteenth century. Canals began to change some coastal areas, and exploitation of natural resources on a commercial scale began during this period except in the hilly interior of the country, which continued under the monarchy. Far more significant changes in the natural environment of the island began after the Kandyan Kingdom fell to the British in 1815.

The full brunt of the colonial rule began with the enforcement of new land laws by the British in the first half of the nineteenth century. The land policy pursued by the British was based on the concept of "crown land," which led to the enactment of legislation to bring vast extents of land directly under colonial administration. The Crown Lands Encroachments Ordinance of 1840 proclaimed that "all forest, waste, unoccupied or uncultivated land shall be presumed to be the property of the crown until the contrary thereof be proved." Thus over 90 percent of the country fell under direct control of the colonial government, which eventually paved the way for large-scale enterprises of plantation agriculture.

The adverse social impacts of colonial land policy, particularly on the villages of the hill country, are better documented than their ecological consequences. The large majority of the peasantry that owned land through various forms of inheritance were unable to produce documentary proof of their ownership rights. Further, no proof of ownership was possible for the common land used for *chena* cultivation. The colonial government took all these lands, the majority of which were under some forest cover, and sold them cheaply to private parties. The hill country, still clothed in thick montane rain forests, became almost totally denuded within less than a half a century. Over four thousand elephants may have been killed in the process.

Equally devastating impacts on landscape ecology followed the process of deforestation. Soil erosion, landslides and siltation of stream and reservoir beds became rampant and significantly altered the surface hydrology. Serious land degradation became so obvious that the colonial government reacted by devising means to preserve the area above 1,500 meters. The birth of the forest department was associated initially with the need for soil conservation in the highlands. Similarly wildlife protection began with concern for preserving game reserves. Crown ownership nevertheless facilitated preservation of natural forest cover, which accounted for some 45 percent of Sri Lanka by the time of National Independence. Plantation agriculture also developed soil conservation technologies such as contour drains and stone terracing, which proved efficient in many well-maintained estates. Despite these attempts, however, soil erosion remained a recurrent public concern in the last years of the colonial rule.

The colonial heritage provided Sri Lanka with a wide variety of legislation that facilitated conservation of natural resources through land orders and regulations. The Crown Land Ordinance of 1947, one such example, provided for the protection of coastal resources, stream banks and the beds of reservoirs. To a large degree the Soil Conservation Act of 1951, though passed after Independence, is a similar legacy of colonial times. The Kothmale landslides of 1947 which destroyed much life and property, requiring resettlement of many families, stimulated public concern, a comprehensive study (Gorrie, 1949), and eventually enactment of the Soil Conservation Act of 1951. Its failure as a regulatory tool suggests the need for a reappraisal of effective techniques -- perhaps based on village community behavior and incentives more soundly linked to Sri Lanka's traditional concern for a sustainable and productive environment.

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A festival scene in Negombo. Sri Lanka's urban population is growing faster than rural population

3 Population Profile

Population Growth

Sri Lanka's population has grown rapidly until recently. By 1986 it reached 16.8 million, yet in the first modern census, conducted in 1822 after the British occupation, population was 889,584. By the next census in 1871 population had increased to 2.4 million, largely due to natural increase and immigration from South India for the plantations (Figure 3.1).

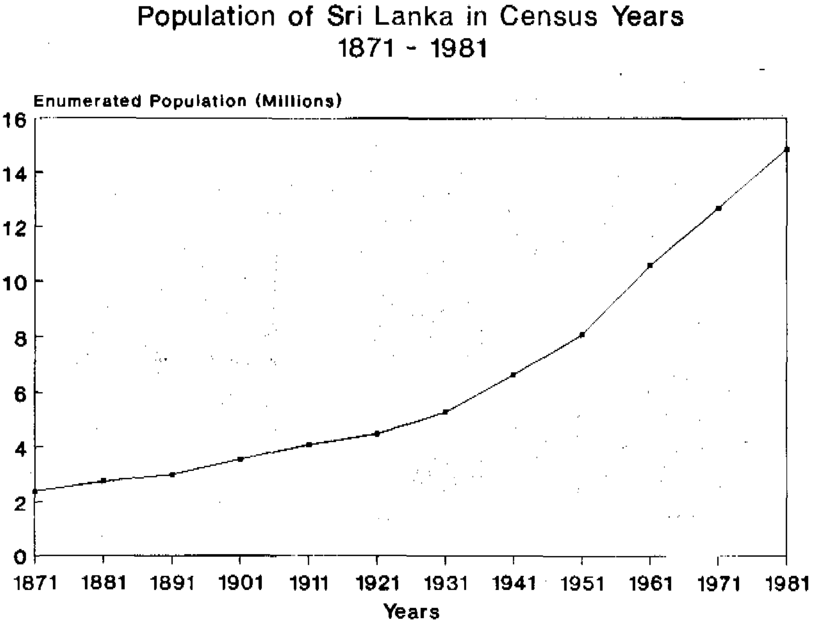


Figure 3.1

Population increased by 518.5 percent between 1871 and 1981, but the rates and causes of growth have been very different. For the intercensal periods 1891-1901, 1921-1931 the percentage increase over each ten-year period was about 18 percent and the average annual rate of growth was about 1.7 percent, but in the first period it stemmed from large-scale migration into the country, and in the latter period it largely resulted from natural increases. Increases in the gap between the birth and death rates, the cohort sizes of females in reproductive age groups, and slow decline in fertility, have contributed to the natural increases that account for over 95 percent of the total population growth in the past few decades.

Changes in Fertility

Sri Lanka had high birth rates at the beginning of the century. Crude birth rate (CBR) fluctuated between 38-40 per thousand in the first few decades of the twentieth century but has now declined to 21.8 per thousand. A more refined measure of population growth is the total fertility rate, defined as the average number of children that would be born to a woman during her lifetime if she passed through her child-bearing years conforming to the age-specific fertility rate of a given year. The total fertility rate, estimated at 5.3 in 1953, was nearly halved by 1987. This decline is reflected in the following rates.

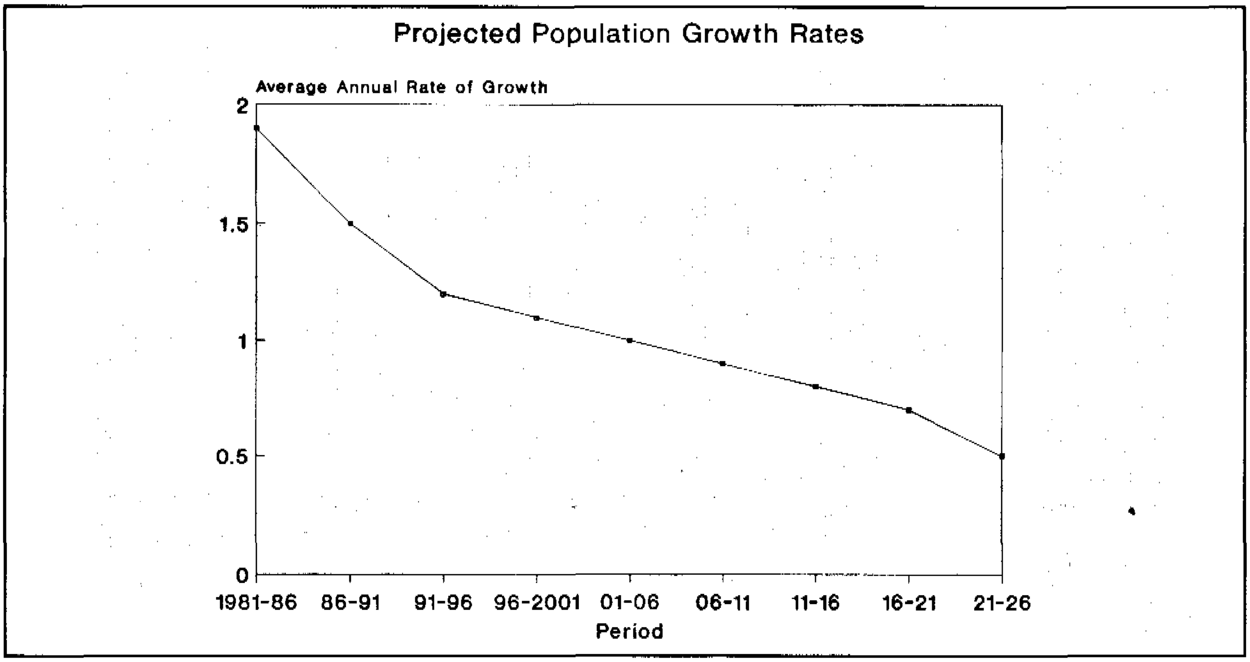


Figure 3.3

Year	Total Fertility Rate
1953	5.3
1963	5.0
1971	4.2
1974	3.5
1981	3.3
1987	2.8

Figure 3.2

Rapid population growth during the past decades, slow economic growth, and problems of unemployment and productivity have determined governmental policy on population. Policies that provide family planning information and contraceptive services contribute to continued decline marital fertility. Population projections constructed in 1988 assumed a linear total fertility decline to 2.1 by 2011, slightly lower than projected in 1985. Some projections have been based on a fertility decline to 2.1 by the year 2000, based on findings of high motivation among married couples to reduce fertilty rates. It is important to note that projections in this analysis, however, assume that total fertility will remain stable throughout the period of projection.

Mortality

Until the 1940s the crude death rate remained at high levels, reaching 30 per thousand in some decades (1911-1920). Several reasons have been cited: "... widespread prevalence of endemic and epidemiological diseases, inadequate curative preventive health services, low standards of living, high illiteracy rates and ignorance of simple health rules among the mass of the people" (ESCAP 1974). Improvements in health and sanitation services and in living standards and literacy levels reduced the live death rates to approximately 23 per thousand by 1930. The malaria eradication program, improvement of health infrastructure and provision of basic services made it possible to achieve a sharp decline in mortality in the mid-1940s. Between 1946 and 1947 the crude death rate declined from 20 per thousand to 14 per thousand, and it has continued to decline to 6 per thousand. Life expectancy at birth increased from 44 years for males and 42 years for females in 1946, to 64 years for males and 68.8 years for females by 1971. The life expectancy further increased to 65.6 for males and 69.9 for females according to data for 1978-1980.

The crude death rate will probably not decline further. As fertility declines and the population ages,

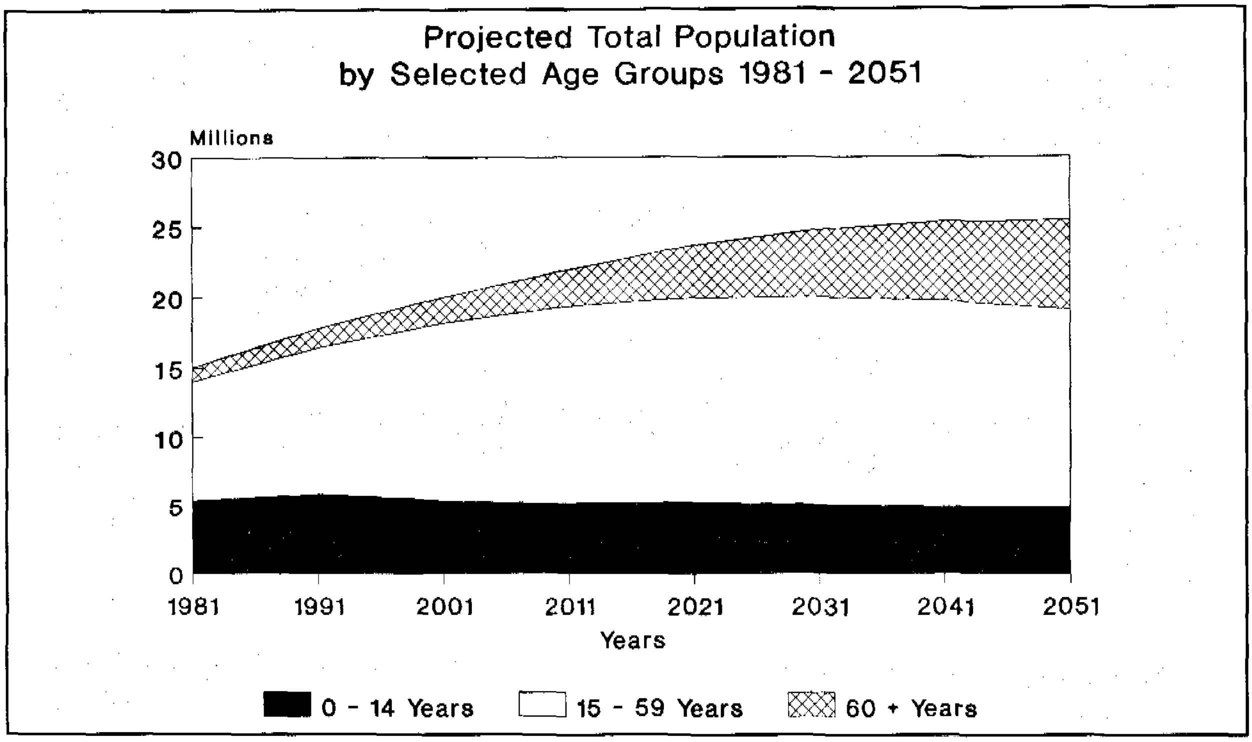


Figure 3.4

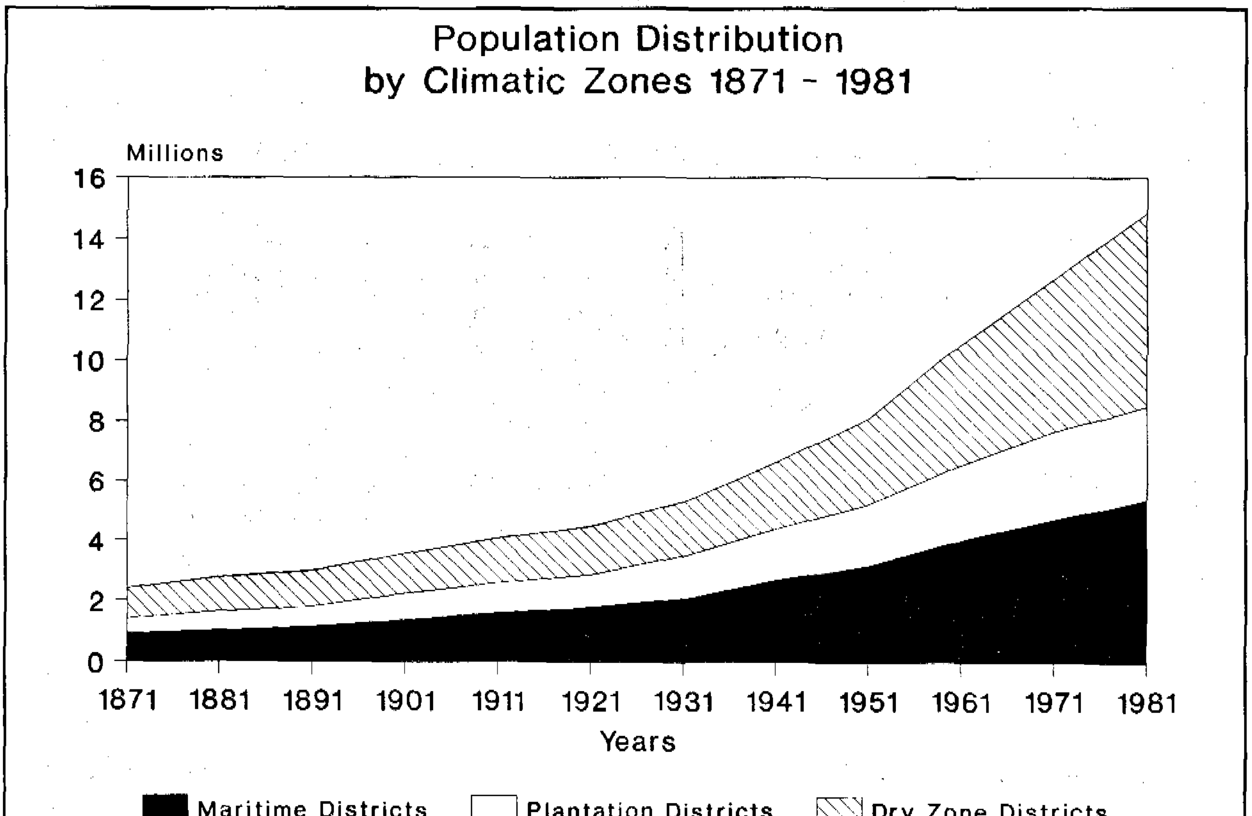


Figure 3.5

the crude death rate will be close to the crude birth rate, and population growth will reach a replacement plateau.

International Migration

It is difficult to predict migration trends, given the social, political and economic variables in countries of origin and destination. The inflow of Indian migrant workers resulted in large net immigration until mid-century.

> Migration into Sri Lanka on a large scale and on systematic basis began in the early 1830s with the opening up of the hill country areas for coffee plantations. The reluctance of the indigenous labor to accept employment on the newly opened estates resulted in a regular recruitment by the European planters of large numbers of indentured labourers from South India. In the past while Sri Lanka has been receiving a large number of immigrants, the number of nationals emigrating from the country had been negligible. None of the indigenous communities are migratory in character. They are attached to their land and have had better fortune with it than have the South Indian peasants. (ESCAP 1974).

Citizenship laws of 1949 regulated immigration, and political changes and new language policies after independence stimulated emigration of Eurasian and Burgher communities to North America, Western Europe, Australia, and other parts of Asia. The Indo-Ceylon Agreement of 1964 for repatriation of Indian migrant workers substantially increased out-migration in the 1970s. Outflows of nationals to developed countries for economic reasons commenced at the end of the 1960s and assumed brain drain proportions in the 1970s. Demand for labor in the Middle East raised the volume of temporary migration after the mid-1970s, when total volume of migration to this region peaked around 225,000. It declined after 1984 and more rapidly with the Gulf crisis in 1990. Ethnic violence in the 1980s resulted in migration of Sri Lankan Tamils to India, estimated at 100,000. Violence and terrorist activities also caused clandestine migration to Western Europe and North America, mostly for economic reasons. The flows were large but reliable data are not available.

The population projection constructed in 1988 assumed net outflow of 50,000 per year in the short term until 1991, and average rates of 35,000 per year from 1991 to 2006 and 25,000 per year thereafter. Major changes in social, political and economic conditions could seriously alter these estimated migration flows, however, especially in the short term.

Projected Population

The population projection used in this profile was constructed in 1988 based on the assumptions outlined above on fertility, mortality and migration. The projection provides only tentative estimates to 2056, primarily to examine the size and composition of the population as growth rates decline. Long range projections have been found reliable only in the short and medium term.

According to the current projection, population has increased from 15.046 million in 1981 to 16.587 million in 1986 and is projected to rise to 20.05 million in 2001, 22.01 million in 2011, and 23.725 million in 2021. In 2046 it should peak at 25.444 million, resulting in a 69 percent increase since 1981. The average rates of annual growth are given in Figure 3.3 and numerical increase in Figure 3.4.

In contrast, other projections have concluded that population will increase to less than 20 million by the year 2000 and will stabilize at about 23 million by 2040. They are based on less conservative basic assumptions.

This projection discloses several noteworthy trends concerning pre-school and elderly populations. The pre-school age group of 0-4 years would increase from the base year 1981 until 1986, decline until 2006, increase again to 2016, and then decline (Figure 3.4). The relative share of this age group would continuously decline from 13.5 per cent in 1986 to 6.5 per cent toward the end of the projection period. Young dependents in the age group 0-14 years would peak near 1991, at about 5.9 million, and would decline thereafter. In contrast, the elderly population shows a dramatic increase. The population over 60 years of age would increase more than threefold, from 982,000 in 1981 to 3.15 million by 2016. Ranks of the elderly would continue to increase to over 6 million toward the end of the projection. As a result, old age dependency would continue to rise. Cost of old age dependency may be less than youth dependency; instead of costs of schools, for example, outlays would be mainly for pensions, health care, and special facilities needed by the elderly.

POPULATION DISTRIBUTION

We can best examine social and economic development in terms of agro-climatic zones by dividing the population into geographical boundaries. The Wet Zone is defined by administrative districts of Colombo, Gampaha, Kalutara, Galle, Matara, Kandy, Nuwara Eliya, Ratnapura and Kegalle, with the Dry Zone comprising the remaining sixteen districts. Within the Wet Zone districts it is useful to distinguish Colombo, Gampaha, Kalutara, Galle and Matara, all of which have maritime boundaries. They also differ from other Wet Zone districts by having relatively high levels of development, industrial employment and urban population. In contrast hill country Wet Zone districts have large plantation sectors.

The distribution of population by climatic zones for the period 1871-1981 is given in Figure 3.5. It shows that since 1871, and until recently, population has largely concentrated in the Wet Zone districts. By 1946, two-thirds of the population lived in 23.7 percent of the country. The increase resulted primarily from the development of the plantation industry in the Wet Zone, the influx of Indian immigrant plantation laborers, growth of trade and commercial activities in Wet Zone maritime districts, and the prevalence of malaria in the Dry Zone. Increased density in the Wet Zone caused overcrowding and reduced per capita availability of agricultural land.

Since 1946 the government has sought to improve the Dry Zone through irrigation, new settlements, and improved health care, education and communication facilities. Repatriation of Indian immigrant labor was also encouraged particularly from hill country plantation districts, where the share declined from 26.4 percent in 1931 to 21.1 percent. Today the relative share of the Wet Zone population has diminished to 54.7 percent. Substantial additional redistribution of the population to Dry Zone agricultural land is not anticipated. Instead, population growth will occur in existing urban areas, and other areas selected for industrial and commercial development.

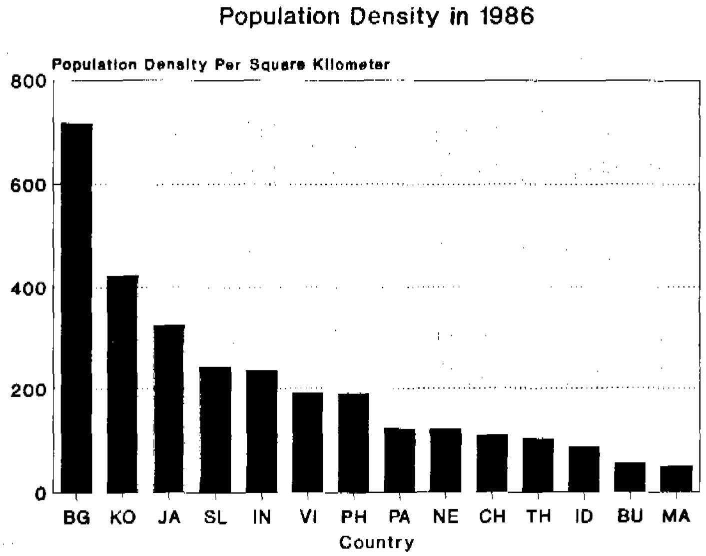
Population Density

Sri Lanka is one of the most densely populated countries in the world, second only to Bangladesh among the less developed countries and otherwise exceeded in Asia only by Japan, Republic of Korea, and small island states such as Singapore and Hong Kong. Population density in Sri Lanka, on the basis of the current estimated population of 16.8 million, amounts to 260 persons per sq. km. Uneven concentration of population in the Wet Zone causes further pressure on natural resources. (Figure 3.6.)

Regional variation of population densities and the growth trends for the decennial period are shown in Figure 3.8, summarized and given by province in Figure 3.7. Some provinces are still relatively sparsely populated. Densities in 1988 varied from a low 42 persons per sq. km. in Vavuniya and 46 in Mullaitivu in the Northern Province to nearly 2,900 per sq. km. in the Colombo district. Wide variation in the Provincial densities occur as well, from 1,175 per sq. km. in the Western Province to 94 persons per sq. km. in the North Central Province. The North Central, Eastern, and Uva Provinces have population densities below 125 persons per sq. km., substantially below the densities of all other provinces except the Northern Province, with its relatively low 145 persons per sq. km.

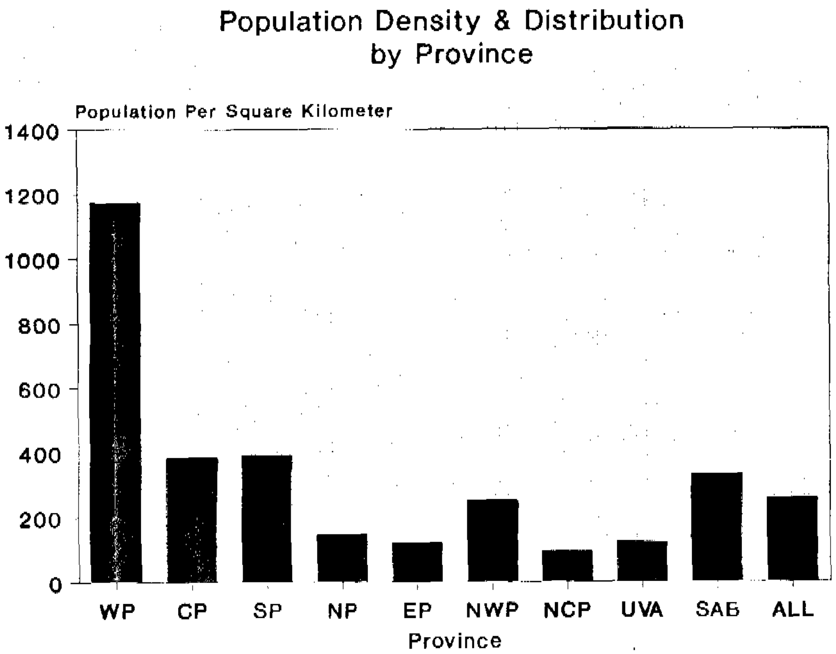
Since independence, inter-provincial and inter-district migration, and peasant settlement in the Dry Zone have reduced disparities in population concentrations.

The distribution of population and population densities are also determined by the industrial profile of the area, and access to jobs. In rural areas, where demographic, social and economic differences are generally not sharply pronounced, migration has depended on opportunities for work, including wage employment in nearby urban centers. The rise in unemployment levels in urban areas has reduced the volume of these rural flows.



BG - BANGLADESH KO - KOREA JA - JAPAN SL - SRI LANKA
IN - INDIA VI - VIETNAM PH - PHILIPPINES PA - PAKISTAN
NE - NEPAL CH - CHINA TH - THAILAND ID - INDONESIA
BU - BURMA MA - MALAYSIA

Figure 3.6



NP - Nothern Province
UVA - Province of Uva
EP - Eastern Province
NCP - North Central Province
SAB - Province of Sabaragamuwa
WP - Western Province
NWP - North Western Province
CP - Central Province
SP - Southern Province

Figure 3.7

Density Of Population Per Square Kilometer By Province And District 1871 - 1988

Province / District	Land area		Density per Square km				
	Square KM	%	1953	1963	1971	1981	1988
Sri Lanka	64,651.83	100.0	125	165	196	230	257
Western Province	3,657.84	5.7	610	776	930	1,072	1,174
Colombo	652.42	1.0	838	1,089	2,297	2,605	2,891
Gampaha	1,398.85	2.2	-	-	839	994	1,067
Kalutara	1,606.57	2.5	328	398	454	516	570
Central Province	5,583.24	3.6	245	304	350	360	385
Kandy	1,890.76	2.9	359	466	508	486	644
Matale	1,988.59	3.1	87	130	158	180	204
Nuwara Eliya	1,703.85	2.6	268	328	377	420	309
Southern Province	5,513.83	8.5	205	259	301	341	389
Galle	1,673.91	2.6	314	388	439	487	542
Matara	1,246.56	1.9	336	418	470	516	596
Ambantota	2,593.36	4.0	74	107	131	164	190
Northern Province	8,685.53	13.4	66	85	101	128	146
Jaffna	2,072.25	3.2	193	248	336	401	408
Mannar	2,002.06	3.1	18	25	37	53	62
Vavuniya	2,645.16	4.1	09	19	23	36	42
Mullaitivu	1,966.06	3.0	-	-	22	39	46
Eastern Province	9,622.07	14.9	37	57	75	101	120
Batticaloa	2,464.63	3.8	38	81	104	134	159
Ampara	4,539.22	7.0	-	72	60	86	100
Trincomalee	2,618.22	4.0	31	54	72	98	115
North Western Province	7,749.76	12.0	110	149	181	220	251
Kurunegala	4,772.83	7.4	133	181	215	254	288
Puttalam	2,976.93	4.6	25	103	127	165	192
North Centeral Province	10,532.97	16.3	22	37	52	81	94
Anuradhapura	7,129.21	11.0	22	40	55	82	96
Polonnaruwa	3,403.76	5.3	-	34	48	77	90
Uva Province	8,405.04	13.0	56	78	96	109	122
Badulla	2,818.17	4.4	56	188	218	227	244
Moneragala	5,586.87	8.6	-	19	35	49	60
Sabaragamuwa Province	4,901.55	7.6	182	229	269	302	332
Ratnapura	3,238.78	5.0	132	171	208	246	277
Kegalle	1,662.77	2.6	287	352	387	412	440

Figure 3.8

Urban-Rural Distribution

Urban growth in developed countries has accompanied economic and industrial development, but that is not necessarily true in developing countries; despite urbanization their national economies can still remain primarily agrarian.

Internationally recognized yardsticks delineate urban and rural areas. The UN has identified five: administrative area, population size, local government area, urban characteristics, and predominant economic activity. In Sri Lanka, with its traditional agricultural economy, urban areas can retain largely rural characteristics. This was true long ago, as described by the census report in 1946.

The great city of Anuradhapura in ancient times, notwithstanding its size and architectural features was not altogether 'urban', for it contained within its limits irrigation tanks, paddy fields, and even forests. Within the municipal limits of Kandy today, there are situated estates of appreciable acreage, while within the area under the administrative jurisdiction of the Badulla urban council there are large paddy fields. Some of the larger villages are more densely populated than some 'towns' which had been brought under the operation of the Small Towns Sanitary Ordinance. Town and village are ordinarily wards of somewhat vague application and are not easily defined and distinguished. (Census of Population 1946 : General Report.)

In recent times the delineation of urban boundaries in Sri Lanka has not necessarily been based on urban character or well-defined guidelines. Today, census definitions of urban areas include Town Councils, Urban Councils, and Municipal Councils. But from 1963 to 1971, for example, Town Council status was given to communities with populations ranging from less than 2,000 to over 40,000. As a result, many truly "urban" areas have been considered "rural." Precise urban-rural distinctions remain somewhat arbitrary and may underestimate urban environmental conditions or growth trends. Unless these factors are recognized, urban statistics may mislead planners and policy makers required to identify needs for urban infrastructure, housing, potable water supplies, health, and other basic human requirements in highly populated areas.

Trends

Between 1871 and 1981 Sri Lanka's urban population increased twelvefold, and the urban share increased from approximately 11 percent to nearly 22 percent. Urbanization has slowed during the past four decades and declined during the intercensal period 1971-1981. Policies of the past five or six decades that emphasized development of rural infrastructure and social sector programs, kept urbanization rates at modest levels, as did low rates of industrialization. Urbanization rates have been lower than those of many countries of the region and the urban sector share of the population has been relatively low (see Figure 3.9). Nevertheless, contrary to these national trends, unusually high rates of growth have occurred within the Colombo Urban Area. (See box on urbanization in Sri Lanka.)

The urban population of 1 million in 1946 increased to 3.2 million in 1981, while total population increased from 6.6 million to 14.8 million (Figure 3.10). Between 1946 and 1981 the urban percentage share of population increased by approximately 6 percentage points. Growth of urban population was higher between 1953 and 1963, when the growth rate reached 4.88 percent per annum, after which the growth rate declined.

Variation in the urban population percentage among the provinces ranges from 46.7 percent in the Western Province to 6.2 percent in the North Western Province. The percentage of urban population in the Western Province is more than double that of any other province except the Northern Province. In the Western Province the urban percentage has steadily increased from 33 percent in 1946 to 48 percent in 1971, showing a decline in 1971-1981. If we included the developed areas, outside the local authority areas then the urban percentage would be even higher. More importantly, 57 per cent of the country's urban population resides in the Western Province. Figure 3.11 shows that the urban population in the Northern Province, lower than the national average in 1946 and 1953, exceeded the national average by 1963. Urban population growth has been relatively slow in the North Central Province and Central Province.

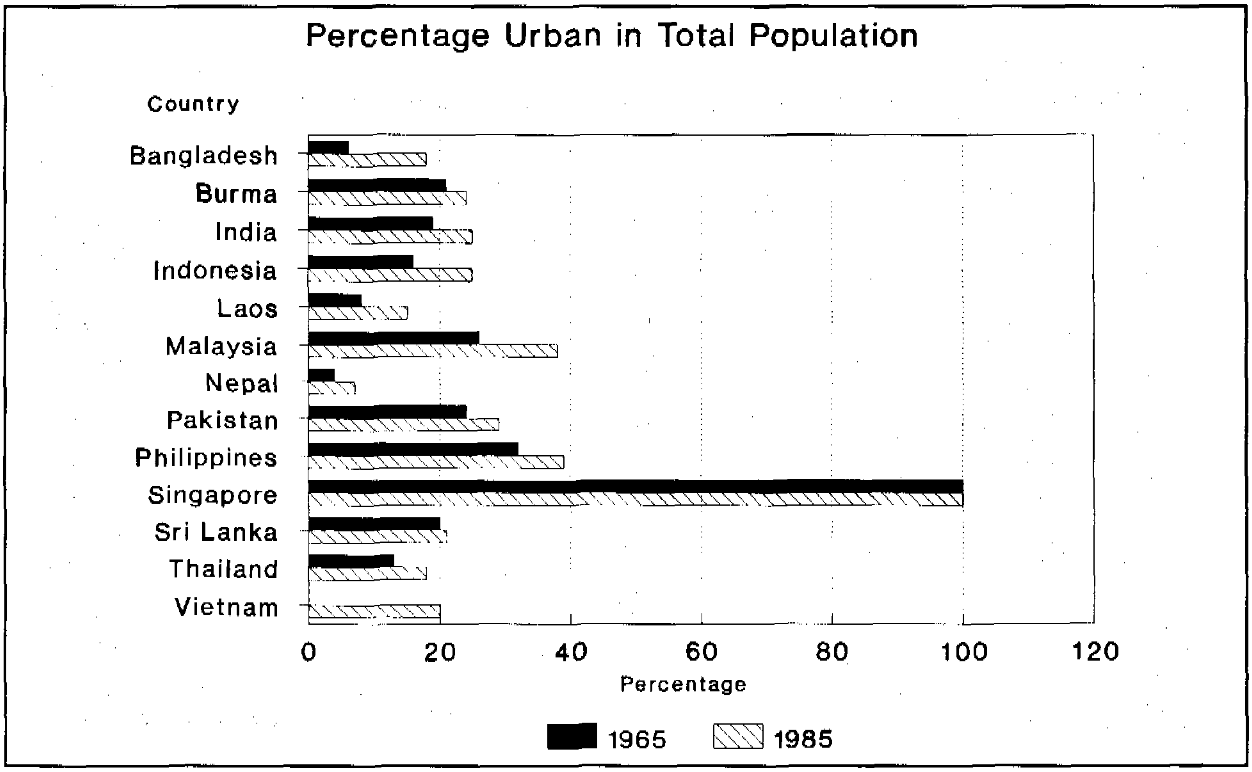


Figure 3.9

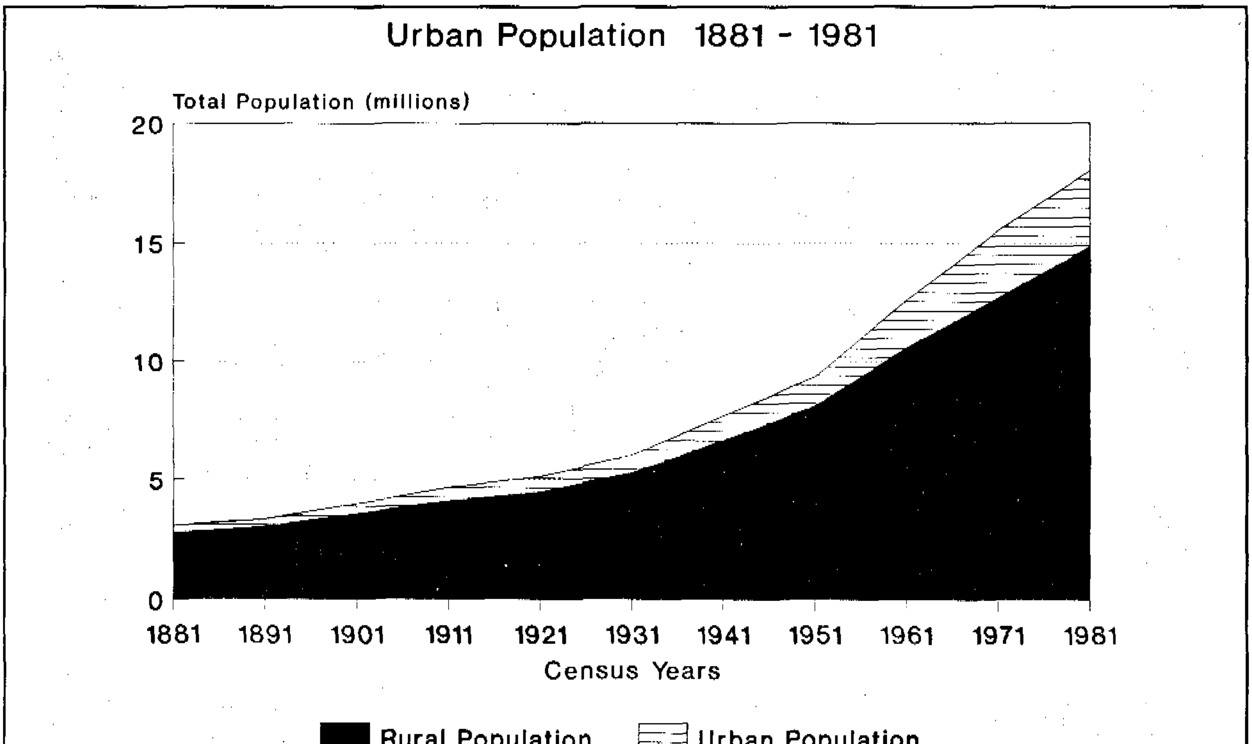


Figure 3.10

Significant changes in urbanization rates are not foreseeable in the long term. Rates of economic growth, and increased industrial employment will largely determine urban growth in the short and medium term. Population growth, pressures on agricultural land and rising rural land prices, expansion of trade and commerce, provision of urban electricity, communication services and amenities and needs to develop manufacturing industries may slowly raise urbanization levels. If, as is possible, urbanization reaches 30 percent by the end of the century, then the population living in urban areas would increase to 6.015 million -- an 88.4 percent increase over the current urban population. If the present urban distribution pattern continues, then as much as 50 percent of the urban population will remain in the Western Province.

These urban projections, when added to existing urban needs (see sections on water and air degradation), point compellingly to new urban planning and investment challenges.
Many other Third World cities now grapple with almost intractable problems of pollution,transportation,and infrastructure inadequacy that have rapidly outpaced urban planning and investment. Sri Lanka would do well to anticipate and prevent a similar fate by attention to potentially significant increases in problems of waste water management, drinking water supply and quality, air quality, solid waste disposal, and adequate housing, transportation, and health services.

FAMILY SIZE AND HOUSEHOLD COMPOSITION

Analyses of families and households determine, and in turn are influenced by, basic demographic variables of fertility, mortality and migration. Recent censuses have paid increased attention to the household as a basic socio-economic unit that supplies and demands goods and services.

The concept of the household is based on the arrangements made by persons individually or in groups to provide themselves with food or other living essentials. A household may be either a one-person household, or a multi-person household that pools income and uses a common budget. Household members may or may not be related.

The censuses and surveys conducted in Sri Lanka have used household as the basic unit of enumeration. The concept of the household as a unit in Sri Lanka has always denoted one or more family units residing in a housing unit. Although a household could comprise more than one family unit the reverse is not feasible. The extended family relationship is accommodated by a definition allowing integration of several family units under one household. The head of the household is accepted as the adult person, male or female, who is responsible for the care of the household.

Growth of Households and Family Formations

Since the census of 1953 the total number of households in Sri Lanka increased nearly 90 percent, from 1.6 million to 3.05 million in 1981. Urban households trebled, from 0.19 million to 0.59 million, due to the rise of new urban centers, internal migration, and increased family size in urban areas. Growth of rural households was slower; including the estate sector, rural households grew by only 73.0 percent. Average household size increased for the country as a whole from 5.0 in 1953 to 5.2 by 1971, due in part to the slow growth of available housing. It declined thereafter to 4.9 persons by 1981. (Figure 3.12 and 3.13)

Trends data show that family formation has occurred at a slightly higher rate than population increase, but in the urban sector population growth outstripped the rate of family formation.

Size of Households

A declining trend in household size is evident from the Consumer Finance surveys, which provide broadly comparable data.

Declines in household size and family size resulted from declines in fertility that began in the late 1950s. Urban sector households have been consistently larger because of boarders, domestic servants and aides. Scarcity of housing in the urban centers has probably slowed the formation of new households as children delay leaving the nuclear family. In contrast, the size of estate sector households has always been lower than the all-island average.

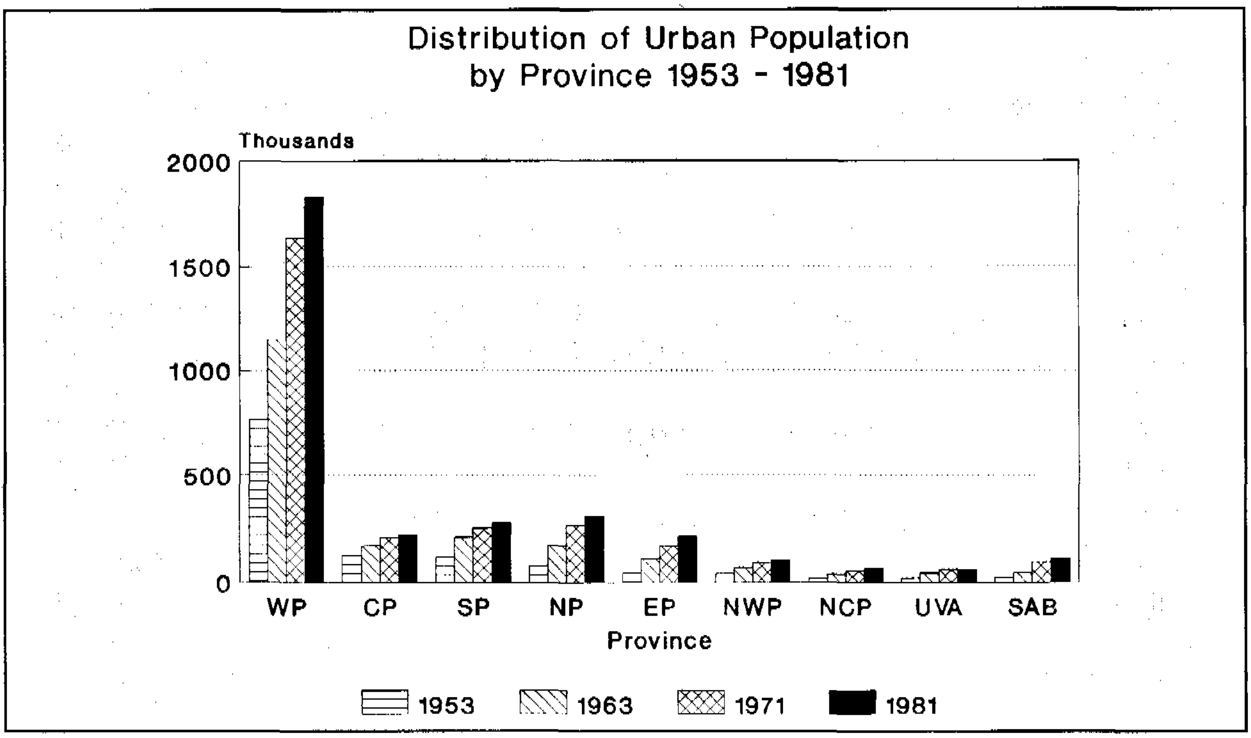


Figure 3.11

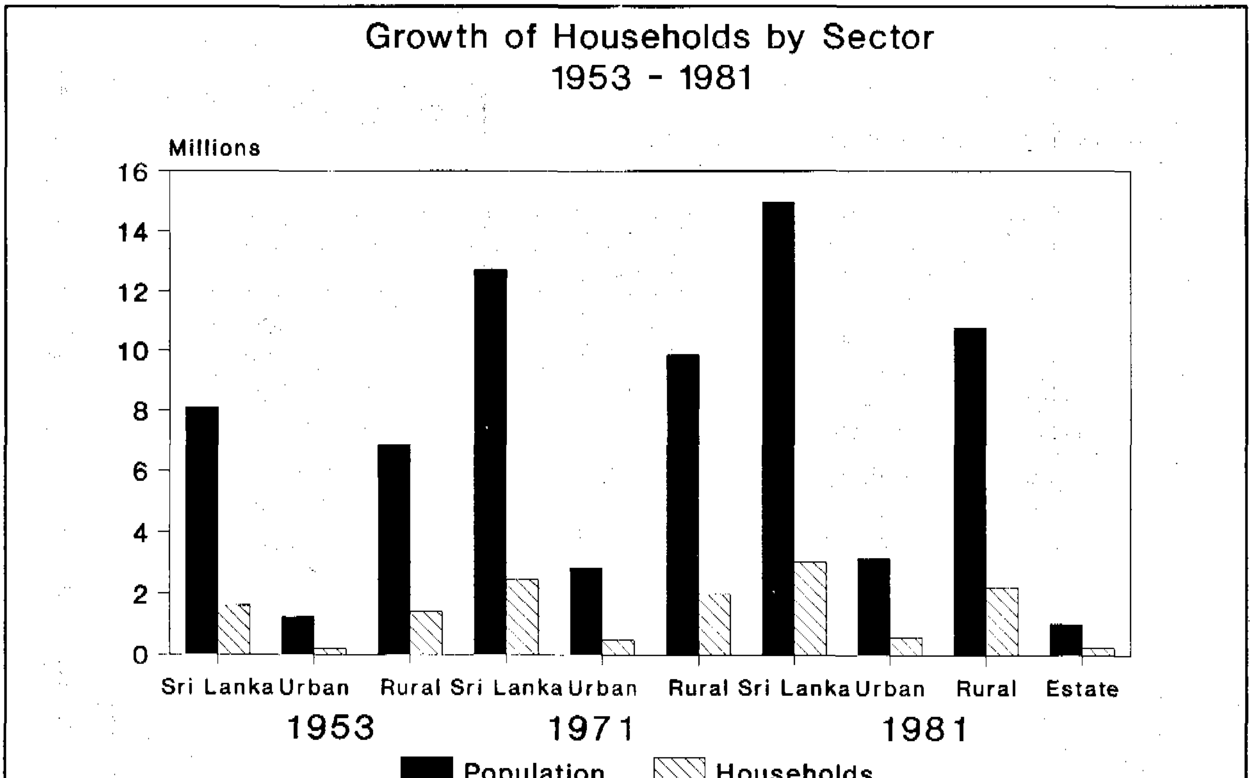


Figure 3.12

Forecast of Households

Projections for number of households and the rate of growth of households improve estimates of housing requirements and the provision of amenities. A general paucity of data on households and family formation and headship collected through censuses and surveys makes projections difficult, however. Based on a formula developed by the UN, and the data from Censuses of Population and Housing 1971 and 1981, estimates have been developed for the total number of households for the quinquennial years 1981-2001, the rate of increase of households in this period, and the average size of households (See Figure 3.14).

The forecast shows the total number of households reaching 4.575 million by the end of the century. This means nearly 400,000 households added during each quinquennial period -- or 1,600,000 householders between 1981 and 2001. Housing facilities and suitable locations will be needed to meet this increased demand. Even so, the rate of increase in the number of households will decline during this period. The average size of households will drop from 4.9 in 1981 to 4.4 in 2001 (Figure 3.13).

HOUSING

The Census of Population 1981 estimated the total number of dwelling places at 3.029 million, of which 2.924 million were housing units and 0.105 million were living quarters other than housing units. The total number of occupied housing units amounted to 2.813 million, and of them 0.110 million, or 3.8 percent, were vacant at the time of enumeration. The percentage of vacant housing units varied in the different sectors, 4.3 percent were vacant in the rural sector, 4.7 percent in the estate sector, and only 1.3 percent in the urban sector.

Growth of Housing Stock

During the intercensal period 1971-1981 the housing stock increased by 26.9 percent while the population increased by 17 percent. Hence the housing stock increased at an average annual rate of 2.4 percent. In contrast housing stock increased by only 12.5 percent in the intercensal period 1963-1971, when population increased by 19.9 percent. The growth of population and housing stock between 1971 and 1981 and the percentage intercensal increases are illustrated in Figure 3.15.

Quality of Housing Units

The structural quality of housing depends on the construction materials used. Three types of housing units have been identified based on construction material used for walls, roofing and floors: permanent, semi-permanent, and improvised units. In general where all material consists of durable products like cement, bricks, tiles or asbestos sheets, the unit may be considered permanent. If units use perishable materials such as cadjan, or discarded wooden planks, the unit is classified as improvised, and when a mixture has been used we consider it semi-permanent. (Figure 3.16) In the intercensal period 1971-1981 the percentage of permanent units increased from 35.4 percent to 41.9 percent, a 50 percent increase. The percentage share of permanent units increased in all three sectors, whereas the relative share of improvised units declined. The major part of the increase in permanent units was in the rural sector. Data on the age of stock show distinct improvements in the pace of permanent housing construction after 1977.

Materials of Construction

The percentage distribution of occupied housing units by principal materials used for walls, roofing and floor by sector is shown in Figure 3.17. Slightly more than half of all housing units have used materials such as mud, wood, cadjan or palmyrah for the construction of walls. For roofing material approximately 42 percent used cadjan, palmyra or similar materials. Just over 50 percent of all occupied housing units used wood, mud or other materials for the floors. All the materials are of domestic origin, although timber and cement imports are beginning to be needed.

Age of Housing Stock

The age of housing stock ascertained at the 1981 Census was based on the year of completion or first occupation. The increase in housing units since 1971 is shown in Figure 3.18. This distribution shows that 62 percent of the housing units were constructed in 1970 or before, and 73.2 percent were permanent units.

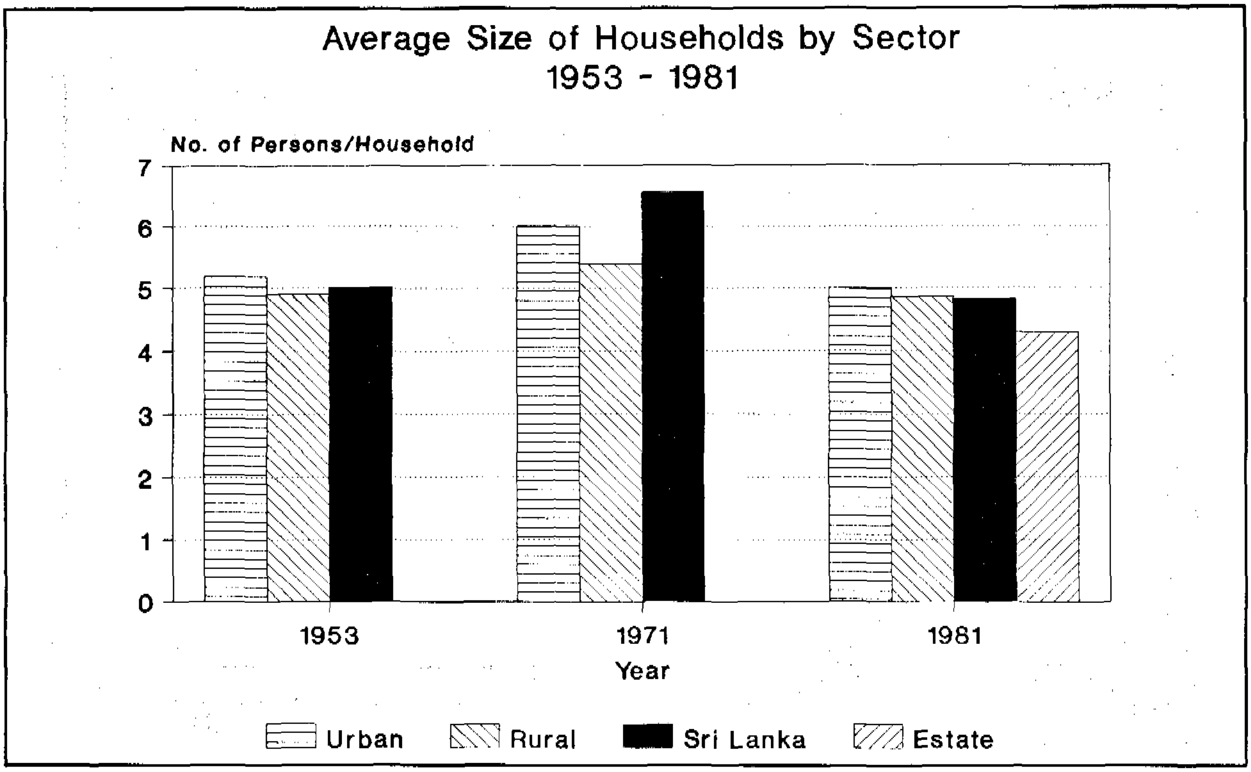


Figure 3.13

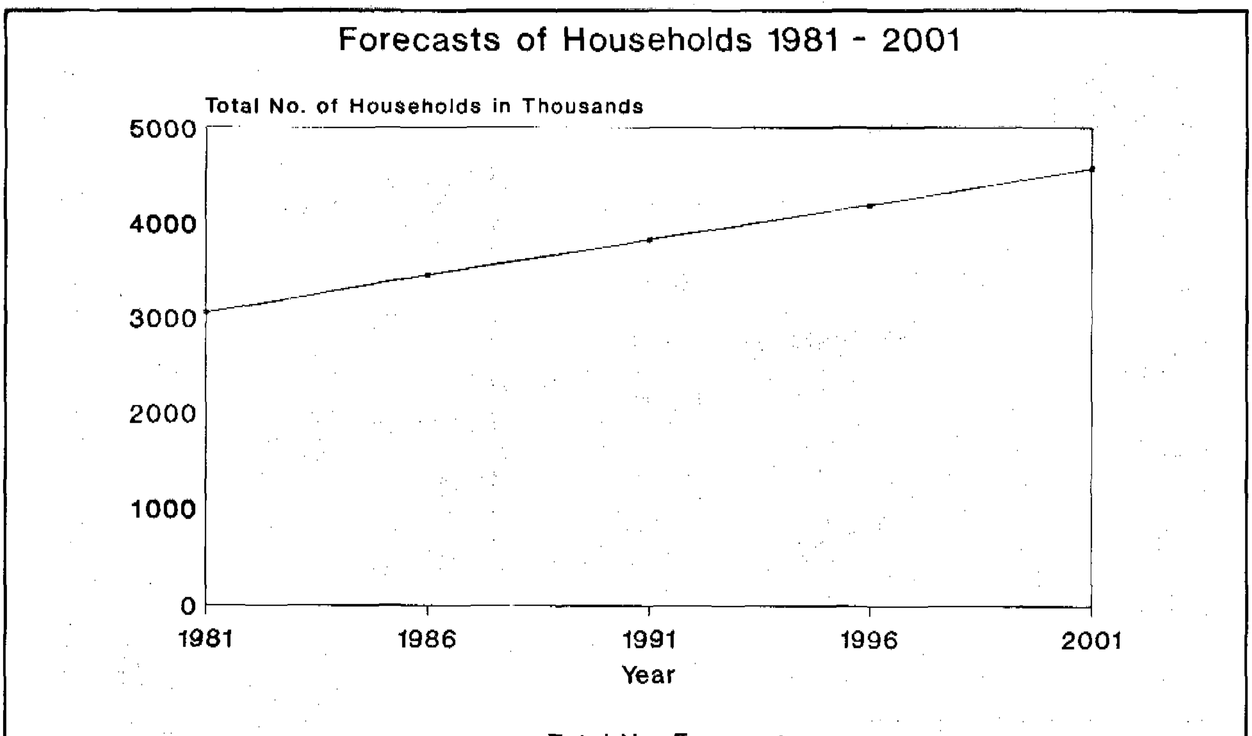


Figure 3.14

Growth of Total Population and Increase in Occupied Housing 1971 - 1981

Sector	Total Population 1971 (million)	Total Population 1981 (million)	% of increase	Occupied Housing Units 1971	Occupied Housing Units 1981	% of increase
Urban	2.848	3.192	12.1	0.421	0.512	21.5
Rural	8.707	10.720	23.1	1.558	2.085	33.7
Estate	1.134	.933	-17.7	0.238	0.217	-8.6
All Sectors	12.689	14.847	17.0	2.217	2.813	26.9

Figure 3.15

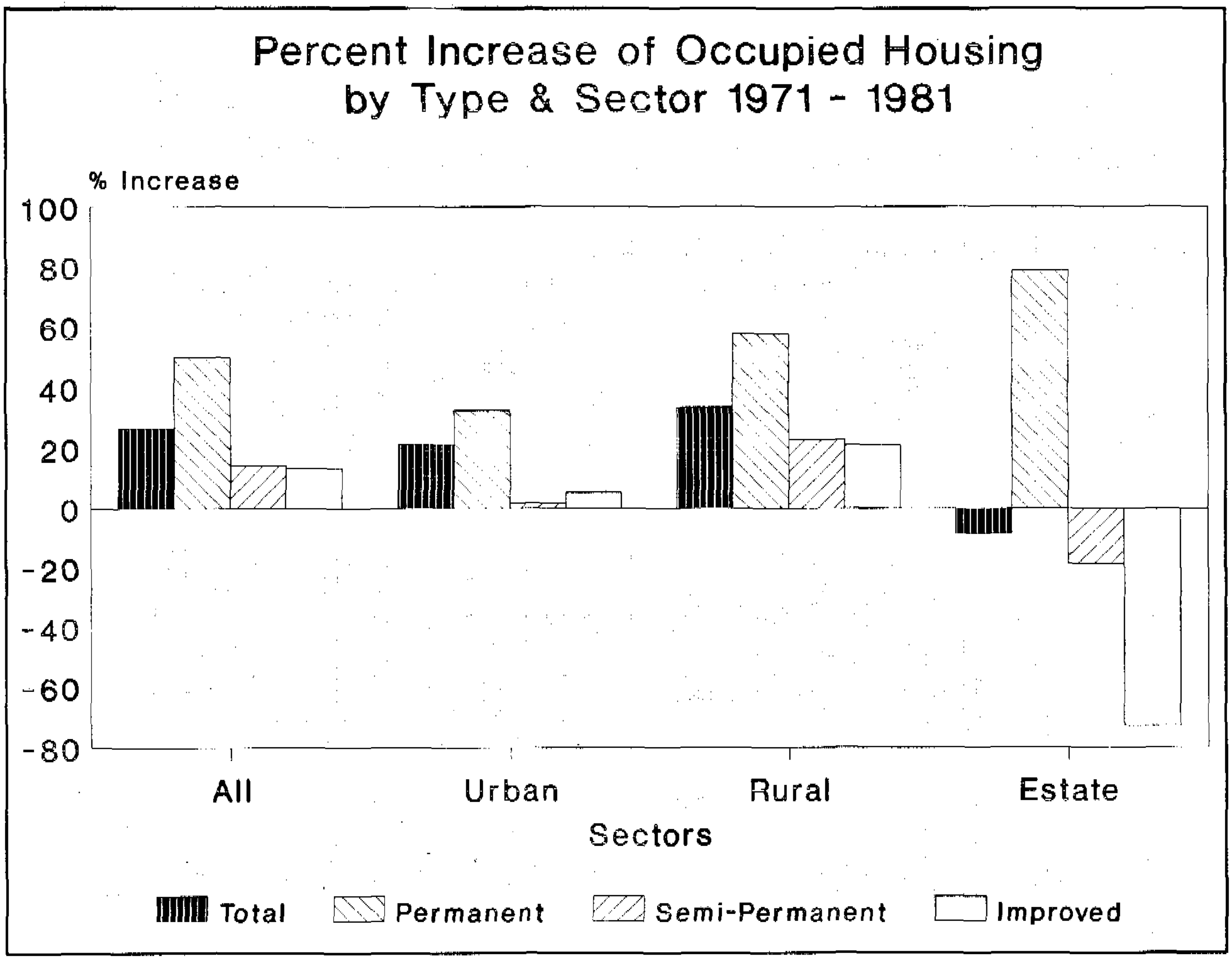


Figure 3.16

Those constructed between 1971 and 1975 amounted to 10.5 percent of the total stock. The growth rate accelerated to 3.9 in 1976, declined to 3.4 percent by 1977, then increased to 4.2 percent in 1978 and 5.3 percent by 1980.

Occupancy and Overcrowding

Sharing of housing units had declined by 1981 in numerical magnitude and as a percentage. The Census of 1981 disclosed that over 90 percent of the housing units in each sector were occupied by single households. Only 4.8 percent of the housing units were shared by more than one household in 1981, compared to 7.6 percent in 1971.

Type of Lighting

The Census of 1981 found that 82 percent of all housing units depended on kerosene lamp lighting (Figure 3.19). Electric lighting increased from 9 percent in 1971 to 14.9 percent in 1981. Housing units using electricity in the urban sector increased from approximately 33 percent to over 45 percent. In the rural sector, only 8.3 percent of the houses received electricity, but the number of rural housing units using electric lighting rose substantially, from 44,000 to 172,000.

In the estate sector, however, the number of housing units using electricity was only 5.6 percent. Rural electrification programs undertaken during the past years may have raised these proportions, but the backlog of units not yet provided with electricity remains substantial in the rural and estate sectors.

Main Sources of Drinking Water

Housing units with access to piped water increased from 0.444 million in 1971 to 0.497 million in 1981, but the proportion with piped water declined from 20 percent to 17.5 percent (Figure 3.20). Housing units dependent on wells for drinking water increased from 63.8 percent to 72.9 percent. Thus wells remain the main source of drinking water for nearly three-fourths of the country's population, and the proportion dependent on rivers, tanks, and other surface sources has remained around 7 percent. By 1981 nearly all urban housing units had access to piped water. The share of estate sector housing units with this facility has been traditionally high at about two-thirds. An insignificant proportion (about 5 percent) of the rural housing units are served with piped water, and about 85 percent depend on well water. Although wells are still Sri Lanka's principal source of drinking water, as many as 20 percent of wells are unprotected and allow inflow of polluted water.

Dispersal of housing units in village areas, absence of potable ground water for drinking, and the cost of providing pipe borne water will remain important development issues, especially because approximately 800,000 additional housing units must be supplied between 1990 and the end of the century. The magnitude of this backlog of housing units requiring safe drinking water is evident from Figure 3.21, which provides data on the main source of drinking water by district. In 14 out of the 25 districts (Kalutara, Matale, Galle, Matara, Hambantota, Mullaitivu, Ampara, Kurunegala, Anuradhapura, Polonnaruwa, Badulla, Moneragala, Ratnapura and Kegalle) more than one-third of the population do not have access to safe drinking water and are using unprotected wells, rivers and tanks. In rural areas the shallow wells used for drinking water are frequently holes dug in the ground that run dry during the dry season and receive polluted water during the rainy season.

Toilet Facilities

Poor sewerage facilities for housing lead to contamination of water sources and the spread of disease. The 1981 Census data disclosed that one out of every three houses lacked sanitary toilet facilities, down from 35.5 percent in 1971. In the urban sector during this period, the proportion not served by sanitary toilet facilities remained unchanged at approximately 20 percent. The rural sector made some gains; the proportion declined from 42.5 percent to 36.5 percent, but in the estate sector the position deteriorated.

Part of the overall decline may have been due to a change in the definition used in the 1981 Census, which categorized a unit using a toilet of another housing unit as one lacking a toilet.

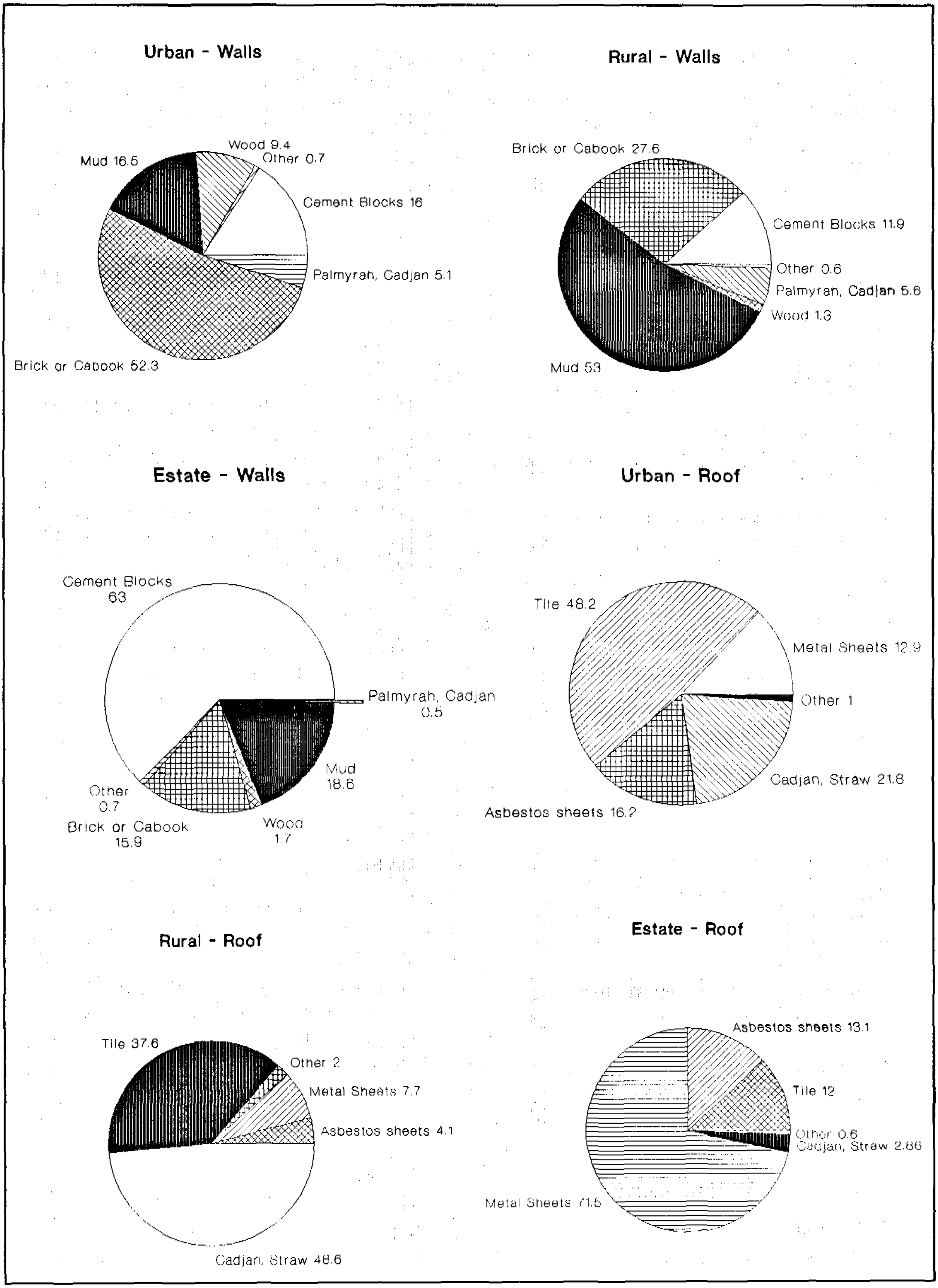
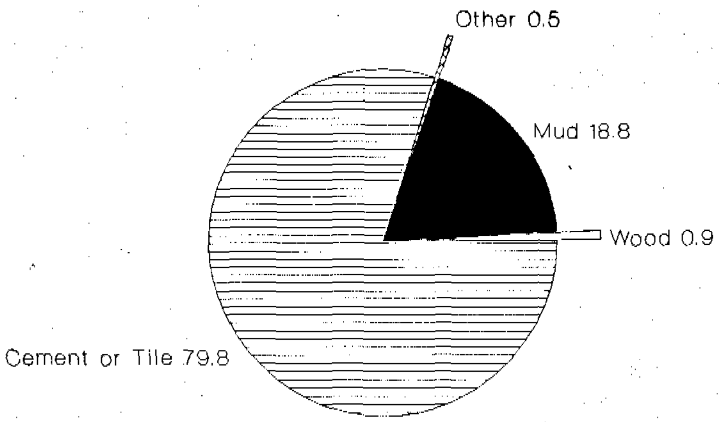
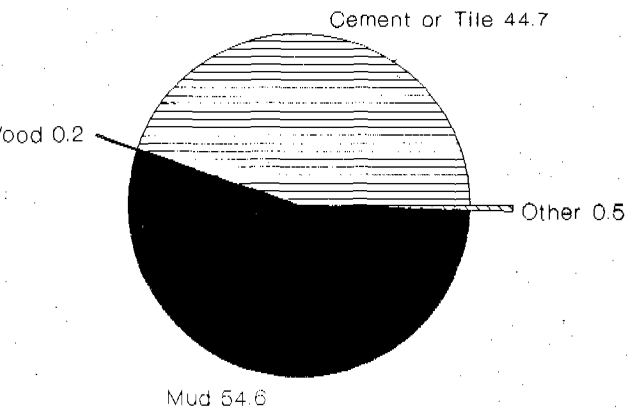

Urban - Walls
Wood 9.4
Other 0.7
Mud 16.5
Cement Blocks 16
Palmyrah, Cadjan 5.1
Brick or Cabook 52.3
Rural - Walls
Brick or Cabook 27.6
Cement Blocks 11.9
Other 0.6
Palmyrah, Cadjan 5.6
Wood 1.3
Mud 53
Estate - Walls
Cement Blocks
63
Palmyrah, Cadjan
0.5
Mud
18.6
Other
0.7
Brick or Cabook
15.9
Wood
1.7
Urban - Roof
Tile 48.2
Metal Sheets 12.9
Other 1
Cadjan, Straw 21.8
Asbestos sheets 16.2
Rural - Roof
Tile 37.6
Other 2
Metal Sheets 7.7
Asbestos sheets 4.1
Cadjan, Straw 48.6
Estate - Roof
Asbestos sheets 13.1
Tile 12
Other 0.6
Cadjan, Straw 2.86
Metal Sheets 71.5

Figure 3.17

Urban - Floor



Rural - Floor



Estate - Floor

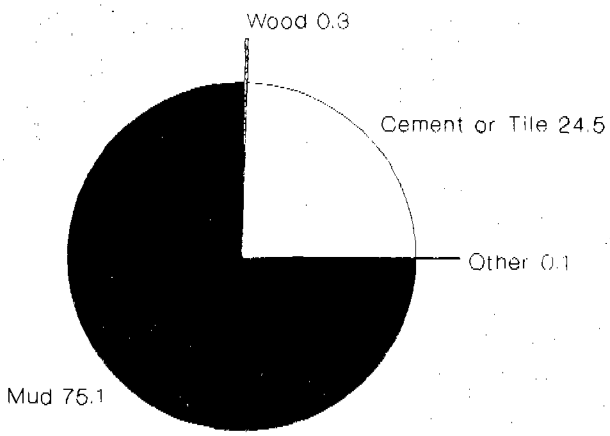


Figure 3.17

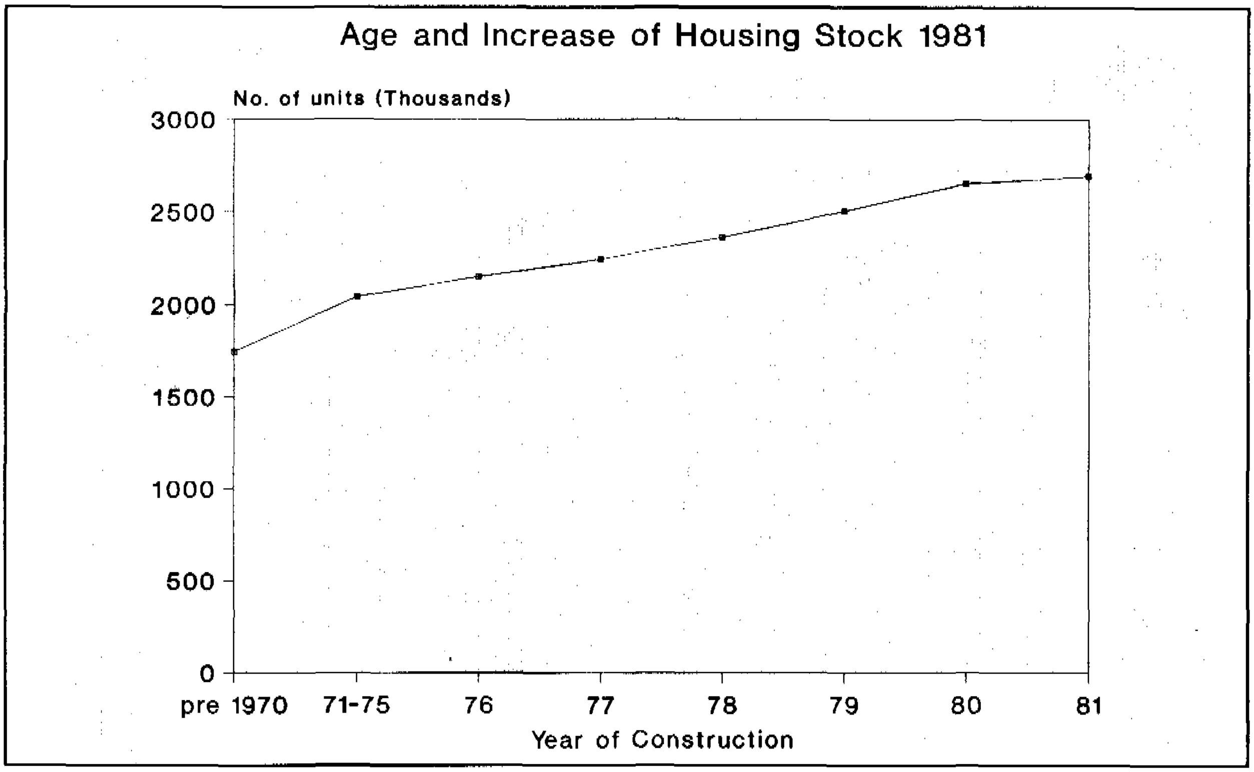


Figure 3.18

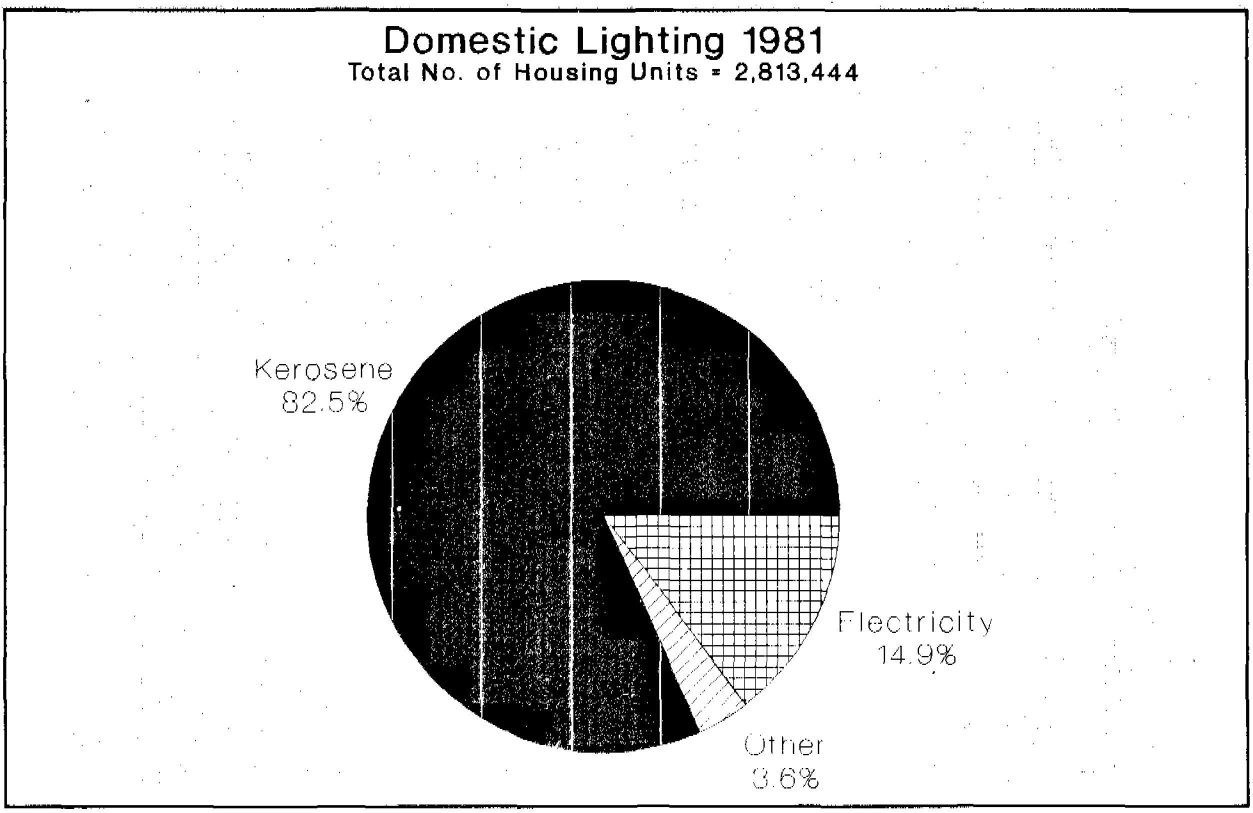


Figure 3.19

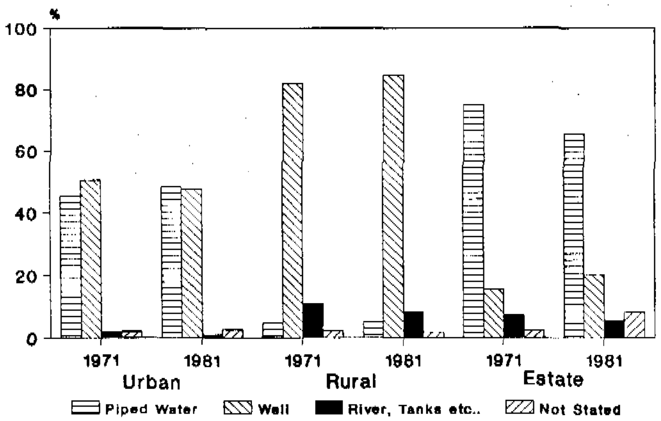


Figure 3.20

Main Source Of Drinking Water In Occupied Housing Units By Districts 1981

District	Total Number	%	Piped Water %	Protected Well %	Unprotec-ted Well %	River,tank & Other Source %	Not Stated %
Sri Lanka	2813844	100.0	17.6	52.2	20.6	7.0	2.5
Colombo	272,488	100.0	52.0	37.8	7.4	0.5	2.3
Gampaha	265,951	100.0	8.7	66.1	21.9	0.6	2.7
Kalutara	160,422	100.0	5.5	59.1	28.7	3.8	2.9
Kandy	178,379	100.0	29.3	44.0	19.7	4.7	2.3
Matale	68,208	100.0	14.2	46.6	24.2	12.8	2.2
Nuwara Eliya	122,828	100.1	61.0	13.2	8.0	10.4	7.5
Galle	146,385	100.0	6.2	61.3	27.6	3.1	1.8
Matara	121,755	100.0	9.9	47.4	36.0	4.9	1.8
Hambantota	80,496	100.0	11.2	41.5	30.1	16.1	1.1
Jaffna	157,609	99.9	10.8	76.9	8.0	2.1	2.1
Mannar	18,049	100.0	21.3	70.3	5.7	2.1	0.6
Vavunia	17,703	99.9	4.6	74.1	13.4	3.7	4.1
Mullaitivu	13,505	100.9	3.8	59.6	27.5	6.3	2.7
Batticaloa	69,090	99.9	4.0	75.9	9.3	9.0	1.7
Ampara	77,974	100.0	7.5	61.6	13.9	12.3	4.7
Trincomalee	47,822	100.0	6.7	64.0	16.7	10.6	2.0
Kurunegala	263,504	99.8	2.2	64.5	26.7	4.5	1.9
Puttalam	105,169	100.0	7.4	66.8	18.8	5.1	1.9
Anuradhapura	107,914	99.9	6.7	60.0	23.4	7.7	2.1
Polonnaruwa	48,183	100.0	2.4	47.9	39.5	6.7	1.6
Badulla	120,182	100.0	43.5	24.0	14.9	13.8	3.8
Moneragala	51,551	100.0	4.7	35.3	29.3	28.8	1.9
Ratnapura	158,686	100.0	19.4	34.8	21.4	22.5	1.9
Kegalle	139,992	99.9	10.0	51.6	28.3	7.6	2.4

Figure 3.21

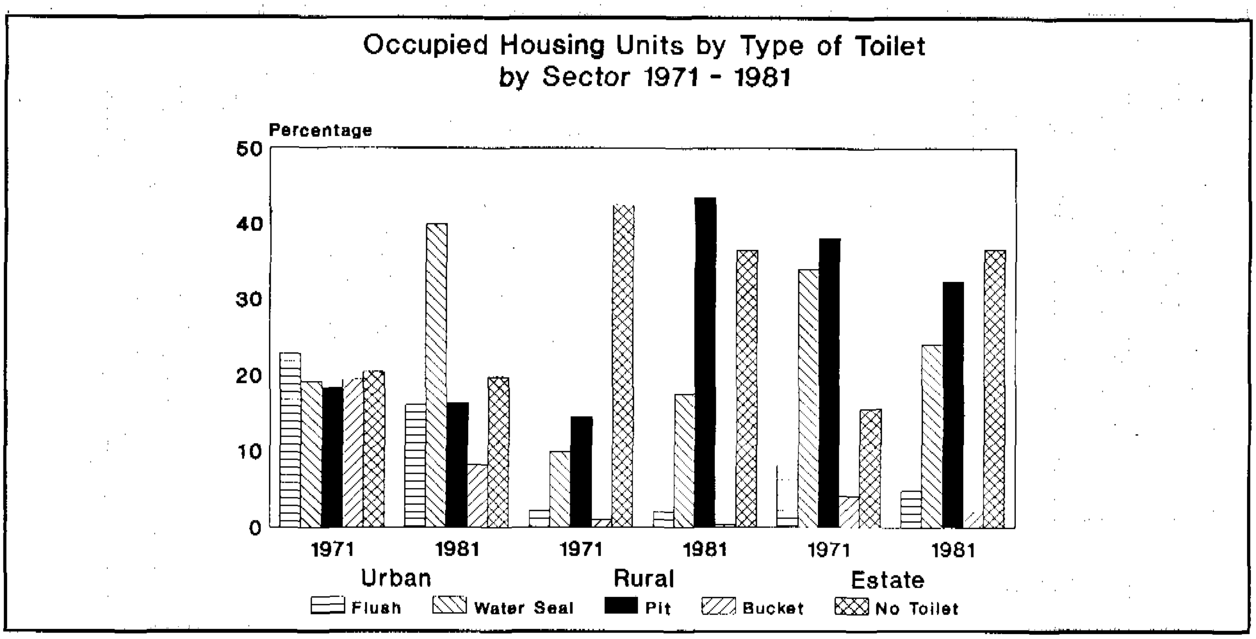


Figure 3.22

The number of housing units using flush toilets also had declined by nearly 9 percent. As a consequence the relative share of this facility declined by nearly 2 percentage points to 4.8 percent. However, the number of water sealed toilets nearly doubled between 1971 and 1981. (Figure 3.22). In the urban sector the number of bucket toilets had declined from 81,000 to 42,000, and the percentage share of this type in all sectors declined nationwide to only 1.9 percent. Figure 3.23 shows the wide variation in the different types of toilets in use and the variations in districts. Outside Colombo the proportion of flush toilets is relatively small, with Jaffna having 8 percent and Kandy 5.5 percent. Water sealed toilets are more evenly distributed. Pit toilets, however, remain the most widely used toilet while the bucket is becoming obsolete. The percentage of housing units which lack any toilets has been exceedingly high. In districts such as Mannar, Vavuniya, Mullaitivu, Batticaloa, Ampara and Trincomalee, more than two-thirds of the housing lacked toilet facilities.

POPULATION AND DOMESTIC FOOD PRODUCTION

Sri Lanka's traditionally dominant agricultural sector has largely produced tea, rubber and coconut products for export, while food imports used a major part of the export earnings. Recognizing the cost of feeding a growing population, policies since the 1930s have encouraged development of croplands in the Dry Zone, through irrigation and peasant settlements.

Between 1946 and 1962 162,0004 hectares of new land were cultivated, and another 147,800 hectares developed for agriculture between 1962 and 1973. Agricultural land increased by 18 percent over this period, raising agricultural croplands from 26.0 percent to 31.5 percent of the country's total land area. The scale of new land development slowed after 1973, but the area developed for paddy alone between 1973 and 1986 amounted to 134,500 hectares. Cultivated land now increases by 10,100 hectares per year.

The agricultural sector still contributes as much as 22.4 percent of the national product and 45.0 percent of total employment. These figures would be even higher if they included industries dependent on agricultural raw material.

Information on land availability and agricultural production has been canvassed through a series of agricultural censuses in 1946, 1962, 1973, and 1982, with the next census planned for 1992. In 1946 agricultural lands totalled 1.727 million hectares. They increased to 2.037 million hectares by 1973. Because of under-enumeration of agricultural lands, particularly paddy

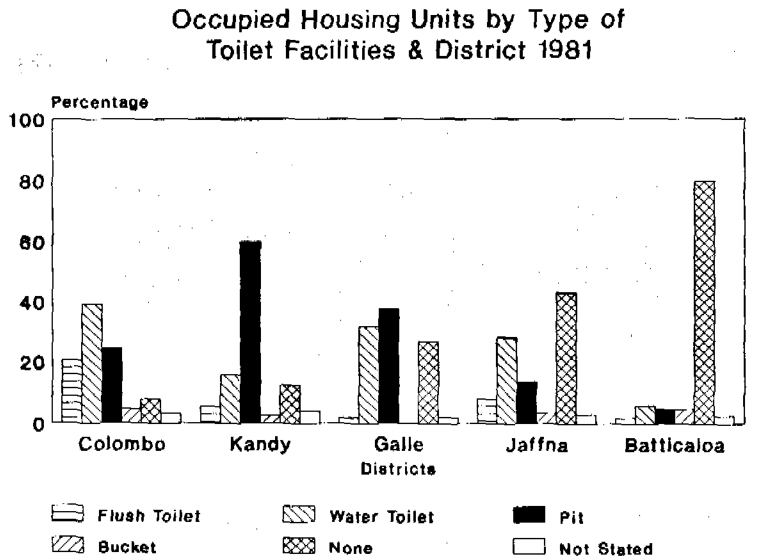


Figure 3.23

fields, at the Census of Agriculture 1982, that census did not disclose the growth of agricultural land during the intercensal period.

The extent of agricultural land ascertained in the 1946, 1973 and 1982 censuses and agricultural land per capita in 1982 are given in Figure 3.24. Average agricultural land availability has been 0.13 hectare per person for the country as a whole. In the predominantly agricultural districts of the Dry Zone the agricultural land availability varied between 0.16 hectare per person to a maximum of 0.28 hhectare per person in Vavuniya. In densely populated areas such as Gampaha and Jaffna it declined to about 0.06 hectare per person. Current distribution and use patterns of agricultural lands by crop are displayed bellow.

Crop	Hectares
Tea	222,700
Rubber	242,900
Coconut	415,000
Other permanent crops	176,100
Paddy	729,900
Highland temporary crops	253,000
Total	**2,037,600**

Plantation crop lands have not increased, but paddy increased from 390,300 hectares in 1952 to 727,900 hectares in 1985. It accounts for about 11 percent of the total land area, and 35 percent of the total cultivated area. Production also increased from 595,000 metric tons to a maximum of 2,661,000 metric tons. A considerable part of this increase resulted from improved productivity.

Lands devoted to other cereals, pulses, roots and tubers and other annuals total approximately 253,000 hectares. Although much of the cultivation is rainfed and yields are low, productivity can improve substantially. About 90 percent self-sufficiency, has been achieved for rice. Barring major droughts, if Sri Lanka maintains its recent productivity gains, it should meet the increasing rice demands in the near future. Continued imports of wheat flour will be necessary in the medium term at current levels. Substantial expansion of sugar acreage will be required to meet rising demands without increased imports.

Projections for food requirements show that the calorie availability needs from vegetables and fruits have not been met and that demand for these items will be about 25 percent above current supply by the end of the century. Per capita caloric, protein, and fat supplies have slowly improved over the past decade despite

Rapid Urbanization In Sri Lanka: Implications and Challenges

Rapid growth of the Colombo Urban Area (CUA), with a currently estimated population of 1.6 million, has gravely concerned local authorities. Fourteen local authorities make up the CUA: two municipal councils (Colombo and Dehiwela-Mount Lavinia), five Urban Councils (Kotte, Moratuwa, Kolonnawa, Peliyagoda and Wattala-Mabole) and the seven Town Councils (Maharagama, Battaramulla, Kotikawatta, Mulleriyawa, Kelaniya, Dalugama and Hendala). Each authority functioned as a distinctly individual entity until about twenty years ago. Now the CUA has grown so as to fuse each local authority with the others. An array of new social, economic and environmental problems has arisen from this high concentration of urban poverty, overloading the urban sewer, water and drainage infrastructure.

The annual rate of growth of urban population for all of Sri Lanka declined dramatically to 1.2 percent between 1971 and 1981 -- down from 6.2 percent and 5.1 percent during the previous two periods, 1953-1963 and 1963-1971 respectively. However, phenomenal growth rates were recorded during the 1971-1981 period by a majority of local authorities in the CUA -- Moratuwa (40 percent), Battaramulla (27.8 percent), Hendala (24.5 percent), Maharagama (19.2 percent), Kelaniya (12.4 percent), Dalugama (12.1 percent), Wattala-Mabole (10.6 percent) and Kotikawatta (10.2 percent). Further, while the density for all of Sri Lanka was only 230 persons/sq.km, density for the CUA was 7,844 persons/sq.km, and 15,917 persons/sq.km for the Colombo Municipal Council.

The physical consequences of such rapid urban growth include sub-standard shelter, improper or inadequate water supply, unhygienic toilet facilities, undesirable and unsanitary solid waste disposal, and gradual elimination of a network of storm water basins.

Shelter

The acute shelter problems, like other urbanization problems, are mostly confined to Colombo's shanty and slum settlements. With nearly 50 percent (or 65,000 households) of the Colombo Municipal Council area's population cramped in such settlements, the urban housing component of the Million Houses Programme, launched by the government in 1984, was aimed at rehabilitating these settlements. Shelters in these settlements are overcrowded and built of improvised material on marginal, usually flood prone land. Occupants typically lack legal rights to the land they occupy.

Through the Million Houses Programme (MHP), families in shanty and slum settlements have been given legal tenure to the land, along with loans of up to 15,000 rupees to improve their shelter through a Housing Option Loans Package (HOLP). As of August 1988, nearly 30,000 shanty families had benefited from the Million Houses Programme.

To overcome acute shortage of land, especially for low-income housing, the government reduced the minimum size of plots for residential development from 303 to 152 square meters, and in some special cases to 51 square meters. The resulting increase in spot densities has strained the infrastructure to its limits and local officials have found themselves unable to control illegal and unauthorized construction, usually extensions for cooking areas, which, due to restricted space, often abut toilets, cattle sheds, or poultry runs in the adjoining plot. The result of these unauthorized structures is unhygienic cooking practices.

Water Supply and Sanitation

As shanty and slum improvement schemes increase so does demand for water supply. Rehabilitation settlements therefore have posed a challenge to the National Water Supply and Drainage Board (NWS&DB). Existing supply lines are already overloaded and new supply now appears feasible only by tapping ground water where the quality is found suitable for human consumption. Collection of rain water is also being explored.

Rising Risk of Water Pollution

In the Colombo District in 1981 about 37 percent of the approximately 272,500 housing units had either pit toilets (24 percent), bucket toilets or none at all. About half (52 percent) of all housing units had piped water, and over a third (37.8 percent) had protected wells. About 10 percent of the housing units used shallow wells highly susceptible to domestic contamination, or they used untreated river water or other sources. At 5.48 persons per unit -- the average urban household size in 1981/1982 -- some 150,000 residents in the Colombo District were at potentially high risk of contracting some waterborne disease from water contamination. Today, assuming no change in the percentage of people who use unprotected water, this high risk group may have increased by more than 20,000 because of Colombo's growing urban population. Numbers at risk will be higher still if piped water or protected well water becomes contaminated. Only 375,000 in Colombo are served by sewers.

Conditions in the Gampaha District are potentially more serious. About 60 percent of the 266,000 housing units had pit toilets (43.8 percent), bucket types, or none (14.8 percent). Of these units, 9 percent received piped water, 66 percent used protected wells, and the remaining 25 percent used unprotected wells, rivers and other sources. This means about 364,000 people were at high risk from contaminated water in 1981. Today there are about 400,000.

If Colombo and other urban areas increase their growth rate over the next ten years as forecast, water pollution problems will obviously grow more serious unless there is significant new investment in urban water and sanitation infrastructure.

In local authorities where wells are the sole source of drinking water, the building of septic tanks within a 152 - square meter plot hits a snag: by-laws require septic tanks to be 15.25 meters away from a well, whether one's own or a neighbors, in order to prevent contamination. Several surveys have shown that these by-laws are not strictly obeyed.

The local authorities along the sea coast face a peculiar problem arising from persistent rural habits unsuited to urban settlement. Squatters encroaching on sea coast reservations are in the practice of relieving themselves directly on the beach. The excreta, washed away by the sea, resurface and pollute other beaches, some of which are frequented by tourists. Providing these settlements with any form of toilet has not yet proved effective.

Solid Waste Collection and Disposal

Domestic garbage disposal requires urgent attention in the CUA. In most parts of the CUA garbage is either collected by "hand carters" from residences and piled at central collection points or households are expected to bring their garbage to these points. The collected garbage remains for a number of days, polluting the environment and inviting rats and dogs, as well as scavenging by the poor, until garbage trucks take it away for disposal, usually dumping in marshy lands away from residential areas.

Safe and convenient disposal sites, however, have become increasingly scarce. As a result, the whole process of garbage collection and disposal has become inefficient; garbage piled at temporary locations often remains unattended for a considerable period, causing a nuisance and health hazard to residents. With rising urban population and garbage output estimated at 470 tons per day by 1992, cost effective alternatives to present garbage collection and disposal systems have become an urgent need.

Elimination of Storm Water Basins

Skyrocketing urban land prices force low and middle income households to seek cheaper residential lands away from the city center. One direct result is the filling of marshy land for residential development. A network of such marshy land within the CUA has served as a natural drainage system for storm waters. With the filling in of these storm water basins -- over 200 hectares by the Sri Lanka Reclamation and Development Corporation alone since 1968 storm drainage malfunctions are causing floods in most of the low-lying areas within the CUA. In the absence of a clear policy to maintain these storm water basins, local authorities have no alternative but to approve applications for filling by developers or individual house builders.

problems of equitable distribution to low income groups.

LABOR SUPPLY

Population censuses and labor force surveys conducted since Independence have shown rapid growth in Sri Lanka's labor force. It increased from 2.6 million in 1946 to 3.4 in 1963, to 4.5 million in 1971 and reached 5.9 million in 1985 (See Figure 3.25). Annual rates of growth during this span:

1946 - 1953	2.1 percent
1946 - 1971	2.7 percent
1946 - 1985	2.1 percent
1963 - 1971	3.3 percent
1971 - 1981	2.5 percent
1971 - 1985	2.1 percent

Between 1963 and 1981 growth rates were particularly high, exceeding 2.5 percent per year, and higher than the growth rate of the total population. This rate of growth in the labor force is unlikely to decline below 2.0 percent in the short and medium term because new entrants to the workforce over the next fifteen to twenty years have already been born. A decline could occur only through a substantial increase of external migration.

Population of Working Age

Analyses of the labor force usually consider age group 15-59 years as the population of working age, with those outside this range being young dependents or elderly. Recent census and labor force surveys canvassed the employment status of persons above 10 years. Some earlier surveys even canvassed the next lower age group of 5-9 years because of the prevalence of child labor. Child labor exists, but it has declined in magnitude and as a percentage of the total labor force. At the 1981 Census child workers in the age group 10-14 years totalled 8,975 -- including 5,840 males and 3,135 females.

With longer life expectancy the economically active population above 60 years has increased, and this trend will continue. The working-age population will increase from 8.677 million in 1981 to an estimated 10.593 million by 1991. By 2001 it will increase by 2.3 million to 12.825 million -- 47.8 percent higher than in 1981. Between 2001 and 2011 its size will increase again by 1.3 million to 14.189 million, but thereafter working-age population will increase only marginally, reaching a maximum of nearly 15 million in 2036. Net additions to the population of working age over the next 20 years will be about 0.9-1.0 million in each quinquennial period between 1986 and 2006.These are critical figures. They show the significant future additions to the labor force and the magnitude of the employment task ahead.

The number of working-age people will increase until 2036, but after 2006 their relative share will decline from 65.01 percent to 59.44 percent, while the share of elderly will increase. Issues of old age dependency and health care are likely to become increasingly significant during this period. Higher life expectancy and consequent larger cohorts in older age groups will affect the internal composition of the productive population. The working population will become increasingly older., the male share will decline in relation to the female share.

Employment by Industry Sectors

Data on the distribution of employment by industrial sector, ascertained through cross section surveys, show how the industrial composition of the workforce has changed over time (Figure 3.26). Structural changes in the economy have been slow, with the agriculture sector remaining large and absorbing as much as one-half of the employed population. The proportion dependent on agriculture, approximately 53 percent in 1953, declined only 4 percent to 49 percent by 1985.

Over this period agriculture absorbed approximately 1 million persons, but its the slow growth rate of around 1.5 percent per year, compared to annual increases of over 2 percent per year in the labor force and the total population, resulted in a large pool of surplus labor. Agriculture could absorb only about one-third of the growing increment in labor supply, which averaged between 100,000 and 125,000 per year. Unfortunately, manufacturing sector employment could not take up the slack. It grew from 290,000 in 1953 to 650,000 by 1985, increasing its share from 9 percent to 12.5 percent. Slow growth of this sector did not keep pace with the increasing number of educated and skilled men and women in the workforce, nor were other sectors able to do so.

Occupational Distribution

Slow structural changes in the economy are reflected in the relatively small shifts from agriculture and related work to professional, technical, production and related service employment. Thus the number of agricultural workers declined by 4 percent between 1953 and 1985, and the share of professional workers increased only marginally, by about 1.5 percent. Classification problems prevent extensive comparisons between the 1953 and subsequent surveys, but Figure 3.27 shows that the share of production process workers increased from 23 percent to about 28 percent between 1963 and 1985. During this time these occupations absorbed approximately 700,000 net additions. Only modest shifts occurred in occupational distribution.

Future population trends, labor force growth, and the rising share of people with educational and other skills require shifts towards employment in manufacturing, agricultural processes and industries, and professional, technical, and service occupations. Creation of new jobs will not suffice; new employment opportunities must match a higher skills profile.

The labor force estimated at 5.563 million in 1980 and 6.395 million in 1986 grew at an average rate of 138,600 per year. By 2001, the projected labor force of 8.78 million will comprise 5.97 million males and 2.81 million females, with an average annual increase of 159,000 by increments of 105,000 males and 53,500 females. By 2016 the labor force will increase by a further 2.2 million, an average of 148,000 per year from 2002-2016, to nearly 11 million, comprising 7.11 million males and 3.89 million females. Most significant is the acceleration of female entry into the workforce. The female net additions to the workforce should increase from about 50,000 in the 1990s to nearly 70,000 in the first 15 years of the twenty-first century. New additions to the workforce will have higher educational attainments and better skills than those leaving it.

Employment Growth Required to Match Labor Supply

An intractable problem in the country during the past three decades has been youth unemployment and the need to increase productive employment for new members of the workforce. Although about 175,000-

Population Density

Province/District	Pop. Number	%	Land Area (hectares)	Density Pop/ha 1981	Total Extent Of Agricultural Land (ha) 1946	1973	1982	Agricultural Land /Cap. 82
Sri Lanka	14,846,750	100.0	6,476,884	2.30	172,691	2,036,989	1,975,639	0.13
Western Province.	3,919,807	26.40	365,927	10.27	272,185	269,583	234,811	0.06
Colombo	1,699,241	11.45	65,268	26.03	168,715	168,336	35,610	0.02
Gampaha	1,390,862	9.37	139,946	9.93			95,744	0.07
Kalutara	829,704	5.59	160,713	5.16	103,470	101,248	103,457	0.13
Central Province.	2,009,248	13.55	559,236	3.58	300,091	309,139	278,457	0.14
Kandy	1,048,317	7.06	236,806	4.42	162,819	174,521	111,024	0.11
Matale	357,354	2.41	199,611	1.78	68,088	67,574	69,555	0.19
Nuwara Eliya	603,577	4.07	122,818	4.92	69,183	67,043	97,878	0.16
Southern Province.	1,882,661	12.68	551,579	3.41	235,285	260,878	247,830	0.13
Galle	814,531	5.49	167,449	4.87	94,487	98,426	94,253	0.12
Matara	643,786	4.34	124,696	5.16	87,503	90,796	80,346	0.13
Hambantota	424,344	2.86	259,433	1.63	53,295	7,165	673,230	0.17
Northern Province.	1,109,404	7.48	868,923	1.28	90,125	110,868	114,677	0.11
Jaffna	830,552	5.59	207,309	4.00	61,906	57,616	49,224	0.06
Mannar	106,235	0.72	200,287	0.52	15,283	20,934	18,491	0.17
Vavuniya	95,428	0.64	264,623	0.37	12,935	32,317	27,784	0.29
Mullaitivu	77,189	0.52	196,704	0.40			19,177	0.25
Eastern Province.	975,251	6.57	807,158	1.21	80,008	134,564	155,187	0.16
Batticaloa	330,333	2.2	246,564	1.33	37,651	46,294	50,907	0.15
Ampara	388,970	2.62	298,667	1.31	29,860	52,796	62,666	0.16
Trincomalee	255,948	1.72	261,927	0.99	12,596	35,475	41,614	0.17
North Western Province	1,704,334	11.48	775,287	2.20	313,866	363,468	363,839	0.21
Kurunegala	1,211,801	8.16	477,474	2.54	236,720	274,185	274,346	0.23
Puttalam	492,533	3.32	297,814	1.65	77,146	89,283	894,93	0.18
North Central Province	849,492	5.72	1,062,685	0.79	68,839	153,378	167,053	0.20
Anuradhapura	587,929	3.96	722,170	0.82	53,658	109,410	113,636	0.19
Polonnaruwa	261,563	1.76	340,515	0.77	15,181	43,968	53,417	0.20
Uva Province.	914,522	6.16	995,725	0.91	107,657	161,542	162,186	0.18
Badulla	640,952	4.32	281,927	2.27	92,296	101,972	98,218	0.15
Moneragala	273,570	1.84	713,798	0.40	15,360	59,570	63,968	0.23
Sabaragamuwa Province	1,482,030	9.98	490364	3.01	259637	273568	250599	0.17
Ratnapura	797,087	5.36	324016	2.47	123812	146860	135782	0.17
Kegalle	684,944	4.61	166348	4.12	135825	126708	114816	0.17

Figure 3.24

Labour Force Estimates

1946 - 1986

Title Of Survey	Labour Force Participation 000' Total	Male	Female	Crude Participation Rate (%) Total	Male	Female
1. Census Of Population -1946	2,611	2,041	570	39.2	57.8	18.2
2.. Census Of Population - 1953	2,993	2,268	724	37.0	53.1	18.9
3. Census Of Population - 1963	3,464	2,742	722	32.7	49.8	14.2
4. Labor Force Survey - 1968	4,150	3,156	984	34.6	50.7	17.2
5. Socio-economic Survey - 1969/70	4,169	3,124	1,045	38.6	57.3	19.5
6. Census Of Population -1971	4,488	3,312	1,176	35.4	50.7	19.1
7. Survey Of Labour Force Participation Rates - 1973	4,560	3,267	1,293	34.5	48.5	20.2
8. Land And Labour Utilisation Survey - 1975	4,957	3,490	1,467	36.5	50.2	22.1
9. Consumer Finance & Socio-economic Survey - 1978/79	5,521	3,712	1,809	38.0	50.4	26.2
10. Socio-economic Survey - 1980/8	15,715	4,109	1,606	37.3	53.1	21.2
11. Census Of Population - 1981	5,105	3,767	1,248	33.8	49.8	17.1
12. Consumer Finances & Socio-economic Survey - 1981/82	5,282	3,843	1,439	34.3	49.7	19.4

Source: Korale, R.B.M. SriLanka Economic Journal: Vol.1, No.1, 1986

FIGURE 3.25

Distribution of Employed Population by Industry Sector

(Figures in Thousands; Percentages in brackets)

	Sector	Census 1953	Census 1963	Census 1971	LF & SES 1980/81	Census 1981	Consumer Finance 1981/82	LF & SES 1985/86
1.	Agriculture hunting, forestry & Fishing	1584.1 (52.9)	1681.9 (52.6)	1828.9 (50.1)	2293.3 (47.3)	1863.8 (45.2)	2360.7 (51.2)	2530.9 (49.3)
2.	Mining & Quarrying	13.8 (0.3)	9.4 (0.3)	13.1 (0.4)	63.4 (1.3)	38.6 (0.9)	77.9 (1.7)	66.7 (1.3)
3.	Manufacturing	289.2 (9.7)	292.3 (9.2)	339.4 (9.3)	572.0 (-)	416.8 (10.1)	573.6 (12.4)	648.5 (12.7)
4.	Electricity, gas & water	3.3 (0.1)	7.8 (0.2)	9.6 (0.3)	19.2 (0.4)	15.2 (0.4)	14.3 (0.3)	21.5 (0.4)
5.	Construction	56.7 (1.9)	85.1 (2.7)	103.6 (2.8)	216.1 (-)	124.8 (3.9)	238.4 (5.2)	226.9 (4.4)
6.	Wholesale & retail trade	228.8 (9.4)	349.1 (10.9)	343.8 (9.4)	485.8 (10.0)	433.3 (10.5)	493.4 (10.7)	513.9 (10.0)
7.	Transport, storage & communication	104.3 (5.5)	137.6 (4.3)	178.9 (4.9)	202.4 (4.2)	189.8 (4.8)	188.6 (4.1)	220.0 (4.3)
8.	Finance, Insurance, real estates & business services	65.1 (2.2)	15.6 (0.5)	24.9 (0.7)	52.6 (1.1)	45.5 (1.1)	68.2 (1.5)	65.1 (1.3)
9.	Community, social & personal services	396.2 (13.2)	440.9 (13.8)	492.8 (13.5)	644.6 (13.3)	596.7 (14.5)	581.4 (12.6)	631.4 (12.3)
10.	Activities not adequately described	197.8 (6.6)	175.4 (5.5)	313.9 (8.6)	301.9 (6.2)	385.8 (9.4)	15.2 (0.3)	206.8 (0.4)
	All economic activities	2993.3 (100.0)	3195.1 (100.0)	3648.9 (100.0)	4851.3 (100.0)	4119.3 (100.0)	4610.7 (100.0)	5131.7 (100.0)

Figure 3.26

Occupational Distribution of the Employed Population 1953 - 1986

(In Thousands)

Major Occupation	**Census** *1953*	**Census** *1963*	**Census** *1971*	**LF & SES** *1980/81*	**Consumer** *Finances* **1981/82**	**LF & SES** *1985/86*
Professional, Technical & Related Workers	113.6 (3.8)	142.7 (4.5)	178.5 (4.9)	269.2 (5.5)	304.1 (6.5)	272.9 (5.3)
Administrative & Managerial Workers	28.8 (0.9)	32.9 (1.0	14.0 (0.4)	25.4 (0.5)	51.4 (1.1)	26.4 (0.5)
Clerical & Related Workers	103.3 (3.5)	110.4 (3.7)	186.1 (5.1)	274.1 (5.6)	262.0 (5.6)	280.5 (5.5)
Sales Workers	221.2 (7.4)	212.2 (6.6)	272.4 (7.5)	396.0 (8.2)	392.9 (8.4)	442.0 (8.6)
Service Workers	439.5 (14.7)	359.6 (8.1)	198.0 (5.4)	265.4 (5.5)	257.3 (5.5)	241.5 (4.7)
Agricultural, Animal Husbandry & Forestry Workers, Fishermen & Hunters	1536.1 1653.6 (51.3)	1782.1 (51.7)	2191.2 (48.8)	2180.0 (45.2)	2438.3 (46.6)	(47.5)
Production & Related Workers, Transport Equipment Operators & Labourers	488.3 (16.3)	739.7 (23.1)	926.4 (25.4)	1415.4 (24.2)	996.4 (21.3)	1420.9 (27.7)
Workers not Classified	62.5 (2.1)	40.6 (1.3)	91.5 (2.5)	14.0 (0.3)	235.9 (5.0)	9.2 (0.2)
Total	2993.3 (100.0)	3199.7 (100.0)	3649.0 (100.0)	4851.4 (100.0)	4678.0 (100.0)	5131.7 (100.0)

Figure 3.27

200,000 new jobs were created from 1978-1982, economic growth has not absorbed the net additions to the workforce or reduced the backlog of unemployed. Slow economic growth during the past few years has raised unemployment from 850,000-900,000 in 1982 to about 1.17 million by 1988. This backlog, added to increasing annual increments of labor supply, substantially increases the magnitude of short- or medium-term employment creation plans. Total growth of employed during the 35-year period from 1946-1991 amounted to only 2.2 million. The net increase in the labor force between 1986 and 2001, plus the backlog, totals about 3.523 million. To achieve full employment by the beginning of the twenty-first century Sri Lanka will need to create an additional 225,000 job opportunities each year over the next 10-11 years.

Net additions to the labor force during 1986-2001	2.383 million
Backlog of unemployed 1986	1.140 million
	3,523 million
Less unemployed residual of 5 percent in 2001	0.439 million
	3,084 million
Average annual rate of employment creation 1986-2001	205,000

In the future the average number of new jobs must be higher than the estimated 205,000 per year because it has not been possible to achieve this level of new employment during the past few years. With the added backlog the average is closer to 225,000 per year.

Based on past experience, meeting this target will be a formidable task. It will require careful planning and implementation of chosen employment generation strategies that can make up shortfalls in any year when job creation lags. Strategies will need to include geographical dispersal of industries, and sites and processes that protect Sri Lanka's environment and natural resources.

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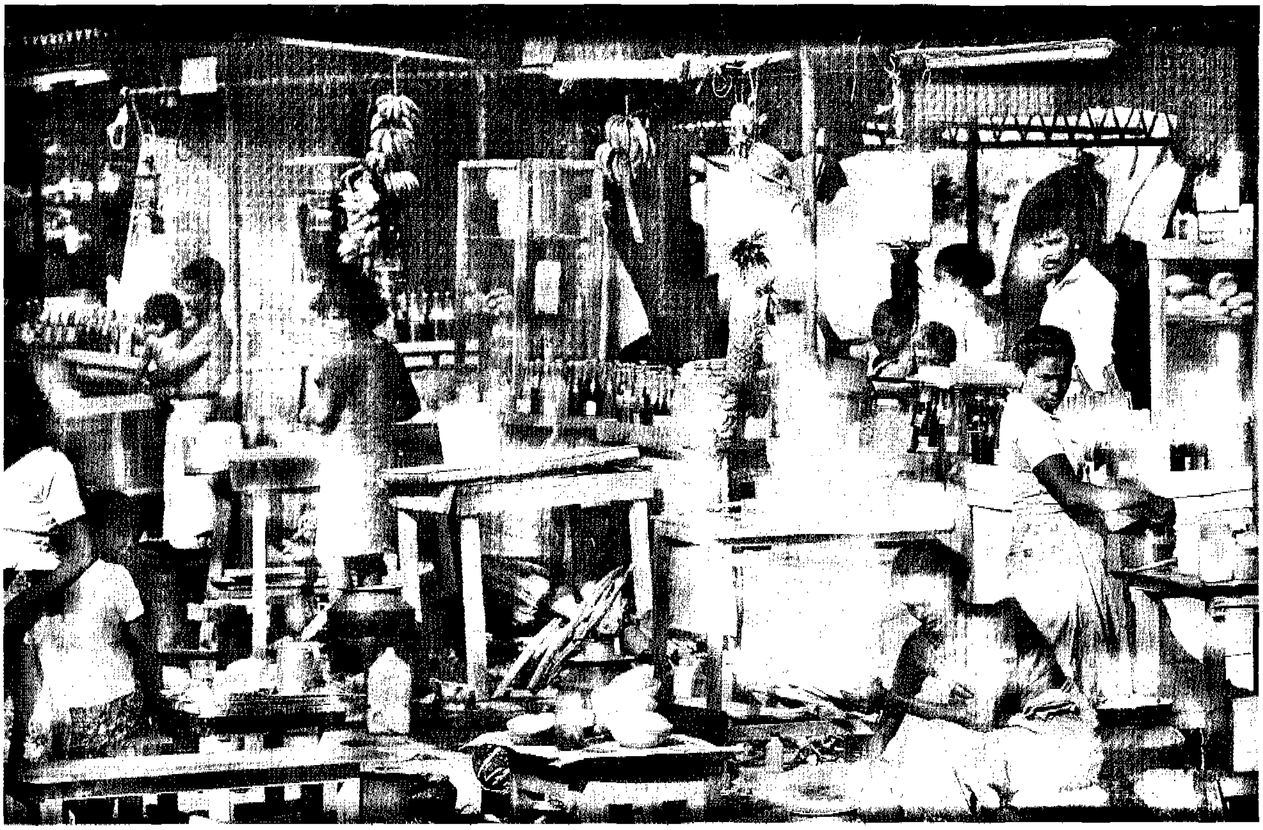


A typical small market serving Sri Lankan consumers.

4 Economic Conditions and Trends

Sri Lanka is one of the poorest countries in the world, with a per capita income of US $375 (Rs.11,939) in 1988 (Central Bank of Sri Lanka 1988). Like many other developing nations it faces chronic economic difficulties, despite a still promising natural resource base. In 1960 Sri Lanka was more prosperous than South Korea, and in 1970 more prosperous than Taiwan (Buultjens, 1990), but 40 years after Independence it suffers from unemployment, inflation and poverty, inadequate managerial capacity.

Deforestation, land degradation, soil erosion, pollution and other environmental stresses add new dimensions to these economic problems because productive, sustainable environmental systems can no longer be assumed. To achieve sustainable development, Sri Lanka must integrate economic thinking into its environmental policies, and vice versa.

This brief economic profile of Sri Lanka since Independence describes the effects of global and national economic changes on Sri Lanka's society, economy, government policy, and natural resources. These effects can be measured by data on capital investment, income generation, employment creation and increases in output. Yet such economic information does not necessarily help us understand the environmental effects of economic changes and actions, and how these environmental impacts affect prospects for sustainable economic development.

Economists and environmentalists increasingly recognize how misleading it can be when any economic investment is considered a contribution to economic growth, regardless of whether it enhances or degrades the environment. Traditional systems of national economic accounting have not become adequately developed to capture the total benefits and costs associated with investment decisions. Total benefits and costs include not only the tangible and market components of inputs and outputs but also the intangible and non-market components. Economists in many countries are working on ways to improve existing national accounting methods, but until we develop better systems and far better information to feed into them, we must make decisions based on the imperfect data and analyses available.

HISTORICAL BACKGROUND

The Sri Lankan economy of the 1950s and 1960s depended primarily on export-oriented commercial plantations of tea, rubber, and coconut. In the rural subsistence sector cultivation of paddy and other subsidiary food crops became increasingly important; no significant manufacturing existed prior to 1950. In the early 1950s, the outbreak of the Korean War stimulated the Rubber Boom, coupled with the Tea Boom a few years later. As a result Sri Lanka enjoyed balance of payments surpluses. Because no severe economic or social problems erupted, policy makers neglected the importance of economic diversification or shifts to industrialization.

Favorable economic conditions did not continue. By the late 1950s Sri Lanka experienced a deteriorating balance of payments and new problems of unemployment and failure to earn sufficient foreign exchange to purchase food and other commodities. To overcome these problems the government established several agricultural projects and various industrial ventures under its direct patronage and supervision.

Successive governments maintained the primary objective of self-sufficiency in food, especially in rice production. Wherever possible, most governments sought to increase the industry's role in the national economy, and they encouraged land settlement in the Dry Zone to reduce unemployment and population pressure in urban areas and to increase food production.

Sri Lanka's five year plan introduced in 1971 may be considered the peak of these inward-oriented growth policies in Sri Lanka. Import substitution and export expansion were the primary means to achieve economic growth. The government exercized vast control over economic activities. Most industries were government-operated monopolies. New public corporations took over production of steel, cement, sugar, fertilizer, refined petroleum, plywood, leather, mineral sands and paper. By the mid 1970s such parastatal corporations carried out most trade and distribution activities.

Continuous deterioration of the balance of payments position and other macro-economic problems required decision makers to initiate an extensive import control program while introducing import licences for most non-essential commodities. They introduced price controls which, by the early 1970s, included more than 6,000 articles. Since 1968 the government has implemented a dual exchange rate system to provide incentives for export diversification and disincentives for imports of non-essential consumer goods. It also established a concessionary tariff policy favoring import of machinery, equipment, and raw materials.

Although these policies restricted consumer freedom, they helped increase industrial production and changed Sri Lanka's economic structure. Low tariffs for imported capital equipment and raw materials made local production for local markets artificially cost-effective. Nevertheless, foreign reserves continued to decline, and the current account deficit in the balance of payments stood at 350 million rupees (59 million U.S. dollars) in 1970. The government also nationalized the privately-owned transport, oil, insurance and banking businesses in the 1960s, and tree crop plantations in the early 1970s. It also limited private ownership of land to 50 acres per person. Public sector economic intervention continued and gradually increased until November 1977.

That year marked the transition to economic liberalization in Sri Lanka. The new government began establishing market-oriented policies and took keen interest in introducing supply side economic policies. Some of the major policies implemented in this direction:

- setting the exchange rate at more realistic levels;
- reducing controls on foreign exchange transactions;
- liberalizing trade and encouraging foreign investments;
- privatizing industries and increasing economic efficiency;
- reducing budgetary burdens of the government.

Liberalization and macro-economic structural changes brought substantial improvements in the production and financial sectors. The industries sector had operated far below capacity because foreign exchange shortages inhibited import of spare parts and raw materials. Capacity use in the industries sector as a whole increased from 54 percent in 1975 to 75 percent in 1984. New Free Trade Zones, the Greater Colombo Economic Commission, and introduction of export incentives helped attract direct foreign investment in export-oriented manufacturing industries. With these measures total industrial exports have increased significantly.

Benefits to the financial sector were more prominent; it became one of the fastest growing sectors of the economy. Interest rates were allowed to fluctuate in accordance with market conditions. In general, these rates were positive in real terms. New foreign banks were allowed to operate in the economy, increasing the number of foreign banks in Colombo to 20. Foreign Currency Banking Units, which operated as subsidiaries of commercial banks, were allowed transactions in foreign currency with non-resident enterprises, such as those established in the Free Trade Zones, and they could accept foreign currency deposits from non-residents, notably Sri Lankans working abroad. The government also opened the non-banking finance market to the private sector with or without foreign participation.

With these positive trends came several unfavorable developments. First, the economy was unable to increase its domestic rate of savings. The resource gap between savings and needs for investment had to be filled through foreign borrowing, which increased the debt service burden on the economy. The overall debt service ratio increased; in 1988 debt reached 28 percent of total export earnings and remittances from abroad. Budget and balance of payment deficits also rose at increasing rates. The budget deficit -- less than 10 percent of GDP in the early 1970s -- increased to almost 20 percent of GDP in 1982. It dropped to 10 percent in 1984 but increased again to 20 percent of GDP in 1988. The current account deficit of the balance of payments, which stood at 2.5 percent of GDP in 1970 increased to almost 12 percent of GDP in 1982. In the late 1980s it reached a manageable level of 5-6 percent.

The second problem was that government had to borrow to meet local and foreign expenditure obligations. Total government debt, around 75 percent of GDP in 1970, surpassed the total GDP in 1988 and reached 108 percent of GDP in 1989. Foreign debt, only 20 percent of the total public debt in 1970, increased to approximately 57 percent in 1989 -- almost a threefold increase within 20 years.

The economy experienced its worst conditions in 1987, when the growth of GDP was only 1.5 percent. Despite some improvements in 1988, the economy achieved only marginal improvements to attain growth of 2.7 percent. Ethnic problems after 1983 and civil disturbances after 1987 caused severe disruption of social and economic life. Work stoppages and disruptions to transport, communications, banking and financial services became almost routine, and they reduced or crippled production and distribution activities. As a result government revenue decreased from 21.2 percent of GDP in 1987 to 18.9 percent in 1988. Increased defense and other consumption expenditures helped to raise the budget deficit in 1988 to 15 percent of GDP -- the highest level since 1982. The government then had no alternative but to finance its deficit through commercial borrowing. The rate of inflation also was high at about 14 percent in 1988 -- highest since 1983. If the government had not drawn down its foreign exchange reserves to support imports and increase the supply of food and other essential commodities, inflationary pressures would have been still higher.

RESOURCE AVAILABILITY AND PERFORMANCE IN THE ECONOMY

Gross Domestic Product

From 1965-1977, the Sri Lankan economy grew at an average annual rate of 4.0 percent. This was comparatively higher than the average annual rate of growth of 3.1 percent achieved by the "low income countries" (excluding China and India) during the same period. Growth from 1987-1989 was approximately 4.9 percent per annum, compared to growth of 2.9 percent achieved by low income countries (World Bank, 1988).

Aided by the open economic policies adopted in 1977, the 4.2 percent growth in 1977 almost doubled to 8.2 percent in 1978. It continued to improve up to 1987 despite the ethnic problems in the country of 1983. In 1987 the GDP growth rate reached the lowest level of 1.5 percent, resulting in a negative growth of real per capita GDP due to severe civil unrest. (Figure 4.1). Ethnic conflicts in the north and the east, civil disturbances in the south, and bad weather conditions experienced throughout the country over three consecutive years were the primary reasons for the poor economic performance during the period of 1987-1989.

Sectoral Contribution: Agriculture

The share of the major economic sectors in the composition of GDP and their growth rates from 1978-1989 are displayed in Figure 4.2. Agriculture still accounts for more than 25 percent of the country's total GDP. Its annual rate of growth averaged about 2.9 percent compared to average annual growth of 4.9 percent in "low income countries" from 1980-1986 and 2.0 percent excluding China and India.

In general agricultural production is weather dependent, and almost every crop subsector has experienced sluggish growth from weather factors. Upward growth in one year has been followed by downward trends the next year. This is evident in the production trends of the major tree crops, tea and rubber. In the paddy subsector production increased for two or three consecutive years, followed by a downfall due to poor weather conditions. However paddy production has

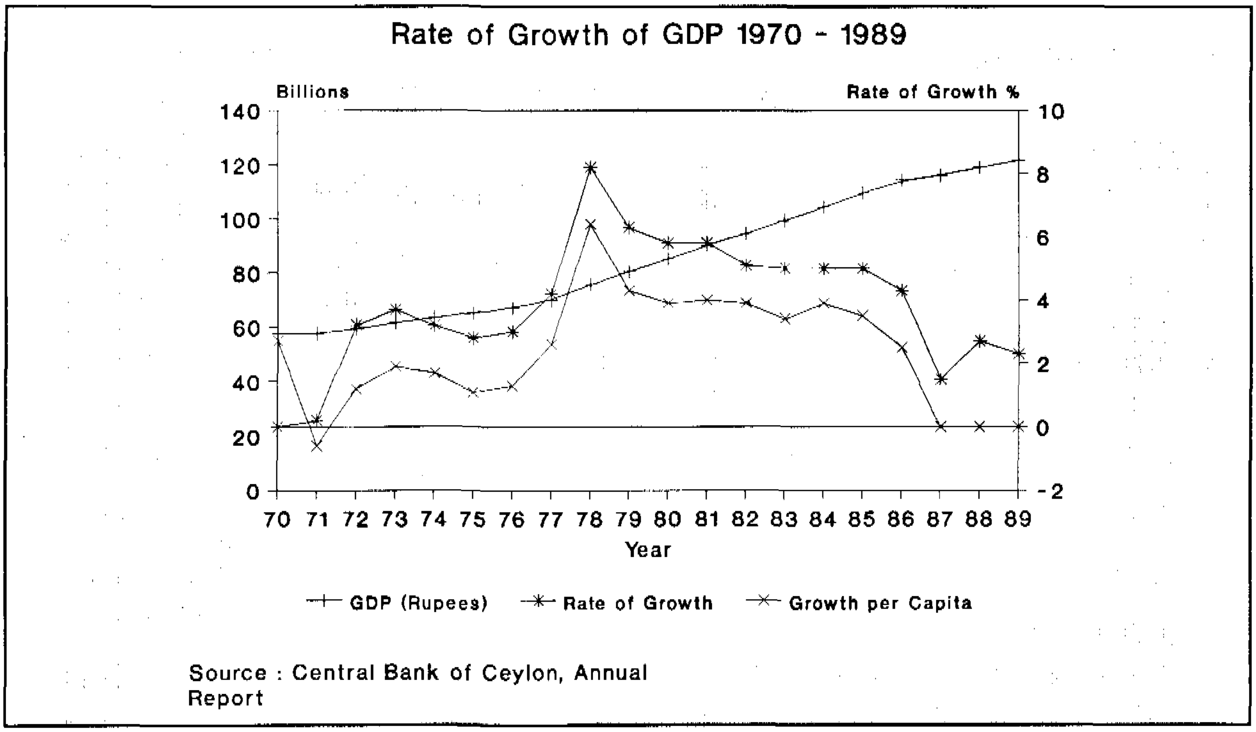


Figure 4.1

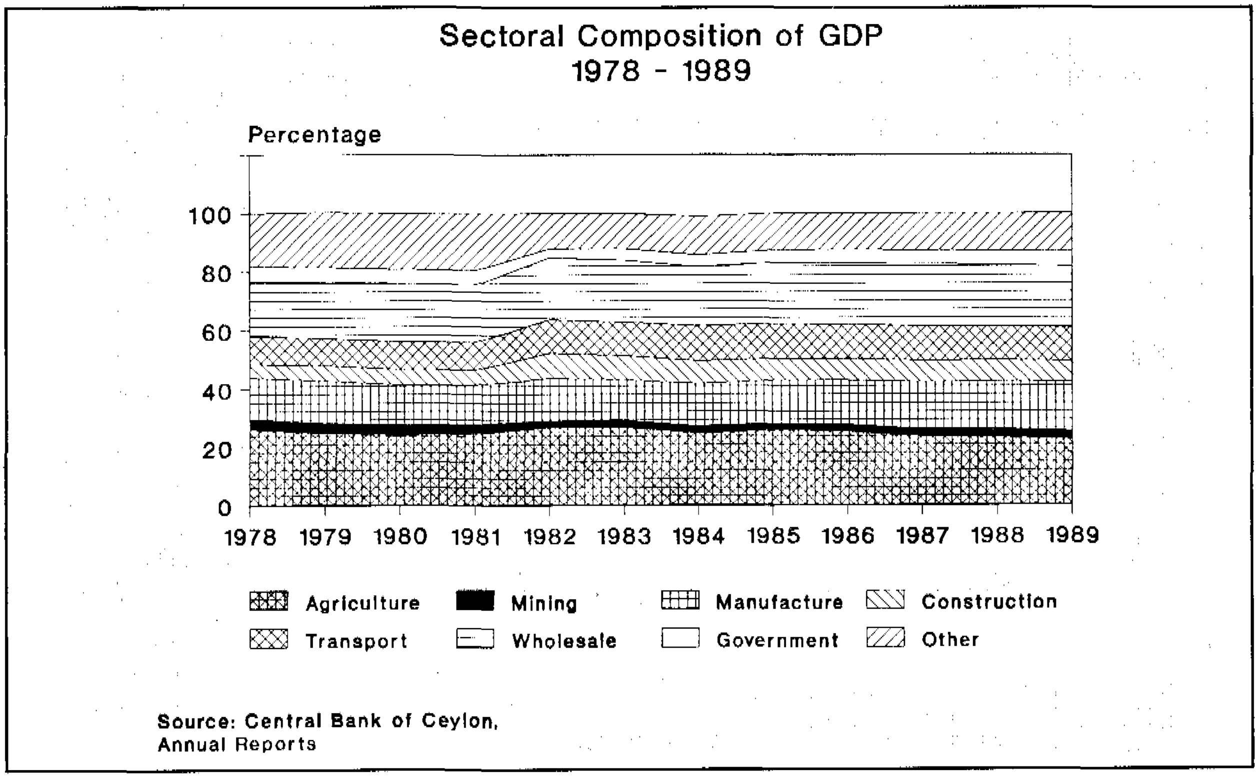


Figure 4.2

The Price Of Pollution

A study by the Central Environmental Authority in 1985 found that due to the breakdown of the electrostatic precipitators installed in the Puttalam Cement Factory the plant emitted about 120-200 tons of cement dust daily. About 10,000 hectares of neighboring lands were affected by the dust fall, including about 3,400 hectares of coconut. The cost of cement dust let loose in the factory was estimated at 20,000 rupees per day, or 6 million rupees per year, not including damage to the quality of cement produced, or the calcium oxide lost with dust evaporation.

To remedy the problem the study recommended replacement or reconditioning of the electrostatic precipitators (at a cost of 30 million rupees) and construction of a water treatment plant and a water conditioning tower (at a cost of another 5.5 million rupees). Because the Cement Corporation had no funds to meet these costs a Government grant of 43 million rupees (inclusive of price escalation) was needed to replace the pollution controls.

A similar example concerns the Hunupitiya Fertiliser Complex and its environmental impacts. This complex ground, mixed, and distributed basic chemical fertilizer ingredients throughout the country. From its inception, the complex stored fertiliser and empty sacks in the open yard because it lacked adequate warehousing facilities. During the rains, water washed the fertilizers into surface and ground water. A study undertaken by the Ceylon Institute of Scientific and Industrial Research in 1984 found that well water in the area within a kilometer radius had become undrinkable and caused irritation to the eyes and skin, formation of calculi, and other health problems. The water pollution also adversely affected home garden yields and poultry.

The total value of resources exhausted, depleted or deteriorated due to adverse environmental impact at the fertilizer plant was estimated at 47.5 million rupees over 20 years. The study therefore recommended pipe borne water to supply the area by extending the Colombo North Water Supply Scheme (at a cost of 14 million rupees) and also construction of additional warehousing facilities (at a cost of 1.5 million rupees) to discontinue storage of fertilizer and empty bags in the open yard. The Government was compelled to provide funds to extend the water supply facility to the area because the Fertiliser Corporation lacked sufficient funds to meet the cost.

increased by 26.7 percent or on average by 2.47 per year during the period of 1977 to 1989.

Attempts to expand agricultural production in Sri Lanka began in the 1930s when the government launched programs to repair, restore and rehabilitate the ancient irrigation systems. After Independence, however, emphasis shifted to a series of multipurpose river valley development schemes -- the Gal-Oya Scheme in 1948, the Uda Walawe Scheme in the late 1950s, and the Mahaweli basin development in the late 1960s. After Independence irrigable paddy acreage increased more than 300 percent, and the-Mahawelialone now provides 60 percent of the electric power of the country.

Irrigation programs for agriculture allowed successive governments to address the problems of unemployment and food production. Yet this approach was highly capital intensive and proved a costly way to provide what amounted to limited employment opportunities. Despite planning to generate secondary activities such as agro-based industries able to absorb the next generation of settlers, in fact the second generation had either to resort to traditional shifting cultivation in the reserved forest areas or find employment in the urban centers.

Government policy towards the agricultural sector has also been unbalanced. It has put special emphasis on paddy production and has devoted large subsidies to that subsector. The export crop sector, however, has not been given the same priority or fiscal and other incentives. Investments in the export crops sector have been insufficient to maintain the production levels attained in the 1960s. Although tea exports have remained roughly constant for three decades, rubber exports have fallen by about half. Sri Lanka's share in the world tea market declined from over a third in the 1960s to a fifth in the 1980s.

Despite these changes, agriculture still plays a predominant role in the Sri Lankan economy. Forty years after Independence Sri Lanka primarily depends on tea, rubber and coconut for exports, and paddy, pulses and subsidiary food crop production for subsistence. Nevertheless, the country's agricultural economy is in transition.

Agricultural structures are changing mainly due to the green revolution and other technological breakthroughs. Paddy production has achieved a remarkable growth since Independence due to increased yield and expansion of land under production and irrigation. Other crops and animal husbandry activities have not shown similar changes due to poor achievements in research and development activities.

Industry

The year 1978 marked a turning point for Sri Lanka's industrial sector. From 1970-77 industrial output grew at an annual rate of 19 percent at current prices. From 1978-89, however, average annual growth of the manufacturing sector rose approximately 22 percent -- at constant 1982 prices this was approximately 5.5 percent per year, compared with the 4.8 percent growth achieved by the low income countries, excluding China and India, from 1980-1986.

A striking feature of the industrial sector has been the differential rates of growth experienced by the public and private sectors. While private sector industries have shown considerable dynamism since economic liberalization in 1978, the public sector has shown only declining trends.

Yet very little structural change has occurred in the mix of outputs in the industrial sector. Over the past decade three subsectors -- food, beverages and tobacco; textiles, wearing apparel and leather; and chemicals, petroleum, coal, and plastic products -- have been predominant in production and value added. They accounted for 86 percent of the total industrial output. In contrast the share of engineering-based industries, often considered to be the core of a country's sound industrial base, remained at about 5 percent of total output. Increasing dependence on the use of imported raw materials has also characterized Sri Lanka's industrial sector. Of the total value of production from the chemicals subsector, over 70 percent consisted of imported materials in the 1980s, compared to 47 percent in the 1970s. The three major industrial subsectors also used almost 65 percent of the energy consumed by the entire sector.

Government involvement in industry began in the 1940s when a number of enterprises were established to produce commodities that could not be imported in wartime. Essentially these were import substitution industries, although the government did not define such an industrial policy until later. Following the balance of payments difficulties incurred in the late 1950s, however, the government explicitly implemented an import substitution strategy because it had to ban or restrict the import of many industrial goods. Under the industrial policy statement issued in 1956, the government assumed control over basic heavy industries such as iron and steel, cement, chemicals and fertilizer, leaving manufacture of light consumer goods to the private sector. But in time even this allowance changed, and the government began several state enterprises to produce such consumer goods, as leather products, vegetable oil, ceramics, textiles, paper, plywood, tires and tubes, and hardware.

Import substitution and state-sponsored industrialization continued through the 1960s and 1970s, until trade liberalization began after 1977. The old strategy had caused several negative economic effects. One was that economic efficiency of industrialization suffered from a disregard of the relatively high costs of produc-

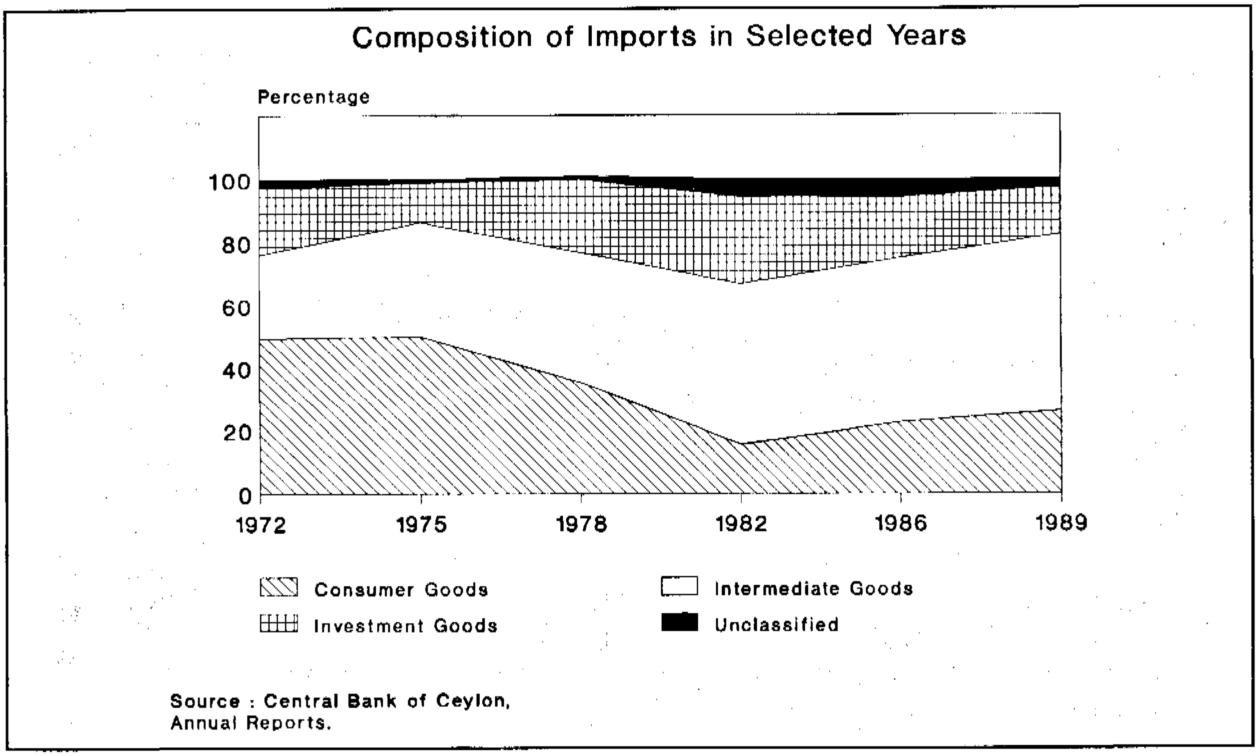


Figure 4.3

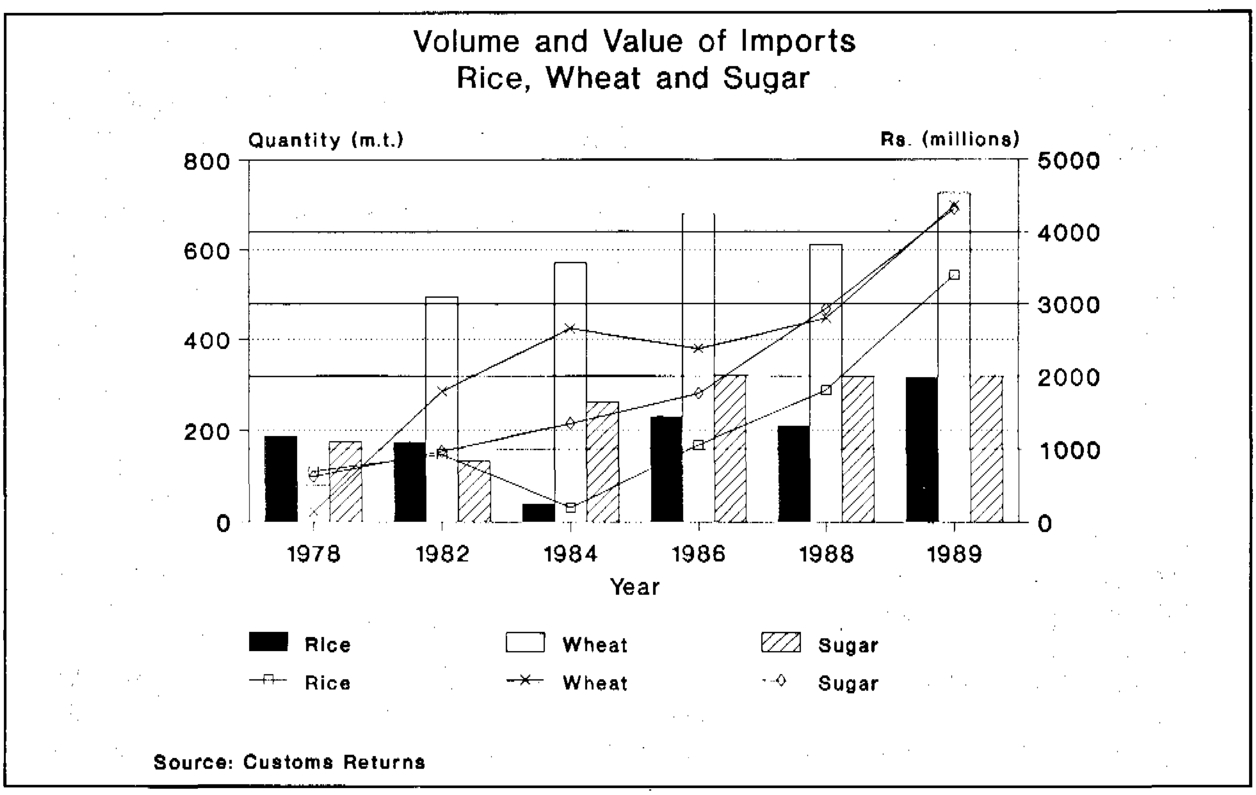


Figure 4.4

tion in the local market. Industries could not expand to sell in the export market, and economies of scale for local industry were also impossible.

In addition state-sponsored enterprises had always sought and usually obtained protection against foreign competition. Tariffs were increased to high levels along with, in most cases, quantity restrictions. Such excessive protection eventually destroyed the competitive edge of many domestic industries that were once considered strong import substitution and export-oriented industries.

Finally the direct employment generated by the protected industries came at a very high capital cost. Policies of fixed exchange rates and concessionary tariffs that allowed importation of capital goods and raw materials favored the acquisition of technologies that were capital, not labor, intensive. The average cost of employing a unit of labor in most of the public sector manufacturing industries was around 60,000 US dollars at 1987 prices! The generation of indirect employment was also limited due to poor linkages between the industrial policy and the rest of the economy.

Services and Construction

With the economic liberalization policies after 1977 the services and construction sectors showed high rates of growth until the civil disturbances in 1983. Between 1978 and 1983 the construction sector experienced annual growth of 8.8 percent, compared with 2.6 percent growth from 1971-1977. The services sector grew at average annual rates of 3.7 percent from 1970-1977, and 7.2 percent from 1978-1983. With the civil disturbance in 1983, construction growth declined to an annual average of 1.0 percent per year, and services growth declined to 3.2 percent.

Civil unrest hit the tourist industry hardest. Total tourist arrivals which peaked 407,230 persons in 1982, declined to 182,620 in 1987. In 1989 tourism increased to 184,732 persons -- an increase of 1.1 percent over 1987. Gross earnings of the industry also declined from 146.6 million US dollars in 1983 to 76.3 million US dollars in 1989 -- 50 percent of 1982 earnings.

The high growth rates achieved by the construction industry from 1978-1982 resulted largely from implementation of the three major government projects: the Accelerated Mahaweli Development Programme, the Katunayake Free Trade Zone Development, and the Housing Development and Urban Renewal Programme.

Imports

Imports, which constitute approximately one-third of the total GDP, are a major resource available for consumption and investment in the economy. The composition of imports has changed considerably over time -- from the high proportion of consumer goods (for example, food and drink) in the early 1970s to the high proportion of investment and intermediate goods in the 1980s. The percentage composition of Sri Lanka's imports in the 1970s and 1980s is given in Figure 4.3.

Within the import category of food and drink the major items included were rice, wheat, and sugar. Relationships between imports and local production are strong in this category. Since rice and wheat are close substitutes, declines in local production of rice were met by additional imports of either wheat or rice, depending on the price at the time of import.

The total volumes and values of imports of rice, wheat, and sugar in some selected years is shown by Figure 4.4. It reveals the vulnerability of the economy and the balance of payments to price changes of food imports. If adverse weather reduces local production or if international food prices increase, then conditions of adverse balance of payments can result.

RESOURCE UTILIZATION

Trends in Consumption and Investment

Consumption and investment patterns from 1970-1989 are shown in Figure 4.5. Important to the investment structure was its source of financing. Approximately 80 percent of GDE from 1970-1977 was financed from national savings, and the balance of 20 percent came from foreign assistance. However, from 1979-1989 investment financing was drastically changed; approximately 54 percent came from national savings and 46 percent from foreign assistance. The financing of the gross domestic investment from 1970-1977 and 1978-1989 is shown in Figure 4.6, and the

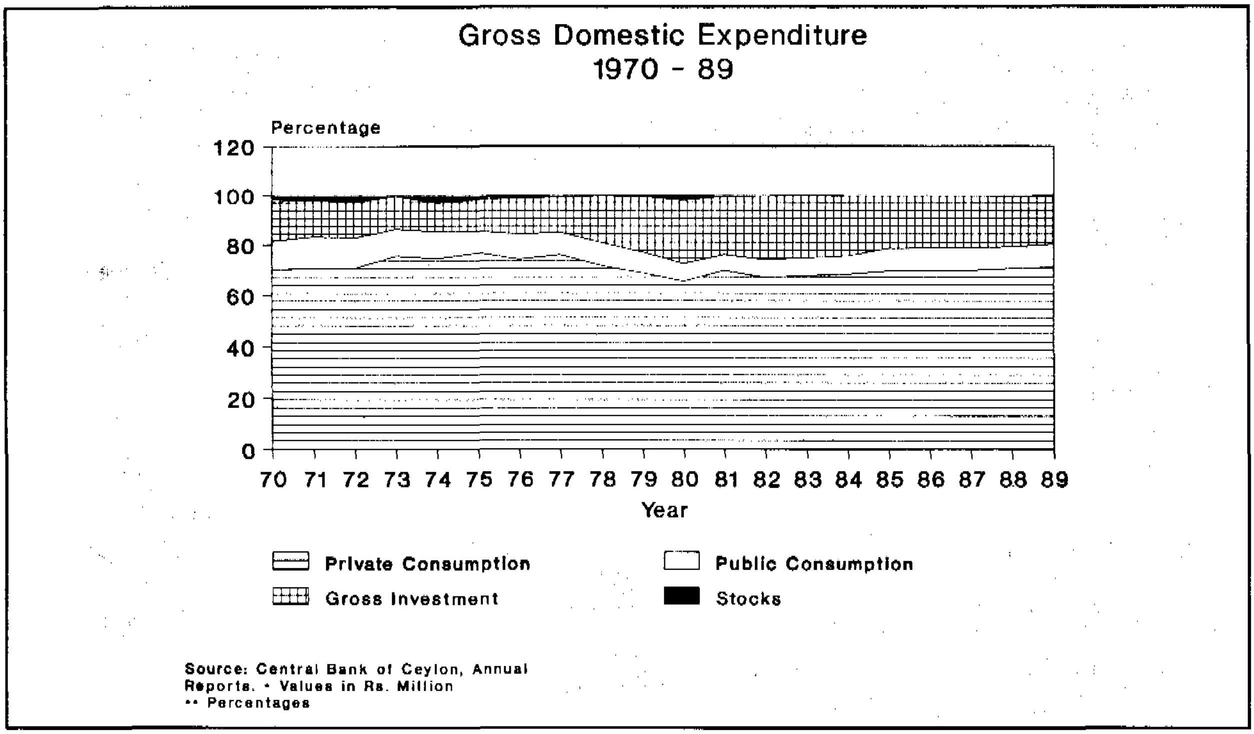
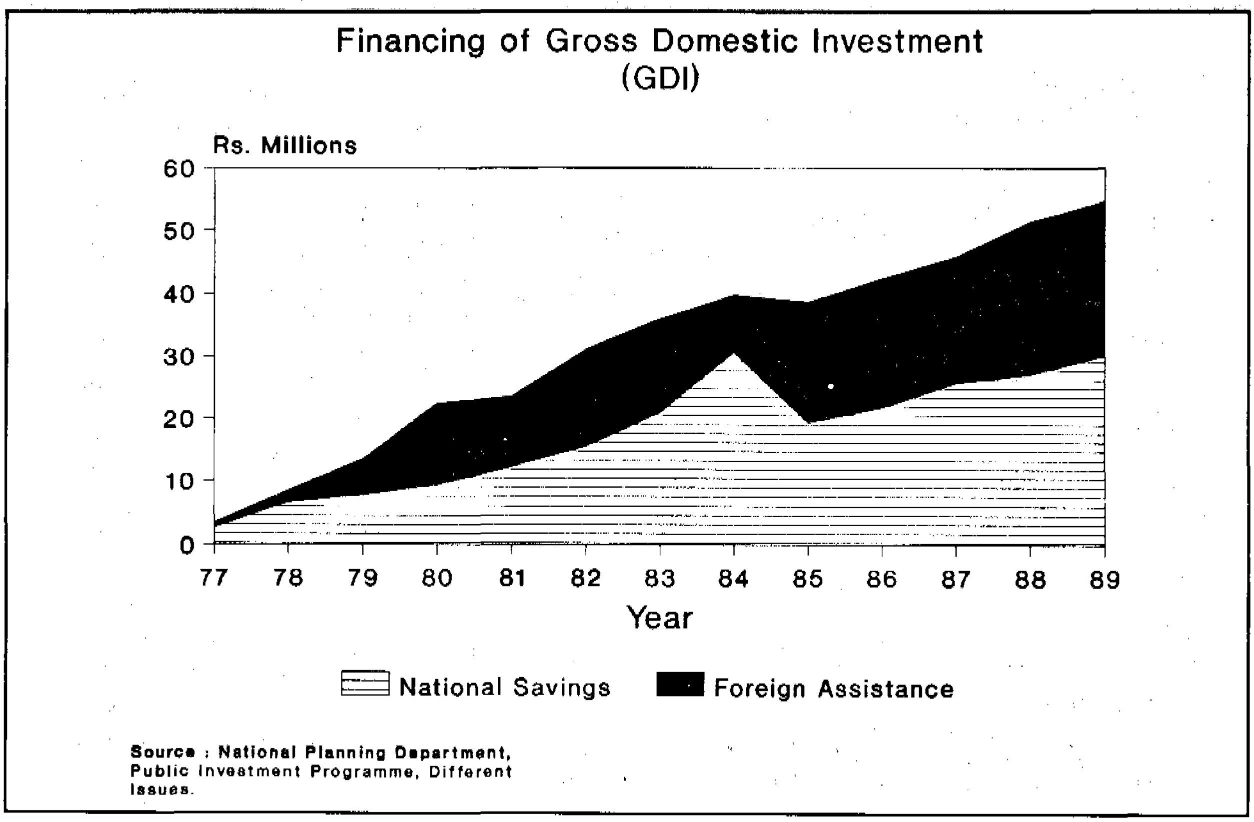


Figure 4.5



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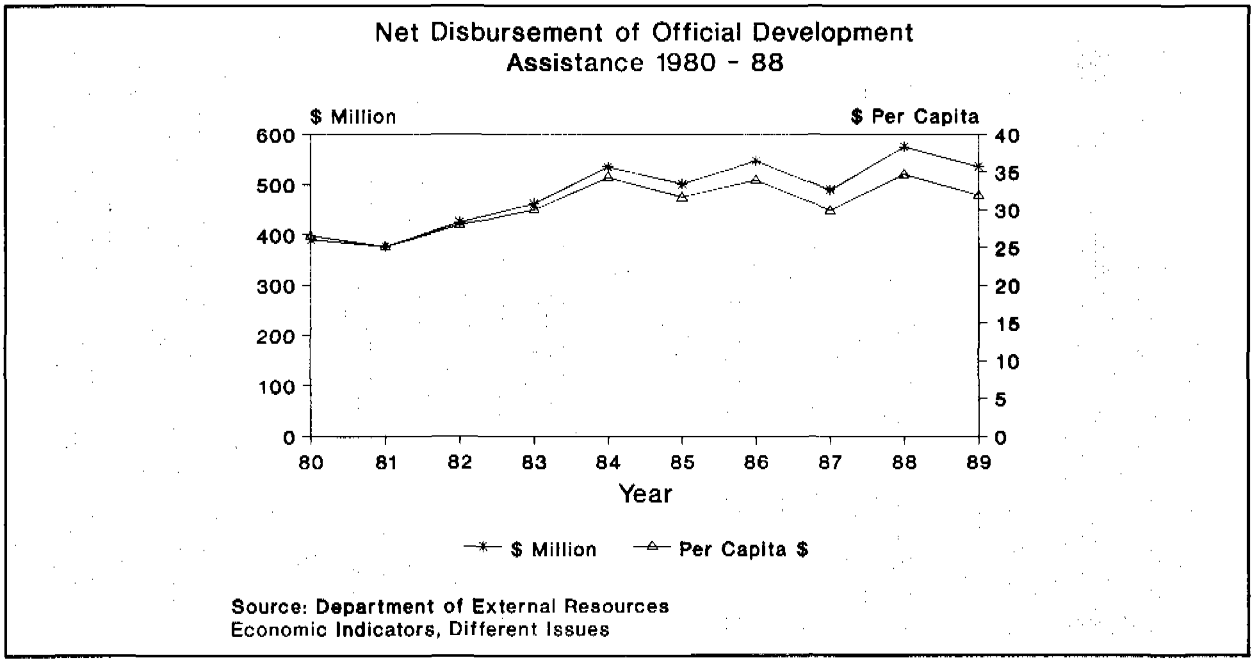


Figure 4.7

disbursement of official foreign assistance from all sources from 1980-1989 is shown in Figure 4.7.

The increase in per capita receipt of external foreign assistance is consistent with the increased flow of foreign savings that were devoted to financing investment expenditure during the same period.

We lack adequate information in Sri Lanka to analyze the sectoral composition of gross domestic investment. Private sector investment is computed inclusive of investments made by the public corporations. During the 1970s the public sector, which includes the government ministries, departments and enterprises other than public corporations, devoted approximately 30 percent of their investment to machinery and equipment and the balance (70 percent) to land development and construction-related activities. From 1982-1984 these proportions changed to 48 percent and 52 percent respectively. However, by the end of the 1980s the proportions again reversed, to 30 percent on machinery and equipment and 70 percent on land development and construction. The increase in investment in machinery and equipment during the early 1980s was due entirely to heavy investments in power generation equipment for the Accelerated Mahaweli Development Programme.

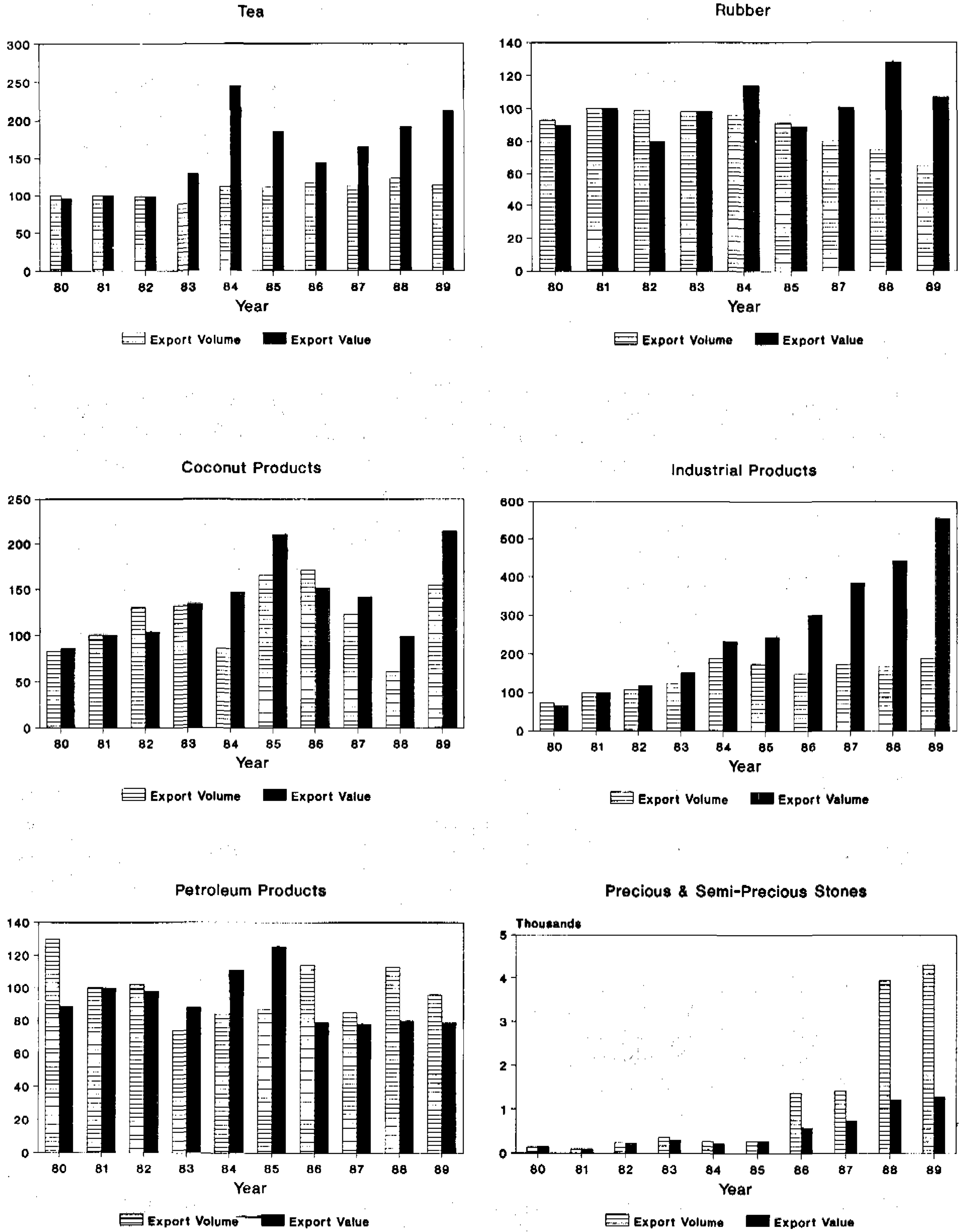
Exports

Over the twenty years between 1960 and 1980 Sri Lanka experienced no substantial increase in total volume of exports. The export volume index of 102 in 1962 (1978 = 100) remained about the same in 1980, with a peak of 111 in 1965. During 1964, 1968, 1970, and 1975 the export volume index reached 107, but in all other years it was well below that.

Since 1980 export volumes have steadily improved to reach a 50 point increase in the volume index 1980-1989. Remarkable increases resulted from exports of precious and semiprecious stones and industrial products; the export volume index (1981 = 100) for precious and semiprecious stones increased from 144 to 4,314 and for industrial products it increased from 74 to 189 between 1980 and 1989. Similar trends can be observed in terms of export values, where the value index of all exports increased from 87 in 1980 (1981 = 100) to 267 in 1989. Trends in export volume and value are given in Figure 4.8.

Statistics on export performance during the past ten years clearly show the growing export diversification of the economy. Sri Lanka no longer depends on three agricultural tree crops. Industrial goods have

Export Trade Indices (1981 = 100)



Source : Central Bank of Ceylon, Annual Report

Figure 4.8

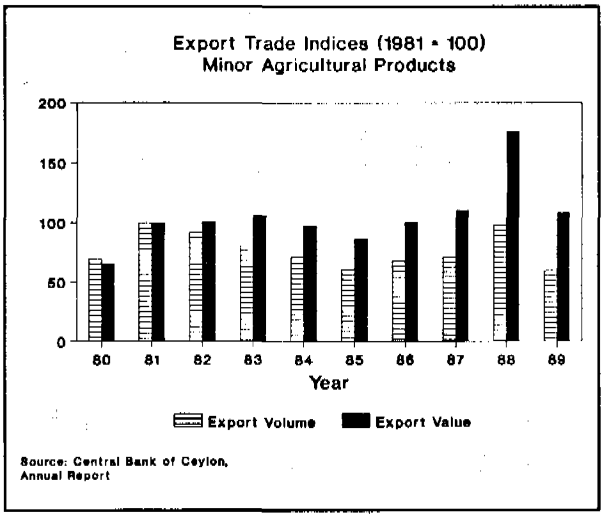


Figure 4.8

surpassed 50 percent and agricultural exports now account for no more than 40 percent of total exports. Nevertheless, as depicted in Figure 4.9, industrial exports depend heavily on imported raw materials, and the value added in industry is comparatively low. Almost 62 percent of industrial exports, or 31 percent 0f the total value of exports, are textiles and garments in which import content can reach 60 percent.

Since the economic policy changes begun after 1977 the government has sought to implement a National Export Development Plan (NEDP), with the first NEDP covering the period 1983-1987. The Plan's priority policy measures were to ensure free trade in inputs required for export processing so Sri Lankan exporters could compete in world markets. To ensure this free access the government implemented schemes for duty rebate, manufacture-in-bond, and duty exemption (to eliminate duties on machinery, equipment, and accessories used in export processing industries).

A basic constraint on industrial export promotion is the lack of automatic financing facilities able to provide working capital at competitive interest rates. Commercial banks require securities and collateral beyond the ability of small exporters who, from a bank's point of view, are not credit-worthy. Although the Sri Lanka Export Credit Insurance Corporation was established precisely to overcome this problem, this measure has been nullified by bank requirements for securities and collateral over and above the Corporation's guarantee limits.

MACRO-ECONOMIC LIMITATIONS AND PRESSURES

Sri Lanka's economy is still passing through a transitional period from a relatively inward-looking, agriculture-based economy to one that is outward looking and industrial. This transformation would have been much quicker and less painful if severe resource imbalances had not been experienced during the last decade. These are important to note and examine briefly.

Unemployment

The total workforce has been growing at an average of 138,500 per year. This is an annual increase much higher than the average annual population growth. In contrast, net employment creation has grown during the past several years at an annual average of 90,000 units, adding approximately 35,000 persons to the existing unemployed backlog. Hence, the open unemployed rate increased from 12.0 percent in 1981 to almost 20 percent in 1988.

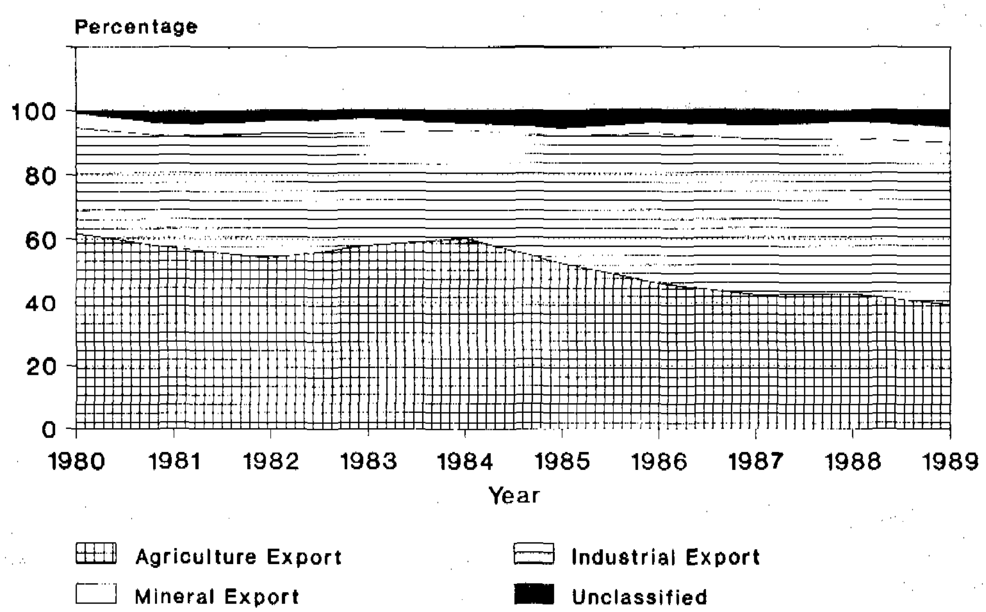
Underemployment is also serious, amounting to over 20 percent of the workforce and mainly concentrated in rural areas. If we assume that the underemployed work only two-thirds of the time this rate adds another 8 percent in equivalent open unemployment to the current figure of 20 percent.

The opening of the economy after 1977 produced a spurt to generate jobs that might have been sustainable in the long run. Yet the civil disturbances in 1983 created such economic dislocation that today Sri Lanka faces a large gap between present labor force growth and domestic job creation, making it exceedingly difficult to bring unemployment down to its 1981 level.

Job opportunities abroad have helped considerably in relieving unemployment, but these opportunities appear more limited in the near future. Nor will massive investment programs, such as the Accelerated Mahaweli Development, be available to increase agricultural employment through expanding irrigation acreage. The economy must now depend on industrial

Composition of Exports 1980 - 1989
(Percentages)

	Category	1980	1981	1982	1983	1984	1985	1096	1987	1988	1989
1.	Agriculture Exports	61.8	57.3	54.3	58.0	60.3	52.5	46.3	42.4	42.8	39.2
	1.1 Tea	35.1	30.6	29.6	33.1	42.2	33.1	27.2	25.9	26.2	24.3
	1.2 Rubber	14.7	13.7	10.8	11.4	8.8	7.1	7.7	7.1	7.9	5.5
	1.3 Coconut	7.0	6.8	7.0	7.6	5.7	8.5	7.0	5.2	3.3	5.1
	1.4 Minor Agricultural Crops	5.1	6.6	6.9	5.9	3.6	3.8	4.4	4.2	5.4	4.3
2.	Industrial Exports	33.0	34.7	38.6	35.1	33.7	39.5	46.6	48.6	48.3	50.7
	2.1 Textiles & Garments	10.4	14.4	16.3	18.9	20.2	22.0	28.3	31.3	30.4	31.4
	2.2 Petroleum Products	17.7	16.0	15.3	10.6	8.8	10.7	6.9	6.3	4.8	4.0
	2.3 Other	4.9	4.3	6.9	5.6	4.7	6.8	11.4	11.0	13.1	15.3
3.	Mineral Exports	4.6	3.8	4.0	4.5	2.2	2.4	3.5	4.4	5.6	4.8
	3.1 Gems	3.8	3.0	3.2	3.7	1.6	1.6	2.2	3.5	4.4	3.9
	3.2 Other	0.8	0.8	0.8	0.8	0.6	0.6	1.3	0.9	1.2	0.9
4.	Unclassified (incl. re-exports)	0.6	3.7	3.1	2.4	3.7	5.6	3.7	4.6	3.3	5.3



Source : Central Bank of Ceylon, Annual Reports

Figure 4.9

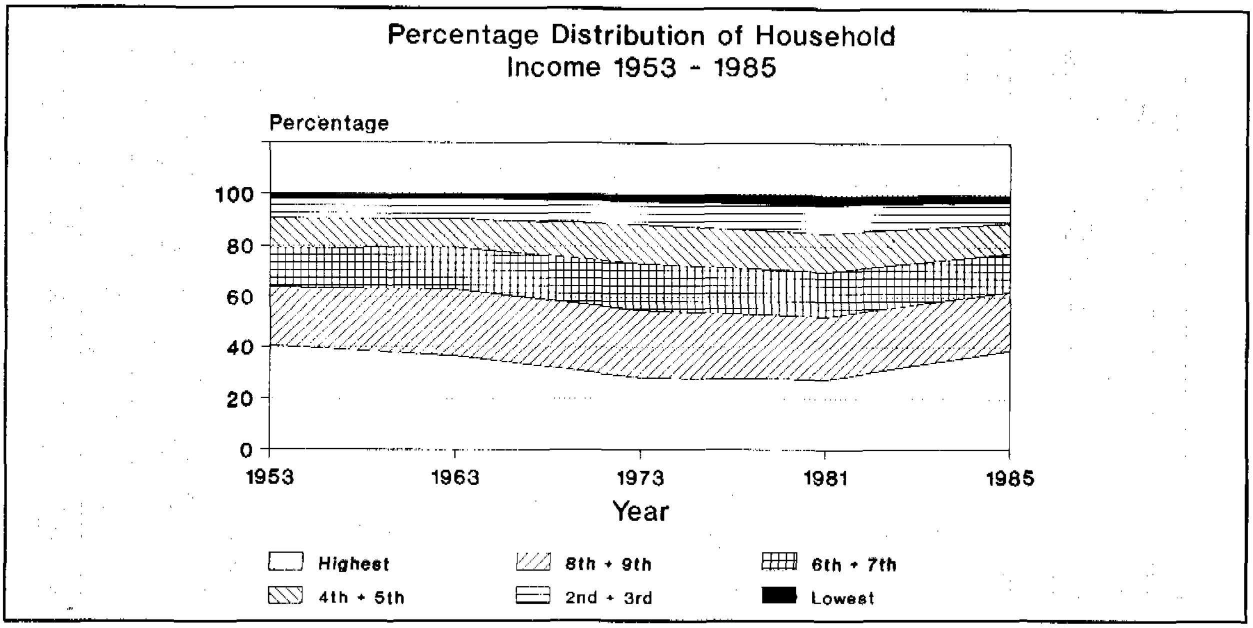


Figure 4.10

and other non-traditional pursuits to create employment opportunities.

In the past Sri Lanka achieved an annual labor productivity rate of approximately 3.0 percent. At this rate, to absorb the annually increasing workforce alone, the economy will need to achieve an average annual rate of growth of 5.1 percent. If, however, the backlog of unemployed is also to be absorbed into the employment stream over a period of perhaps ten years, the annual rate of GDP growth must be increased to 7.0 percent, assuming a constant rate of productivity and an increase in the workforce.

Income Distribution and Poverty

Trends in the pattern of income distribution and the related problem of poverty can be gleaned from the Consumer Finances and Socio-Economic Surveys of the Central Bank, and the Socio-Economic and Labour Force Participation Surveys of the Department of Census and Statistics. They provide detailed information on the income distribution pattern in Sri Lanka during the years 1953, 1963, 1973, 1981 and 1985. Although these two data sources are not strictly comparable, due to definitional problems, Figure 4.10 shows the percentage distribution of household income during the period 1953-85.

The data suggest that the income benefits of economic growth experienced after 1978 have, so far, favored upper income groups more than the lower groups. The share of the bottom 40 percent, who received a total income of 19.29 percent in 1973, increased to 21.4 percent in 1981, but it declined to 16 percent in 1985. During this period the share of the highest 20 percent increased from 42.95 percent in 1973 to 52.3 percent in 1985. World Bank analysts, using 1985-86 poverty survey data, concluded that despite improvements in mortality, crude death rates, and population growth rates, about 20 percent of Sri Lanka's population was living in poverty (World Bank 1990).

Malnutrition

The nutritional surveys of 1976, 1981/2, and 1985/6 reveal high levels of malnutrition among infants and preschool children. Chronic malnutrition of children in this age group was 34 percent in 1976 and 36 percent in 1981/2. In 1985/6 however, it fell to 27.5 percent for the 3 months to 3 year old age group. A 1987 health survey has indicated that about 25 percent of pre-school children were under height for their age because of malnutrition (World Bank 1990).

Micro-nutrient deficiencies of iron, iodine and vitamin A have been major malnutrition problems in Sri

Lanka. Iron deficiency of a mild nature seems to be around 50-60 percent in children and pregnant and lactating women. Goiter incidence ranges from 6-35 percent in the goiter endemic regions.

Government policy has traditionally emphasized increased agricultural productivity to overcome the nutritional problems. Because the removal of subsidies on wheat-flour, rice, fertilizer, and bus fares threatened to reduce consumption levels of the poorest 20 percent of the population, the government stretched out the elimination of rice and wheat-flour subsidies into 1990. In addition, several special programs such as the Triposha distribution program, school biscuit feeding program, and primary health care intervention program, have also been implemented, along with the Janasaviya Program, and the School Mid-day Meal Programs.

POLICY IMPACT

Macro-economic and development policies have direct and indirect effects on the productive sectors of the economy. Comprehensive study of the economic conditions and trends requires analyses of the direct impacts of fiscal, monetary and pricing policies over the past ten to twenty years.

Before 1977 predominant state intervention in economic activities emphasized regulatory measures through price controls and fixed exchange rates. Government subsidies were commonly directed to producers as well as consumers. After 1977, however, the state concentrated on ways to create necessary infrastructure for economic development and to reduce or eliminate direct involvement in economic activities. These policies were reflected in import liberalization, a floating exchange rate, and removal of price controls and quantity restrictions. Market forces strongly affected economic decisions.

Before 1977 policies encouraged the establishment of high capital intensive industrial ventures under government patronage. Pricing policy adopted by these enterprises basically sought to maintain a lower cost of living, giving secondary consideration to profitability or economic efficiency. Often no margin existed to cover maintenance or replacement costs of machinery and equipment. As a result, small breakdowns in the production process required government funds for a remedy, and sometimes the establishment was closed for months for want of repair funds. (See box -- The Price of Pollution.)

Environmental Degradation and Economic Development

Production or consumption inevitably creates wastes and environmental emissions as by-products. The effects of these by-products cause three kinds of impacts that economists consider externalities:

- direct externalities affecting the producer that he has reason to internalize and so reduce or prevent, such as pollution of his own water supply;
- spatial externalities generated in one place but affecting another place which the producer has no incentives to correct, such as air pollution emitted through a tall stack;
- intergenerational externalities likely to affect future generations, such as improperly managed toxic waste.

These impacts occur regardless of ownership, public or private. Various regulatory and economic tools are available to address these problems.

After 1977, to correct the investment failures that caused these kinds of problems, the government removed price controls and adjusted exchange rates. Results were encouraging. Some inefficient industrial enterprises halted production. Other industries found that they were better able to generate sufficient funds to meet repair and maintenance costs. Depending on their profitability, public sector agencies were also able to borrow funds from the financial markets for these and other purposes.

Economic policies after 1977 stimulated new investments in industry, tourism, export agriculture, and aquaculture where high profit margins have been most assured. These investment opportunities are likely to encourage more intense commercial use of and competition for water, land, and other natural resources. So it becomes increasingly important to include the costs of environmental degradation in the industry's cost of doing business. This can be done by developing

Victoria Dam on the Mahaweli Ganga is Sri Lanka's major producer of hydroelectricity.

5 Energy Resources

The major forms of primary energy used in Sri Lanka are biomass (70 percent), hydroelectricity (10 percent), and oil (20 percent). Not included in this energy budget is solar energy, used to dry agricultural produce and fish and extract salt from sea water, and draught power commonly used to transport goods in rural areas, plough paddy fields, and harvest timber.

Hydro energy and biomass are indigenous resources, but all oil must be imported. No fossil fuels have been discovered in Sri Lanka or its offshore territorial jurisdiction. Until 1973, woodfuel use was gradually shifting to oil for household cooking and in some small industries, but that trend stopped with the oil price hikes of the 1970s. Rising oil prices caused severe and continuing strains on Sri Lanka's economy; in 1982 net oil imports rose to 47 percent of export earnings. Escalation in oil prices in the 1970s helped accelerate Sri Lanka's Mahaweli development project -- earlier conceived mainly as an irrigation project to boost domestic agriculture. The large hydroelectric generating capacity of its storage reservoirs assumed new importance. As oil became expensive, household and small industry sectors began turning back to woodfuel.

Consumption of commercial energy (electricity and petroleum) by sector divides into transport (54 percent), industry and commerce (26 percent), domestic (17 percent) and others (3 percent). Transport consumes only petroleum products. Domestic consumption of commercial energy (electricity and kerosene) is mainly for lighting, although the last ten years has seen a significant increase in use of electrical appliances such as fans, cookers, and refrigerators, particularly in urban households.

In the near future, at least, biomass fuel will retain its dominant energy position. Most biomass fuel is used in domestic cooking. Because of highly inefficient traditional cooking methods the energy wasted from biomass conversion is particularly high; in terms of useful energy, the contribution of biomass fuel to the national energy budget reduces to about 40 percent. (See Figure 5.1)

ELECTRICITY DEMAND

Electricity consumption has grown rapidly during the past two decades. From 1970-1977, despite slow economic growth and declines in petroleum consumption, electricity demand grew at an annual rate of 7 percent. This high growth may be attributed in part to the absence of tariff increases (when the petroleum prices rose 50 percent), and a growing industrial and commercial market for electricity.

Supply and distribution of electricity is the responsibility of the Ceylon Electricity Board (CEB), a government agency. In 1988, the total electric sales were 2370 GWh. The consumption by different categories of users is shown in Figure 5.2.

From 1977 to 1983 average annual consumption rose to 9.5 percent, spurred by the opening of the economy, new industries in the Export Promotion Zone, the booming tourist industry, and general expansion of the services sector. The large number of new tourist hotels created a new and significant demand for lighting, air conditioning, cooking, water heating and refrigeration. In the domestic sector, too, increased use of newly available domestic appliances significantly increased electric demands. So did greatly accelerated rural electrification after 1977. Demand grew despite several substantial increases in electric rates.

With civil disturbances in 1983 came a decline in the rate of economic growth and, concomitantly, in the rate of growth of electricity consumption. From 1983 to 1988 annual growth in consumption dropped to 5.5 percent. Overall, since the introduction of economic reforms, from 1977 to 1988, average annual growth of electricity consumption (sales) was 7.8 percent in con-

Proportions of Primary Energy consumed in Sri Lanka in terms of 1. Total Energy and 2. Useful Energy

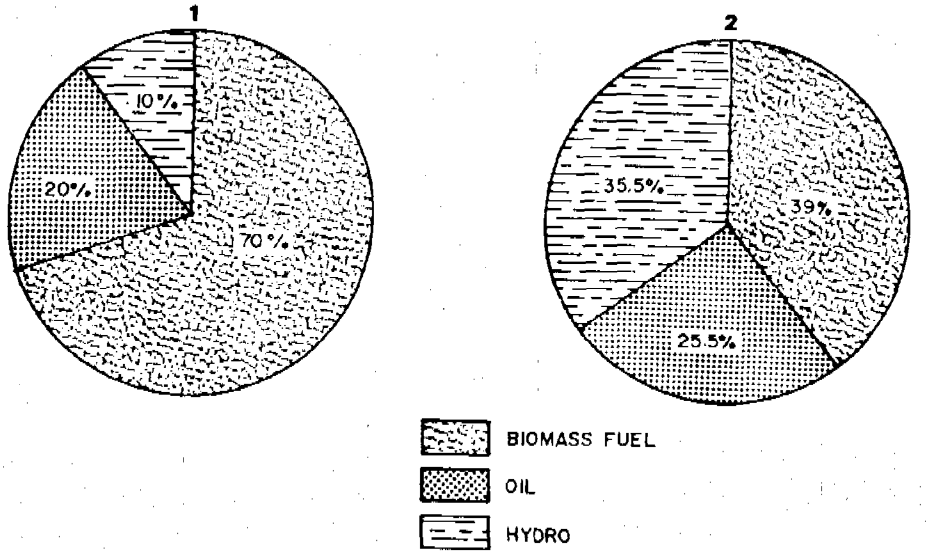


Figure 5.1

Energy Use in GWh.

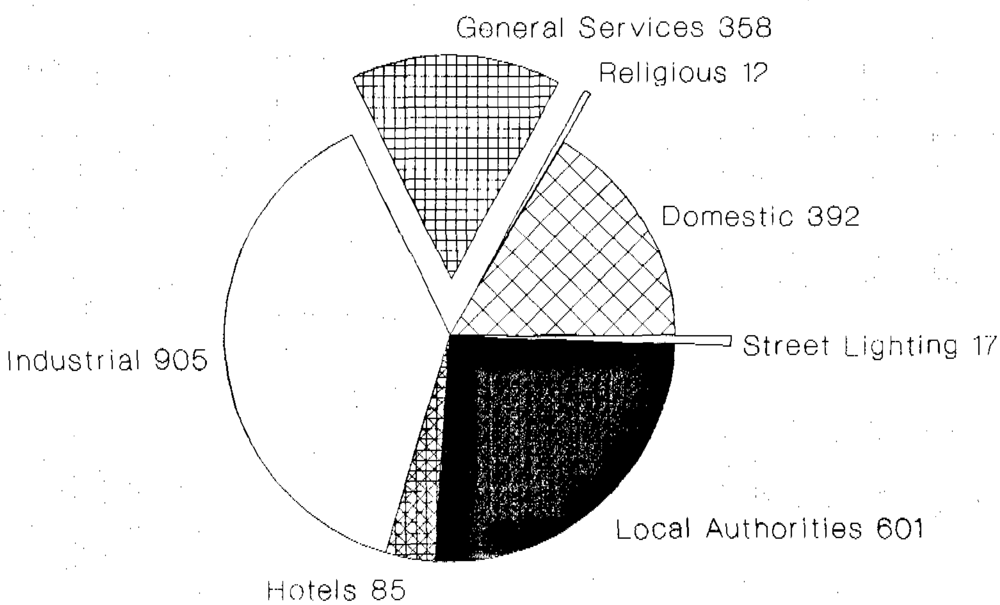


Figure 5.2

Electricity Demand Forecasts and Hydropotential (from GTZ Master Plan)

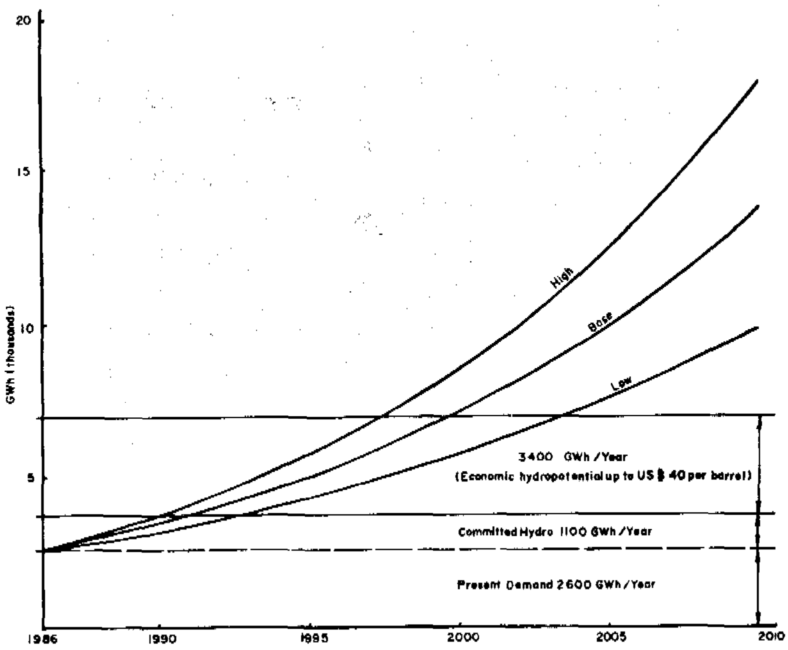


Figure 5.3

Annual Electricity Generation - Hydro and Thermal

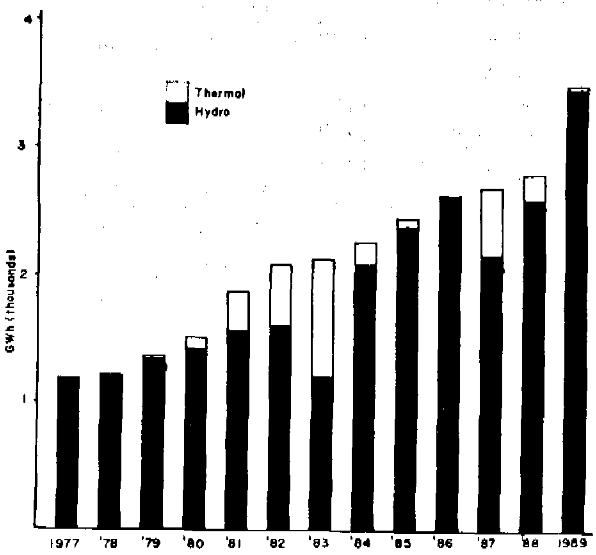


Figure 5.4

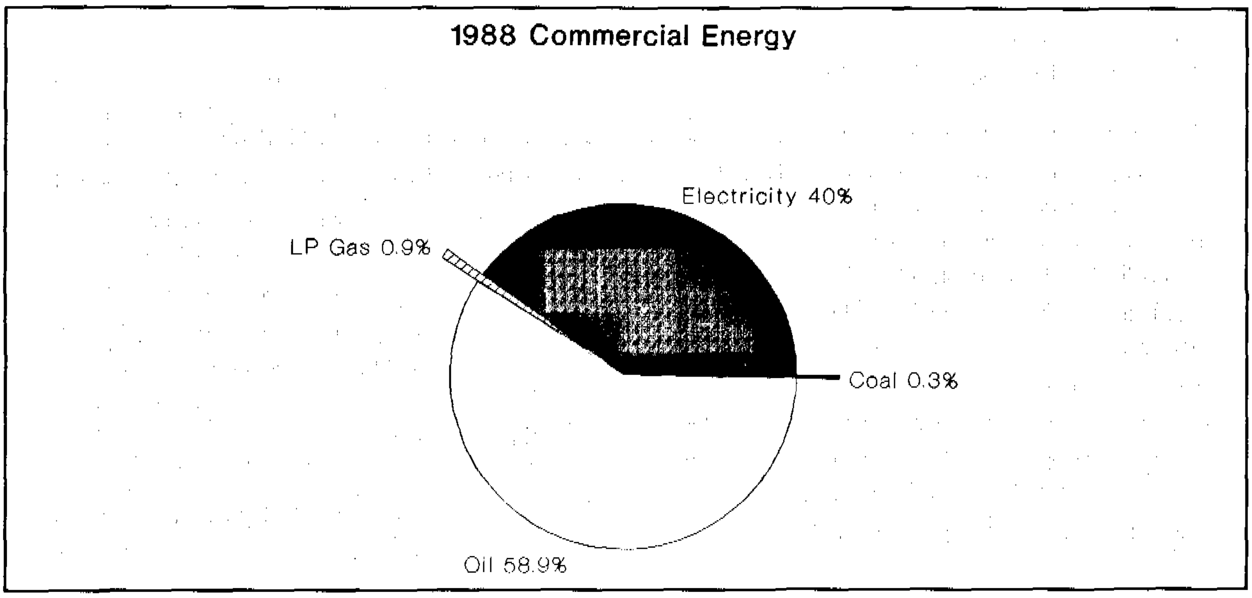


Figure 5.5

dropped sharply, making a coal-fired plant uneconomic.

Subsequently, a smaller coal-fired thermal plant was analyzed for location on the coast south of Galle. In light of the environmental concerns expressed, in October 1990 the President directed the Ministry of Power and Energy to suspend work on the proposal until all alternatives had been given careful consideration.

Economic and Social Costs of Hydropower

Hydropower generation is capital intensive and requires substantial foreign exchange, yet its low operating costs and overall profitability have made it an attractive energy choice. Moreover, there has been no serious problem in securing the funds for hydro development from low-interest loans or as outright grants from foreign governments or funding agencies.

Hydropower generation from large dams carries a high social cost, often inundating fertile land (e.g. in the Dumbara and Kotmale valleys) and displacing many families and even whole villages. In the Dumbara valley construction of the Victoria reservoir required evacuation of nearly 6,000 families. State assistance was necessarily provided to resettle displaced families and mitigate their financial burden and cultural shock.

A health hazard has arisen from the impounding of water and restriction of river flow. Mosquitoes breed in the stagnant pools of downstream river beds, which may be a factor responsible for the spread of malaria.

Another adverse impact of impounding water upstream is the drying up of wetlands in the riverine flood plains, reducing habitat for animals, fish and birds.

Despite the social costs, with adequate mitigation measures hydropower development has substantial advantages over other forms of conventional electricity generation in Sri Lanka. Its reservoirs also provide irrigation water for thousands of hectares of land. This in turn brings more benefits as well as potential environmental and social costs including land salinization and pollution by agrochemicals.

The relatively low cost of hydropower has helped meet social objectives for rural populations. The CEB is expected to function as a commercially viable enterprise, but as a government institution it must be sensitive to social needs. Hence rural electrification, although not offering attractive financial returns, is actively pursued to help improve the quality of life of the large rural population by opening avenues for rural industrial development and agricultural production.

The CEB tariff structure seeks to provide a basic minimum supply of electricity to domestic consumers at rates low-income families can afford. The latest domestic tariff for monthly bills, introduced in April 1990, is 0.55 rupees per unit for the first 10 units, 1.05 rupees per unit for the next 40 units, 2.00 rupees per unit for the next 50 units, 3 rupees per unit for the next 350 units, and 4 rupees per unit for consumption over 450 units. A fixed charge of 10 rupees is levied from households whose monthly consumption is 10 units or more, while the charge is reduced to 5 rupees where the consumption is less than 10 units. Taking into account the social needs and statutory obligations to function as an economically viable enterprise, the CEB tries to maintain a modest 8 percent return on the revalued capital assets.

PETROLEUM SUPPLY AND DEMAND

Supply and Processing

In 1988 oil supplied 59 percent of Sri Lanka's commercial energy as shown in Figure 5.5. Although there has been limited exploration for oil on-shore and off-shore, no indigenous sources have been found. Hence, the country has had to rely on imported crude oil and refined products to meet demand.

The Ceylon Petroleum Corporation (CPC) is the sole importer and processor of petroleum products. Because the government establishes domestic prices no direct relationship exists between international crude oil prices and the domestic price of refined products. Prices were increased gradually during the 1970s as international oil prices rose. Between 1981 and 1989 the government raised the local price of refined products twice, a 40 percent increase for most products in 1983, and a 20-25 percent increase in 1989. In response to Iraq's invasion of Kuwait in August 1990, the government raised the local price of petrol from 20 rupees to 25 rupees per liter, and in November 1990 to 35 rupees per liter.

Sri Lankan refinery capacity. Since 1969 crude oil has been processed at a refinery in Sapugaskanda with a capacity of 50,000 bbl/day. Originally designed to process Iranian light crude, after foreign exchange constraints and supply uncertainties it was redesigned to process other crude oils as well. Countries and crude oils supplying Sri Lanka are Abu Dhabi (Upper Sakus), Egypt (Suez Blend), Iran (Iranian Light), Malaysia (Mirri/Tapis), Oman (Oman), Saudi Arabia (Arabian Light), Qatar (Qatar Marine), and, until the recent embargo, Iraq (Basrah Light).

The refinery meets most domestic demands for petroleum products, with the shortfall, primarily in auto diesel, met by spot purchase. As demand for Liquid Petroleum Gas (LPG) increased, the supply shortfall was met by imports. Proposed plant modifications will enable the refinery to meet demands for auto diesel and double the production of LPG by 1992. Excess production, largely fuel oil, is exported directly.

Sources of Demand

Transportation dominates the consumption of petroleum products (Figure 5.6). Approximately 60 percent of finished oil products supplies motor vehicles. In industry, the largest demand for petroleum comes from cement, tea, paper, steel, tire, and glass manufacturing (GEB, 1990). Foreign demand is comprised of aviation fuel and bunker oil.

Local sales of super petrol, auto diesel and super diesel have generally risen since 1983; the decrease in 1989 reflected an increase in local price (Figure 5.7). Transportation largely consumes diesel fuel (Figure 5.8); the public transportation service relies on it and the policy of pricing it below gasoline has stimulated imports of a high proportion of diesel vehicles.

Bus service -- public (SLTB) and private -- accounts for over 80 percent of the passenger traffic in Sri Lanka. Operations have been greatly affected by civil instability; the 1988 SLTB fleet size decreased by 13 percent from its 1984 peak -- from 8,005 down to 6,996, which is now lower than the 7,254 existing in 1979. Consumption of diesel fuel for the SLTB declined to 21.2 million gallons per annum for 1988 but may rise to 23.5 million gallons in 1990.

Petroleum usage in industry has significantly declined since 1984, except for supplies required for thermal electricity generation to meet hydroelectric shortfall from drought in 1986 (Figure 5.9). Several factors contributed to the decline. Civil instability slowed economic growth, industries switched to

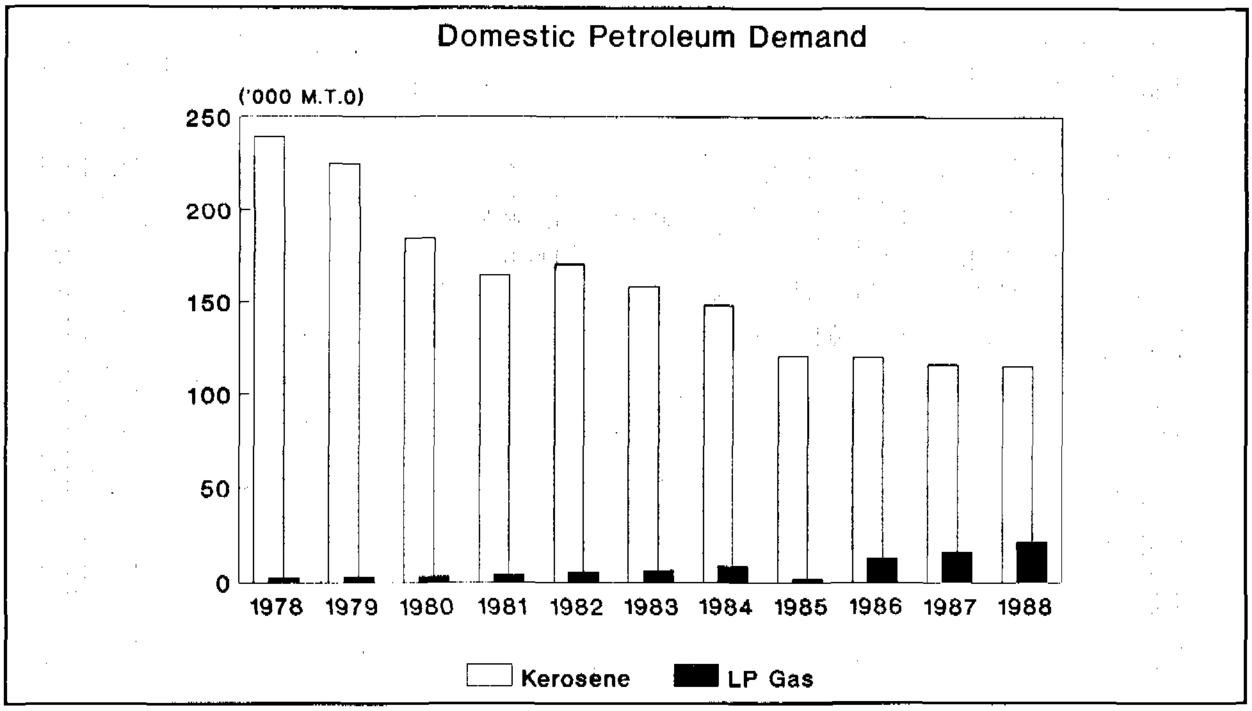


Figure 5.10

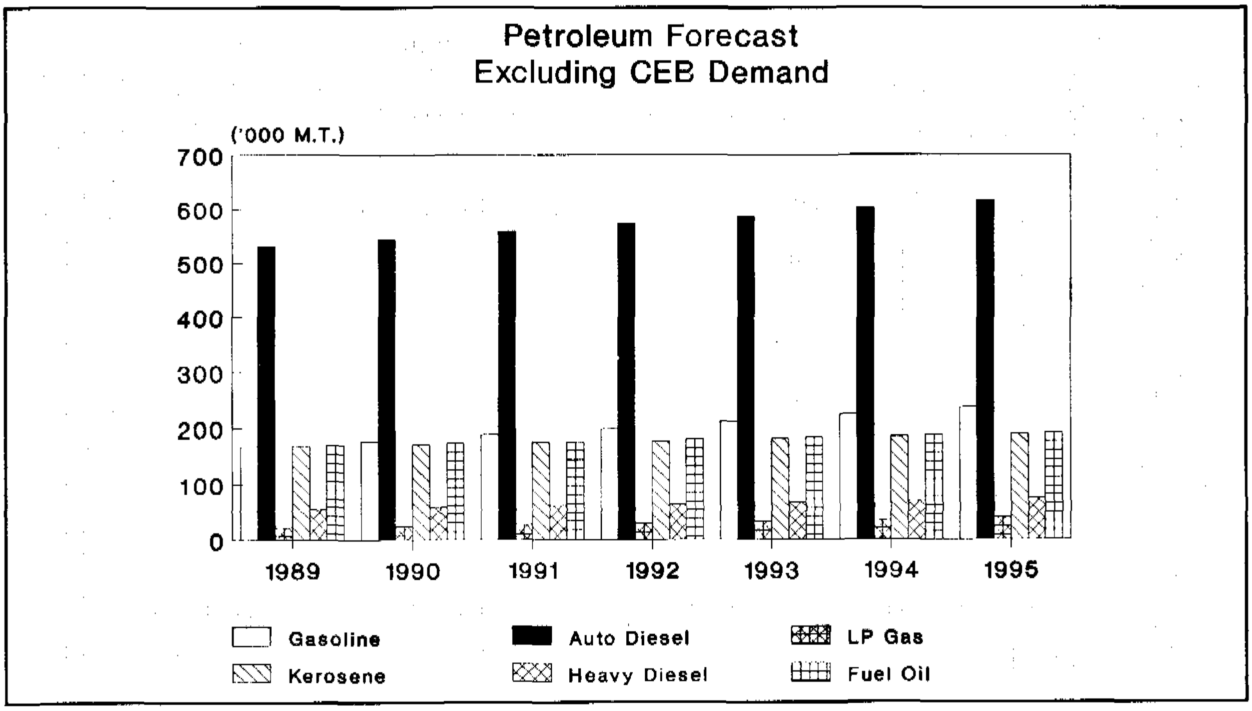


Figure 5.11

electric energy following completion of the Mahaweli dams, and some industries switched to biomass as a cheaper source of fuel. The share of industrial energy from biomass increased from 69.4 percent in 1978 to 75.9 percent in 1987. Major efforts were made in the early 1980s to promote fuel efficiency and reduce industrial and commercial waste of energy.

Oil products for domestic consumption are kerosene and LPG gas (Figure 5.10). Use of kerosene for lighting has decreased from approximately 82 percent of households in 1981 to 76.3 percent in 1988. The decline can be attributed to the expansion of the rural electrification during this period. Demands for LPG gas have increased significantly over the past few years as a relatively inexpensive cooking fuel compared to electricity.

The forecast for petroleum products (Figure 5.11), excluding demand from the Ceylon Electricity Board (CEB) for thermal generation, indicates that the fastest growth in demand is expected for gasoline and LPG. Demand for aviation fuel will depend largely on tourist business. Bunker oil demand depends on the bunker prices at Singapore and Middle East ports, and demand for fuel oil will depend on the proposed diesel generation plants to be established in the future and the industrial practices of fuel substitution.

BIOMASS FUEL

Consumption

Biomass provides cooking fuel for 94 percent of Sri Lankan households and, in addition, the source of heat for many small industries. Biomass fuel accounts for 70 percent of the primary energy consumed in Sri Lanka.

In 1983, a statistically designed study of household fuel consumption provided a wealth of new, badly needed data. It found that total biomass fuel consumption by households in 1983 was 7.5 million tons (air dry, ready-to-use condition), which is 35 percent higher than previous assumptions. Per capita consumption of biomass fuel for household cooking was 496 kilograms per year for the island as a whole and 526 kg per year for the rural sector, which used biomass fuel exclusively. Two years later, in 1985, the Forestry Resources Development Project estimated biomass consumption at 7.8 million tons. Assuming a 1.5 percent annual growth since then, the 1990 consumption would be 8.21 million tons.

Many industries (tea, rubber, desiccated coconut, bricks, tiles) use woodfuel as the source of heat. The total consumption in 1988 was estimated at 1.15 million tons, or about a seventh of the biomass fuel consumed by households. (See Figure 5.12).

Future Demand Trends

Growth rates in biomass fuel consumption coincide with population growth of 1.5 percent. The population growth rate is forecast to decrease until within three to four decades population stabilizes. Substitution of oil, electricity, or liquified petroleum gas (LPG) for biomass fuel in household cooking will probably not appreciably reduce per capita consumption of biomass fuel in the 1990s.

Programs of the Ministry of Power and Energy, among others, promote fuel-efficient woodfuel stoves in place of the traditional three-stone open fire and the semi-enclosed mud stove. If, as expected, these programs continue successfully, they could significantly reduce per capita consumption of fuelwood. Taking into account decreasing population growth rates and the expected decrease in per 'capita consumption of biomass fuel, growth in biomass fuel consumption by households may steadily decline from its present 1.5 percent. Figure 5.13 depicts three alternative consumption scenarios given in the Forestry Master Plan. Over a million households may well replace their traditional mud stoves or three-stone open fires with fuel-efficient cook stoves by the year 2000. If so, the projected biomass fuel demand by the household sector should follow path 2, or possibly path 3. By the year 2000, the difference in biomass requirements per year between scenario 3 and 2 is equivalent to a 10-year-old forest plantation of 2,500 hectares.

Annual demand for fuelwood by industries, now standing at 1.15 million tons, will also grow, but probably at a slower rate than the growth in the industries themselves owing to expected introduction of energy-saving technologies. The Forestry Master Plan forecasts industrial demand to peak around the year 2000, at 1.28 million tons and to drop slowly there after.

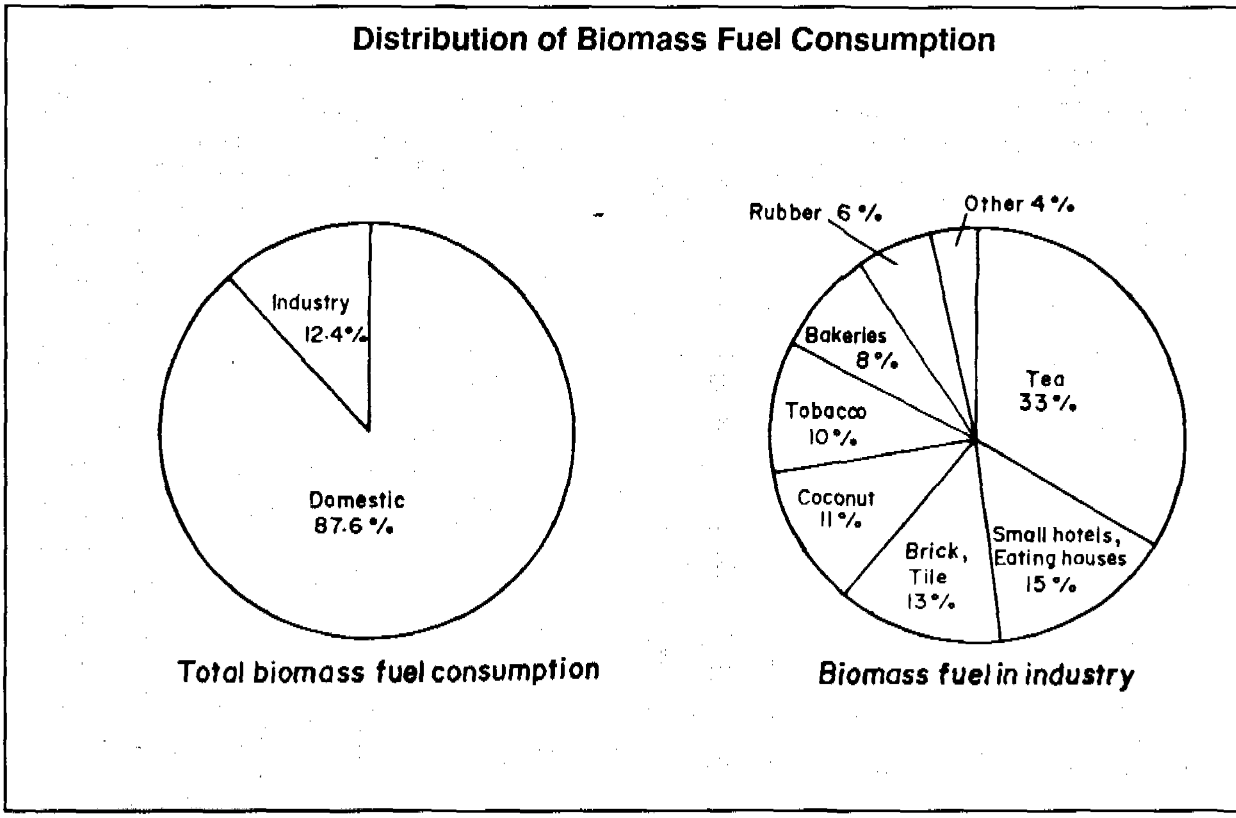


Figure 5.12

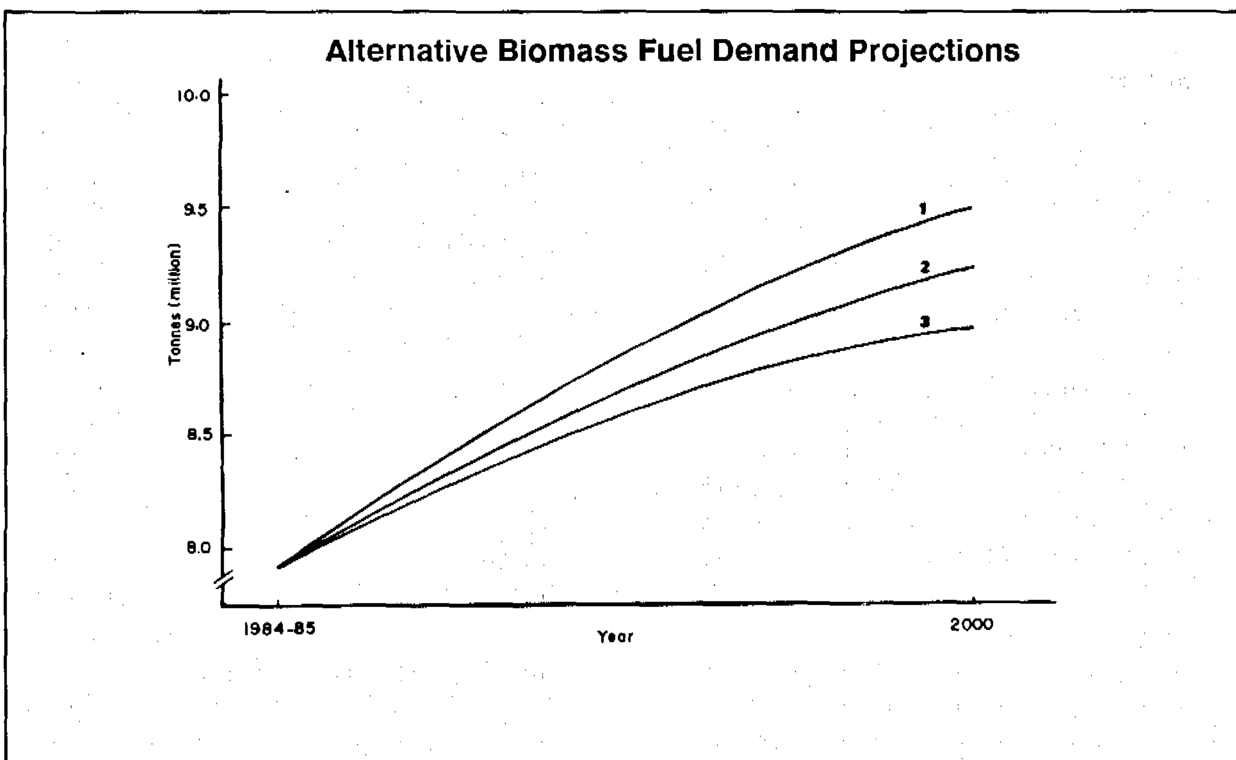


Figure 5.13

Sources of Biomass Fuel

The 1983 household biomass fuel survey revealed that rubber wood accounted for 18 percent of the consumption, crop wastes 28.8 percent, and other wood fuel 53.2 percent. Crop wastes consisted mainly of coconut tree wood, fallen fronds, husks and shells. Other crop wastes included uprooted tea bushes, manioc and cinnamon sticks, arecanut wood, and paddy husks. All biomass fuel not within categories of rubber wood and crop wastes were placed in a third category of "other fuelwood."

Rubber and coconut plantations are found in four distinct agro-ecological regions, and their contribution to fuel supply is of special importance. The proportions of the different types of biomass fuel consumed by households in each of the zones are shown in Figure 5.14. In the most densely populated southwest sector plantation coconut and rubber play a crucial role in meeting the energy demands.

In rural areas the vast majority of households (80 percent) gather all their own biomass fuel. Most urban households purchase at least a part of their requirements. Only a small proportion of household collection exceeded one mile (1.6 km). Because in most places no high forest is close to villages, many collections are apparently made from crop plantations or waste- and scrub-land. However, in many hill country areas fuelwood does come from natural forests, causing severe forest degradation.

Of the three categories of biomass fuel referred to in the biomass study, "other fuelwood" accounts for 53.2 percent of consumption. This category includes fuelwood from the forest and all biomass fuel gathered from waste, scrub-land and private lands (excluding rubber wood and crop wastes). The proportion coming from the forest cannot be large given the presence of biomass fuel from other closer sources. A reasonable assumption is that, taking the total consumption of biomass fuel by households, the proportion coming from high forest amounts to 20 to 25 percent, including the official supplies of the State Timber Corporation.

Only recently has Sri Lanka used charcoal as a household fuel. Availability of large quantities of low quality wood in forests cleared under the Mahaweli scheme prompted the State Timber Corporation to produce charcoal for domestic use and export. Because charcoal had not been used previously as a household fuel, the project included plans to develop and produce an inexpensive charcoal cooker and to make charcoal popular for cooking. The target group was urban households.

In contrast to households where an appreciable proportion of biomass fuel consists of sticks, twigs, coconut fronds, and similar material, industries use biomass in woodfuel billets. Industries obtain 49 percent of their biomass fuel from rubber wood, and 38 percent from natural forests. The balance comes mostly from forest plantations, home gardens and estate cuttings, while a small part consists of crop wastes such as paddy husks and bagasse.

Future Trends in Supplies

At present, Sri Lanka has no overall shortage of biomass fuel, but regional deficits occur in Colombo and in the hill country. Fortunately in the rural areas, where cooking relies entirely on biomass fuel, it is generally available. Over the past decades, several hundred thousand hectares of natural forest have been converted to scrub-land, and these areas, provide useful woodfuel pickings for villagers. However, if, as recent trends indicate, large areas of waste land are put to other economic use, this will reduce areas available for woodfuel. Moreover, as economic conditions improve, the people may neither have time nor inclination to gather fuelwood, so they may purchase the material. Such trends are already observable in new settlement areas. In the future, therefore, biomass fuel supplies from traditional sources will probably decline and demand for woodfuel through commercial channels will grow. Steps will then be needed by the Forest Department in particular to raise fuelwood plantations in strategic locations.

In Colombo and other urban and suburban areas in the southwest, rubber plantations taken up for replanting provide a substantial proportion of the fuelwood needs. Yet this wood also, when chemically treated, has served as furniture wood for local and export markets. If promising trends continue, fuelwood supplies will require new fuelwood plantations.

Biomass Fuel Survey - Agro-Ecological Zones and Percentage Composition Of Biomass Fuel Types used in Each Zone

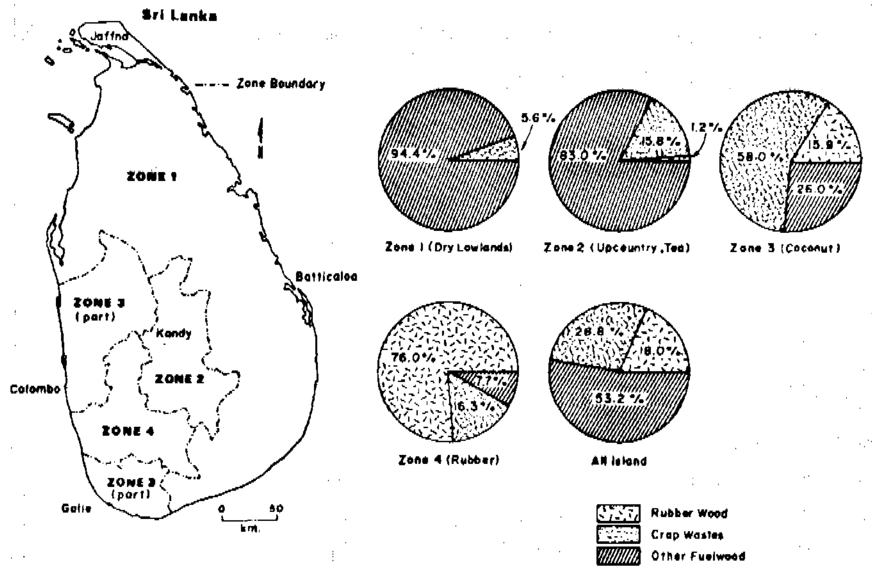


Figure 5.14

Energy Efficient Cook Stoves

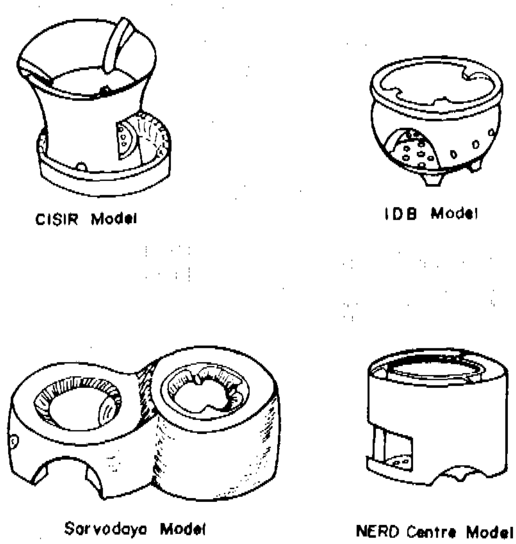


Figure 5.15

Paddy husk is another little-used biofuel. About 500,000 tons are produced annually, some of which is used for household cooking by families living near rice mills, and as a source of heat for parboiling paddy. The vast bulk is burnt off unused. It is a potential resource that can be used when traditional fuels become scarce or expensive.

MAIN ISSUES AND INSTITUTIONAL RESPONSES

In 1982 an Energy Adviser to the Minister of Power and Energy (a position then held by the President) was appointed to establish an organizational framework for integrated energy planning, create and develop analytical procedures, and train the manpower necessary for planning. The tasks were largely achieved during the ensuing three years.

In 1985, a non-governmental Sri Lanka Energy Manager's Association, was formed to upgrade energy management skills in the private sector, carry out energy audits, and take effective measures for saving energy in industry. That same year the Ministry of Power and Energy created an Energy Conservationor Energy Conservation fund to provide financial assistance for improving energy utilization and promote the use of alternative energy resources. A Project Ministry for Energy Conservation was created in March 1990 to promote identified energy conservation programs.

Electricity

By 1992, Sri Lanka will have tapped all its major hydropower resources, and further development must then focus on medium, small and mini hydro resources, thermal generation, and other options. The government is considering several options. Many small-scalehydropower sites could be developed, and costs may be and costs may be attractive if oil prices for thermal generation continue to rise. The GTZ has pointed out that hydro development will create several thousand more jobs and avoid more pollution than comparably sized oil-powered units. However, supplementary thermal generation will still require gas, diesel or coal-fired plants. In addition, 10 to 15 MW electricity generating units may be distributed in the coconut growing areas using coir dust for fuel.

It is the general view of energy planners that over the next ten years large thermal power stations will need to be introduced into the generation system to meet projected demands and backup requirements. However, it is not clear how this can be achieved, because the most recent attempt to install a coal-fired power station on the southwest coast has been stopped because of environmental considerations. Among the range of available alternatives is the hitherto overlooked possibility of increasing generation capacity of existing hydropower systems, which now generate an average of only 3,375 GWh per year, with installed capacity of 1017 MW. Increased capacity could be achieved by regulating the inflow into the reservoirs -- a well-known function of forests. Increasing the percentage of forest cover in the catchment area is therefore vitally necessary.

Conservation

While recognizing needs for increased generation capacity, it is important for the national economy that electricity conservation measures be adopted in all sectors. In the manufacturing industry, for example, outdated and faulty equipment results in a considerable waste of energy. Energy audits should be carried out routinely in factories to indicate where waste occurs and the corrective action needed. Significant energy savings could often be effected with simple housekeeping improvements where the pay-back period is only a matter of weeks.

Hotels can also save energy. They have stimulated rapid growth in electricity demand. A large luxury-class hotel consumes as much electricity as a provincial town. Although hotels must be maintained to attract international tourists, it is still possible to reduce electricity consumption. For example, large quantities of water could be heated to 60°C using direct solar energy. Locally produced solar heaters are available but not widely used. By adjusting the tariff structure, hotel owners can be encouraged to reduce excessive electricity use.

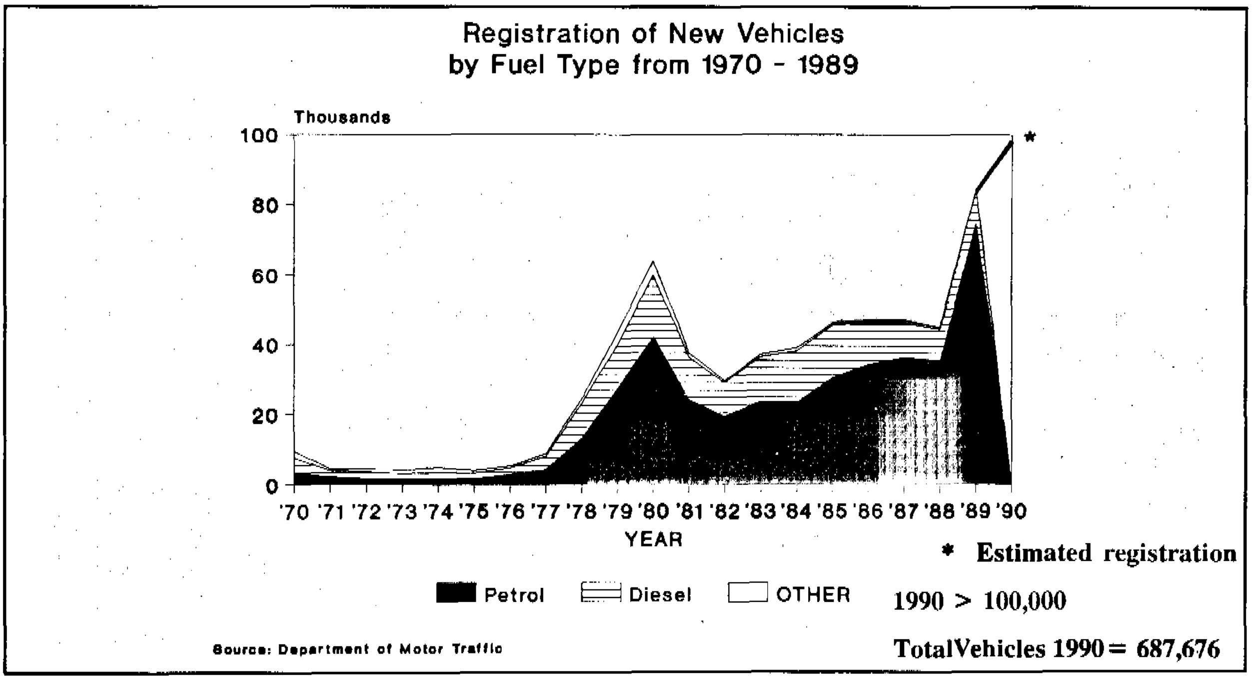


Figure 5.16

Although the Rural Electrification Programme receives high government priority, rural households are generally too poor to pay for service connections and internal wiring. Electric supply has also failed to stimulate rural industries as much as expected. To help resolve these problems the government has introduced a package of incentives to help domestic consumers and entrepreneurs in rural areas, including low-interest loans, easy repayment terms, low-cost service connections, and internal wiring provided by the CEB.

Phase II of the Rural Electrification Programme, now in progress, will provide electricity to 600 more villages and augment supplies to 600 others. Plans are also being prepared for Phase III, so that by the year 2000 all villages in the country will be either connected to the electricity grid or provided with another assured source of energy.

Biomass fuel

The general availability of biomass fuel in the country today should not discouragethe development of resources and conservation measures.

Because traditional cooking stoves and three-stone open fires used by the large majority of households waste biomass fuel, many institutions, both government and non-government, have encouraged use of improved, fuel-efficient stoves (see Figure 5.15.) Whereas traditional cooking methods obtain 8 to 14 percent useful heat, some improved cookers obtain 35 percent. Several programs now propagate use of these cookers. Under one program the Ministry of Power and Energy has replaced traditional cookers with a two-burner cooker in over 200,000 rural households in over 13 administrative districts. Continuation of this program, together with the sale of other models of improved cookers through private outlets, could result in over a million households changing to fuel-efficient cookers before the year 2000.

Technologies adapted for use in Sri Lanka by the National Engineering Research and Development Centre, are biomass gasifiers for tea leaf drying and smelting brass, windmills to charge batteries for domestic lighting, and bread baking ovens which save biomass fuel. The Water Resources Board developed a windmill for pumping water for irrigation. The dramatic fall in the price of oil in the mid-1980s slackened efforts to stimulate renewable energy. The rapid oil price rise following the Persian Gulf crisis illustrates how short-sighted this neglect has been.

Air Pollution

Air pollution is one of the chief by-products of energy production and consumption, but in Sri Lanka it also results from *chena* fires and burning of refuse. Unfortunately, we lack reliable information on the amounts of air pollution produced in Sri Lanka and how it affects human health and the environment. Yet the problem has become increasingly serious in urban areas, and public concern for cleaner air is growing.

The Colombo district, where two-thirds of the population is urban, accounts for over 60 percent of the manufacturing industries, 60 per cent of registered vehicles and both diesel power plants. Hence, the most significant air pollution is generated primarily in this region.

SOURCES OF POLLUTION

The major air pollution sources are summarized below:

Stationary Sources

The domestic sector, at nearly 69 percent of the total, is the primary energy consumer. Its contributions to air pollution result from domestic cooking and lighting fueled by wood, electricity, kerosene, and gas. Overall pollution is insignificant, but domestic health impacts of fuelwood and kerosene burning have not been measured.

Industrial processes, consuming about 17 percent of total energy, also contribute particulates and gases to the atmosphere. A 1989 survey found that over 4,000 manufacturing facilities had potential for air or water pollution. About 40 percent are chemical, food and textile plants using fuelwood or furnace oil, and nearly 25 percent are quarrying and mining activities. A well-known example of industrial air pollution is the Puttalam cement works, which belched tons of particulate matter into the environment, degraded surrounding agricultural fields and may have caused health problems (see Chapter 4 - The Price of Pollution). Despite such cases, the industrial survey indicated that industry has low emission levels and is localized in areas of dense population; water pollution is still a more significant industrial problem than air pollution.

Power generation. Sri Lanka's electricity generation, largely hydro, includes two diesel generating units with a total capacity 260 MW in the Colombo metropolis. Additional units are being planned to augment hydro supplies. There are 21 generating facilities, with capacities ranging from 1 MW to 25 MW, located in four power stations, which use gas, heavy oil and diesel as fuel. As yet, however, no large thermal power plants have been built in Sri Lanka, so air pollution from power generation remains low.

Refuse burning. Open burning of domestic and industrial refuse is widespread. Particularly in urban areas the resulting pollution is a well-recognized public nuisance.

Mobile Sources

The transport sector, accounting for 12 percent of Sri Lanka's energy consumption in 1989, and 60 percent of all petroleum consumption, causes the most serious air pollution due to its concentration in populated areas. In 1990, 60 percent of the country's more than half a million registered motor vehicles were concentrated in the Colombo district.

The number of vehicles registered annually in Sri Lanka between 1970 and 1990 increased 14-fold (see Figure 5.16). Fuel is primarily petrol or diesel, refined locally from imported crude oil by the Ceylon Petroleum Corporation. Sulphur content in refined fuel is maintained below 0.1 and 1.1 percent by weight respectively for petrol and diesel. Lead in the form of tetraethyl is added to refined oil at the rate of 0.34 to 0.55 grams per liter. Consumption rates recorded by the Ceylon Petroleum Corporation between 1970 and 1986 (Figure 5.17) show that petrol consumption has declined marginally, but consumption of diesel has doubled due to the increased number of private buses.

Vehicles account for nearly all the pollution resulting from petroleum consumption in Sri Lanka, based on estimates of 1989 consumption and WHO and US Environmental Protection Agency emission factors. Of all petroleum combustion emissions, vehicles produce 98 percent of the carbon monoxide, 92 percent of the hydrocarbons, 79 percent of the oxides of nitrogen, 75 percent of particulates, and 46 percent of the sulphur dioxide. Buses and trucks are the major offenders, responsible for two-thirds or more of all vehicle emissions other than carbon monoxide.

Recognizing the growing vehicle pollution problem, the government appointed a committee of experts in 1987 to draw up plans to combat vehicular emissions. As yet none of the 20 committee recommendations have been implemented.

AIR QUALITY MONITORING

The first major effort to monitor air quality began in early 1989 when the National Building Research Organization initiated its three-year Colombo Air Quality Monitoring Program (CAMP). Phase I requires a preliminary assessment of Colombo City air quality through determinations of sulphation rates, measured by concentration of sulphur compounds like sulphur dioxide, sulphur trioxide, and hydrogen sulphide, and dustfall, measured by the total settleable dust in the atmosphere. Locations showing adverse air quality will be monitored in Phase II to measure suspended particulate matter, SO_2 and NO_X. The joint CEA/NBRO program is a necessary first step toward several objectives: to establish a database for Colombo City; to formulate National Air Quality Standards; and to establish a permanent monitoring station.

In the first phase, nearing completion, 52 locations were selected for continuous monitoring, and year-long data are now available for 39 of these. To facilitate simultaneous monitoring of sulphation rates and dustfall, the NBRO delineated individual sampling units, with monitoring stations about 0.8 kilometers apart. Results showed that sulphation rates ranged between 0.04 and 0.45 milligrams per 100 square centimeters. The highest level was obtained from a sampling station located in the Kollupitiya commercial area. Dustfall measurements showed the highest value of 1,472.5 milligrams per square meter per day at a station near the Colombo North Industrial Zone in Grandpass, while a station in Narahenpita recorded the lowest value of 139.70 milligrams per square meter per day.

The following criteria were adopted to classify air quality in identifying Phase II locations:

Excellent: Dustfall less than 200 milligrams per square meter per day and sulphation rate less than 0.1 milligrams per 100 square centimeters per day.

Moderate: Dustfall 200-300 milligrams per square meter per day and sulphation rate less than 0.1 - 0.2 milligrams per 100 square centimeters.

Unsatisfactory: Dustfall more than 300 milligrams per square meter per day and sulphation rate more than 0.2 milligrams per 100 square centimeters.

Monitoring results rated 18 locations as excellent, 12 as moderate and 9 as unsatisfactory. All unsatisfactory locations were situated in commercial/industrial areas or at major traffic intersections. Preliminary monitoring of SPM, SO2, NOX and CO has commenced at these 9 locations.

INSTITUTIONAL AND LEGAL FRAMEWORK

Legal instruments. The National Environmental Act of 1980 as amended in 1988 prohibited pollution discharge into the environment. Sections 23J and K prohibit emission of pollutants into the atmosphere. The CEA is charged with establishing and enforcing the pollution law through regulatory requirements, and the National Environmental (Protection and Quality) Regulations of 1990 now prohibit the discharge of wastes into the environment. Discharge standards have been prescribed only for liquid wastes, however, so stationary sources of significant air pollution remain difficult to regulate. Moreover, the regulations do not address vehicle pollution.

Institutions. Although the CEA is charged with preserving air quality, its expertise in air quality management needs to be expanded and improved. CEA has designated the NBRO as lead agency for air quality monitoring. Other agencies will also be involved, including the Ceylon Institute of Scientific and Industrial Research (CISIR), which is capable of monitoring ambient air quality and source emission, and the Division of Occupational Health, which monitors the workplace environment.

Sri Lanka's limited air pollution controls contrast with the increasingly tight regulations in developed countries, including stringent emission controls over the growing numbers of vehicles. The United States requires lead-free petrol and (since 1975) emission control devices on all new cars. Japan, Canada, and several European countries also have rigorous vehicle emission controls. These measures require new technology and efficient inspection and enforcement systems. In the Third World, however, similar investment in vehicle pollution control has appeared too costly, even though vehicles cause increasingly severe air pollution in cities like Bangkok, Cairo, Jakarta and Mexico City.

FUTURE ACTIONS

Development of a comprehensive air pollution control program in Sri Lanka will be a long-term effort. It requires careful planning for industrial siting and transportation. It also requires immediate efforts to obtain data on the health and economic impacts of air pollution and to build cost-effective monitoring and enforcement programs. Control of vehicle emissions demands high priority, given the steady increase in vehicles and the lack of any pollution control program.

Health impacts

Data on health impacts of air pollution need to be established, based on analyses of lead content of urban dust, incidence of respiratory illnesses, and other health data. In recent years scientists have warned that even low concentrations of lead cause serious poisoning, affecting urban children in particular. Worldwide, about 90 percent of the lead in urban air comes from motor vehicles. Concern is also growing about the impacts of the small particulates emitted from diesel engines. Uncontrolled diesels emit about 30 to 70 times more particulates than petrol engines. Studies indicate that these particulates have caused increased tumors in animals and may be carcinogenic to exposed workers.

Sources and Effects of Air Pollution

Common pollutants generated by human activities are sulfur dioxide, oxides of nitrogen, lead, carbon monoxide, photochemical oxidants and suspended particulate matter. Concentrations of each pollutant in Sri Lanka are unknown because emissions have not been monitored. Nor do we have information on correlations between air pollution and respiratory illnesses or incidence of lead poisoning. The chart below lists the characteristics, sources, and effects of each major air pollutant.

POLLUTANT	CHARACTERISTICS	PRINCIPAL SOURCES	PRINCIPAL EFFECTS
Carbon monoxide (CO)	A colorless, odorless gas with a strong chemical affinity for hemoglobin in blood	Incomplete combustion of fuels and other carbon-containing substances, such as in motor vehicle exhaust; natural events such as forest fires or decomposition of organic matter	Health: Some reduced tolerance for exercise, impairment of mental function, impairment of fetal development, death at high levels
Photochemical oxidants (O_3)	Colorless, gaseous compounds which can generate photochemical smog	Atmospheric reaction of chemicals under the influence of sunlight	Health: Aggravation of respiratory and cardiovascular illnesses, irritation of eyes and respiratory tract, impairment of cardio pulmonary function. Other: deterioration of rubber, textiles and paints; impairment of visibility; leaf damage and reduced growth of premature plants.
Sulfur dioxide (SO_2)	A colorless gas with a pungent odor; SO_2 can oxidize to form sulfur trioxide, which forms sulfuric acid with water	Combustion of sulfur-containing fossil fuels, smelting of sulfur-bearing metal ores, industrial processes, volcanic eruptions	Health: Aggravation of respiratory diseases, including asthma, chronic bronchitis, emphysema; reduced lung function; irritation of eyes, respiratory tract; increased mortality. Other: corrosion of metals; deterioration of electrical

			contacts, paper, textiles, leather, finishes and coatings, building stone; formation of acid rain; leaf damage, reduced growth in plants; impairment of visibility.
Total suspended particulates (TSP)	Any solid or liquid particles (diameter ranging from 0.3 to 100 microns) dispersed in the atmosphere, such as dust, pollen, ash, soot, metals, various metals	Stationary combustion, especially of solid fuels; construction activities; industrial processes; atmospheric chemical reactions; smoking tobacco; forest fires, wind erosion, volcanic eruptions	Health; Directly toxic effects or aggravation of the effects of gaseous pollutants; aggravation of asthma or other respiratory or cardiorespiratory symptoms; coughing, chest dis-comfort; increased mortality. Others: soiling deterioration of building materials, other surfaces; impairment of visibility; cloud formation; interference with plant photo-synthesis.
Nitrogen dioxide (NO_2)	At high concentrations, a brownish-red gas with a pungent odor, often formed oxidation of nitric oxide	Motor vehicle exhaust, high-temperature stationary combustion, atmospheric reactions	Health: Aggravation of respiratory illnesses. Other: fading of paints, dyes; impairment of visibility reduced growth, premature leaf drop in plants; formation of acid rain.
Lead	A non-ferrous heavy metal occuring in air as vapor, aerosol or dust	Available in nature; lead mining, smelting, processing; motor vehicle emissions; manufacture of lead products (e.g. batteries)	Health: Accumulation in body organs; anemia; kidney damage; central nervous system damage.

Source: Thailand Natural Resources Profile

Paddy cultivation on 760,000 hectares makes rice Sri Lanka's dominant crop in terms of land use and dietary importance.

6 Land Resources

Sri Lanka covers about 6.56 million hectares (16.21 million acres), of which 1.8 percent includes inland waters. But Sri Lanka's land resources are not measured by surface area alone; they include various soils -- critical for productivity -- underlying geology, topography, hydrology, and plant and animal populations, and how these resources have been significantly affected by past and present human activities.

A rough indicator of demands on land resources can be seen from the land-man ratio. In 1871, when Sri Lanka contained only 2.4 million people, about 2.7 hectares were available per person. Today, at about 17 million, land has decreased to 0.38 hectares (about one acre per person). As Figure 6.1 shows, the land-man ratio will decrease further as Sri Lanka continues to grow to its forecast population, levelling off at about 25 million after 2036. Competition for land among various users and appropriate management of land according to its capabilities will, inevitably, become a more pressing problem. Adding to this challenge are the economic, social, and environmental impacts of continued degradation of Sri Lanka's land resources from misuse and over exploitation.

Part I of this chapter discusses trends in land use over five decades, present land use conditions, focusing particularly on lands under tea and paddy, and the importance of soil resources. It concludes with a discussion of current land resource use and allocation policies and institutional responses.

Part II focuses on land degradation problems, particularly soil erosion, landslides, coastal erosion, salinity and waterlogging. It concludes with a brief discussion of institutional responses.

Given the breadth of this topic, this chapter cannot be comprehensive; the chapters on mineral resources, coastal resources, and forestry address additional aspects of land.

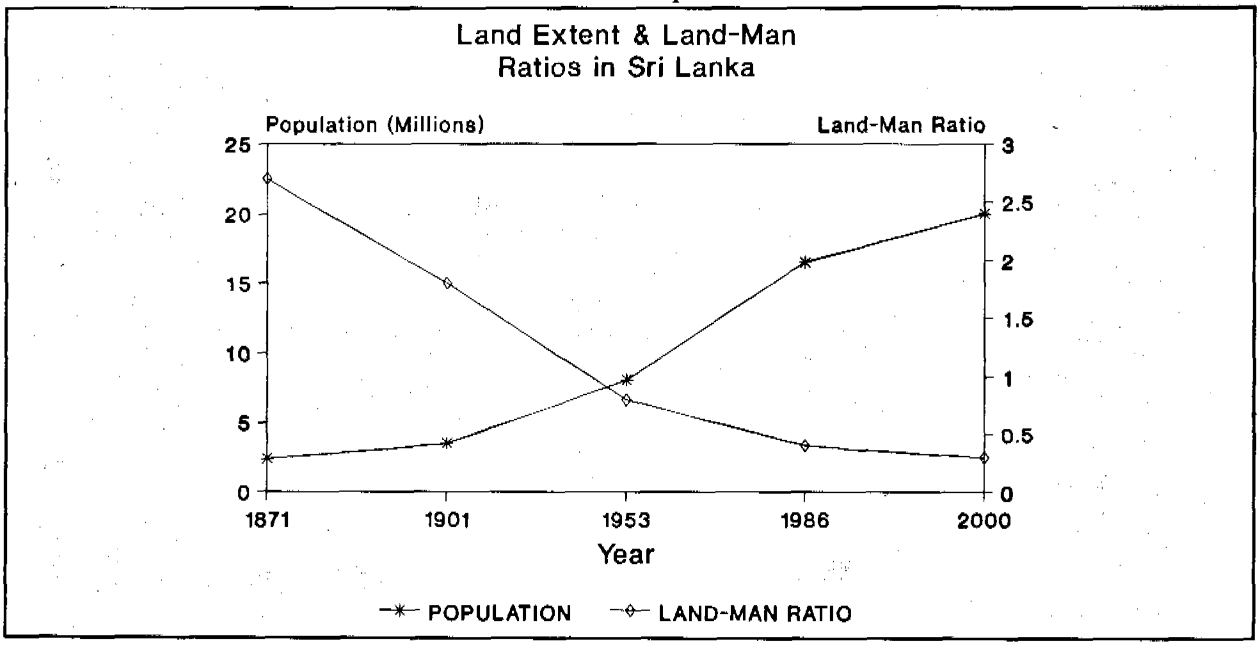


Figure 6.1

Land Use Changes (1956-1984)

(in thousands of hectares)

Total Measured Land Use = 6,525,000 ha

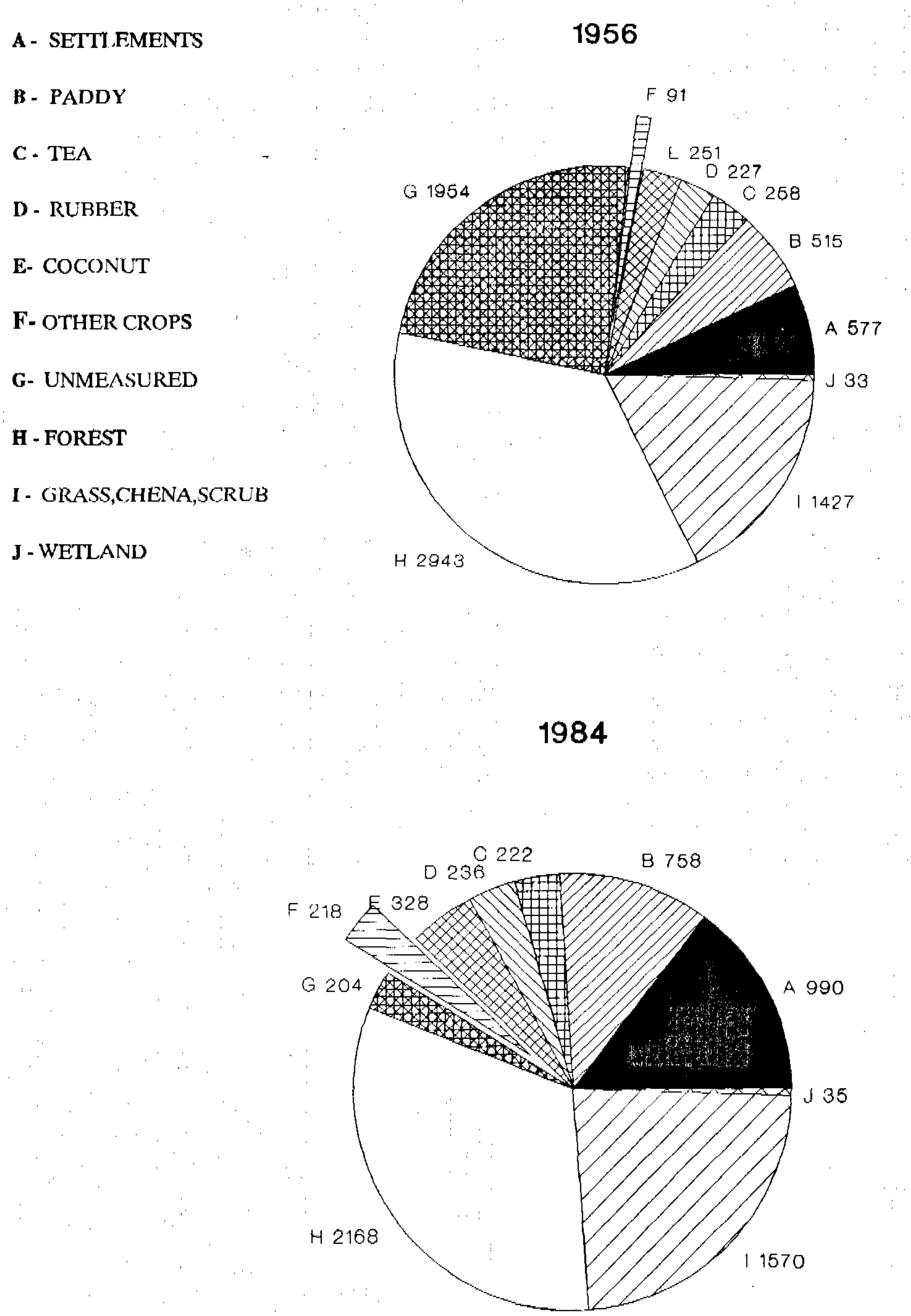


Figure 6.2

PART I
LAND RESOURCES AND USE
1956 TO PRESENT

Population increases have significantly changed land uses since Independence, when high growth rates intensified competition for land. At present, developed agriculture includes nearly a third of the land area, land under forest and wildlife conservation occupies another third, and transportation, human settlements, home gardens, and a variety of other uses, including undeveloped land, account for the rest. Information on these present land uses, although imperfect, comes from land use mapping by the Survey Department, the Irrigation Department, the Land Use Policy Planning Division, the Agriculture Department, and annual data gathered by the Department of Census and Statistics and other Departments and local officers. By comparing present information with results of the first comprehensive land use mapping effort for Sri Lanka compiled from aerial photography in 1956 we can determine significant changes in land use and land conditions over the past 45 years. Land use changes for eight broad categories from 1956 to 1984, and hectares per person are shown in Figure 6.3. Highlights of the changes:

Smaller natural forests. Forests have taken the brunt of the change. Since 1956 natural forests shrunk from 2,900,000 hectares to 2,150,000 hectares in 1984. Assessed against population increases, forests declined from 0.35 to 0.13 hectares of forest per head.

Dry Zone settlement. New irrigated lands brought over 300,000 families into the Dry Zone including settlement of 51,000 hectares of the Mahaweli region, where 10,000 people moved from the newly constructed Mahaweli reservoirs. Population also shifted significantly into Mullaitivu, Mannar and particularly Vavuniya, following loss of employment from nationalized tea plantations in the early 1970s. Even so, the Land Commission (1990) estimates that about 2.5 million hectares -- nearly 40 percent of the country, mostly in the Dry Zone -- remains "developable" in some way.

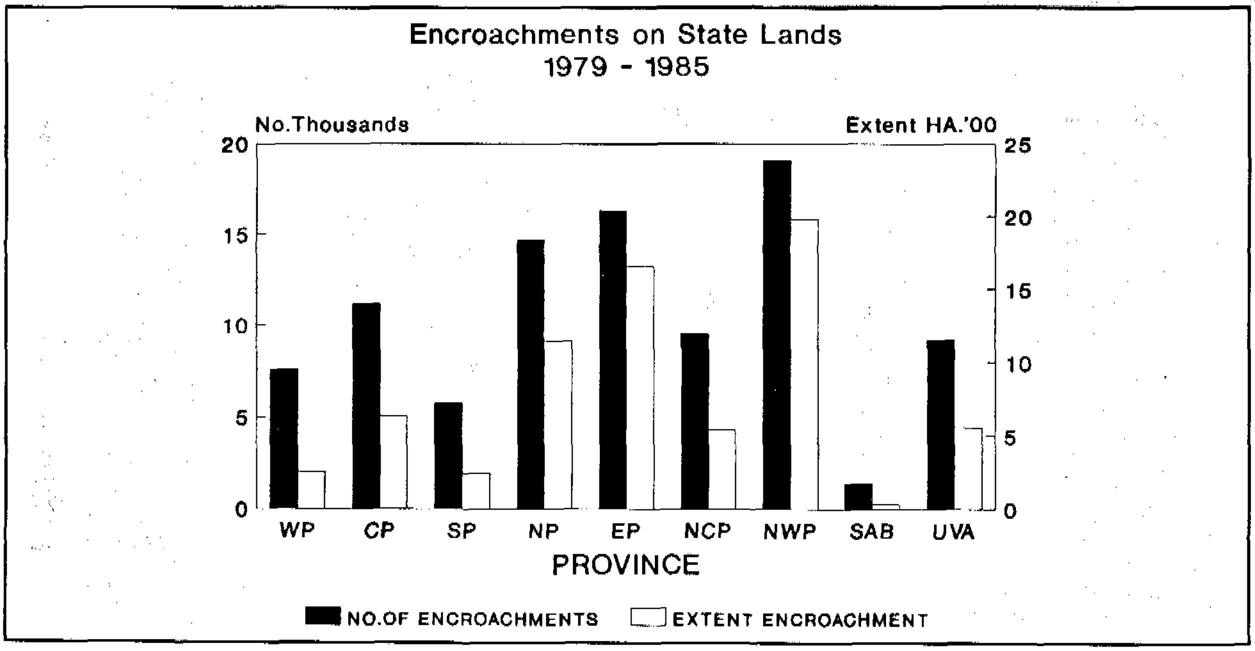
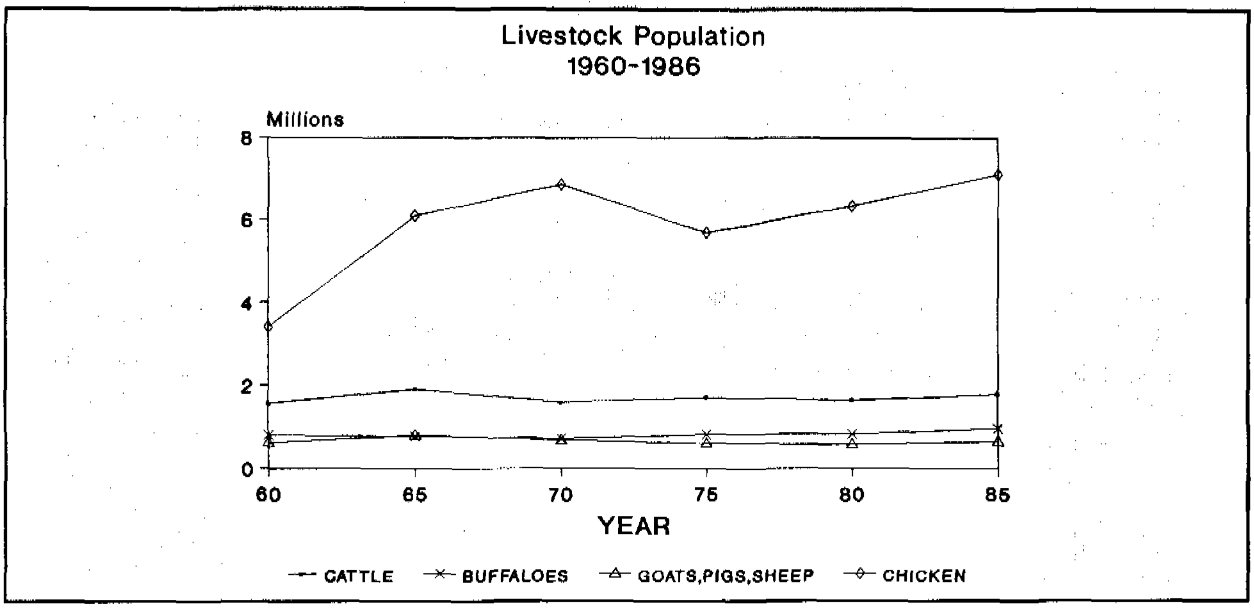


Figure 6.3



Figire 6.4

Encroachments on state land. The government's first official report on this problem found that by 1979 an estimated 500,000 people had encroached on 6 percent of the country since well before Independence. Between 1979 and 1985 another 104,000 encroachments totalled over 70,000 hectares -- a 19 percent increase -- mostly for residences and usually on land reserved by the state along roads, streams, and canals. The highest rate of increase occurred in the Central Province. Figure 6.3 shows encroachments per province since 1978.

Urban expansion. Urban areas have steadily sprawled into areas still not officially defined as "urban," frequently causing settlement and filling of floodprone lowlands. Urban expansion reduced rubber and coconut plantations around Colombo and Gampaha by 25 percent. In Colombo, where the government owns 25 percent of the land, an estimated 9,000 encroachments occurred since 1979, primarily for housing along canals and road and railway embankments.

Agricultural shifts. Paddy increased from 514,000 hectares to 760,000 hectares in 1988, mainly in the newly irrigated areas of the Mahaweli. Sugarcane, which barely existed in 1956, increased to about 20,000 hectares with the opening of plantations in the Southern and Eastern dry zone. Other agricultural changes: increased livestock population, and twice as many chickens, mostly in commercial farms (see Figure 6.4), and moderate growth in non-traditional export crops such as coffee, pepper, cocoa, and in fruits and cut flowers.

Plantations. Tea plantations declined in size by about 10 percent, but the overall acreage of developed agricultural land -- about 30 percent in 1982 -- barely changed. The Land Commission estimates a 10 percent coconut decline between 1962 and 1982.

Increased shifting cultivation. Lands under shifting cultivation (*chena*) increased from about 1 to 1.2 million hectares. But whereas in the mid-1950s about 90 percent lay in the Dry and Intermediate Zones, now they are found in every region, from Galle to Jaffna, despite government prohibitions. (See box -- Whither *chena?*)

PRESENT USE

Plantation Agriculture -- Focus on Tea

Of the 839,000 hectares under plantation agriculture, tea has been the dominant crop and immensely important environmentally as well. The discussion below focuses on the environmental and economic conditions and trends of tea production.

WHITHER CHENA?

Chena (anglicised from *hena*) cultivation, probably Sri Lanka's oldest agriculture, still continues, primarily in the island's sparsely populated, relatively dry regions. It involves forest clearing and cultivation for a season or two, abandonment to fallow which allows the forest to regenerate, and subsequent repetition of the cultivation cycle.

Forest clearing occurs during the dry season before the *maha* rainfall. Burning follows before the onset of rains, after which seed beds are prepared for an assortment of crops, including sweet corn, finger millet, mustard and country vegetables grown under rainfed conditions. Watch-huts on taller trees and log fences provide protection from wild animals and birds. Harvesting begins toward the end of the rainy season and continues during the dry spells thereafter. A second season of *chena* is often attempted on the same land (*yala hen*) based on the minor rainy season, with more drought-resistant crops such as gingelly. This cycle repeats on the same land with fallow periods, traditionally ranging from a minimum of 3 to 10 years.

"Slash and burn" agriculture may have been practised since the neolithic age. Evidence prehistoric man at Bandarawela indicates the burning of drier mountain forests in the Uva basin by prehistoric communities may have led to the formation of *patanas* or montane grassland. *Chena* continued throughout Sri Lanka's hydraulic civilization, and when the European naval powers arrived *chena* cultivation was practised everywhere. Even the present Kotahena in the heart of Colombo City may once have been a *chena*. Expansion of plantation agriculture into the central hill country occurred largely at the expense of Kandyan *chenas* for which no definite titles could be established. Thus, although most tea estates have English, Scottish or Irish place names, many of their original deeds retain the suffix 'hena', indicating that some had previously been under *chena*.

Chena became a land settlement controversy during the British period. The Crown Land Encroachment Ordinance of 1840 created a strong presumption of Crown ownership, but some contended that all Kandyan *chenas* belonged to Kandyan villagers. Conceding that it was "manifestly unfair to presume" Crown ownership, the First Land Commission (1927), which considered the *chena* in depth, argued that removal of the presumption would cause villagers more harm than good and bring "great mischief" to community interests. Consequently, *chena* lands became Crown property.

H.R. Freeman, Government Agent of the North Central Province, presented to the First Land Commission a very different perspective. He recognized that villagers depended on *chena* for food; when low rainfall caused tanks and paddy crops to fail *chena* crops provided some extra margin of security. He recommended protection of reserve lands required for Crown forests (about 600 square miles) and village forests, allowing villagers to cultivate *chena* and graze cattle on the rest of the land without restriction.

But the Land Commission came to another conclusion:

> Chena cultivation is a primitive and uneconomic form of cultivation. By means of it a bare livelihood may be obtained with the least amount of sustained exertion. For this reason it tends to demoralize persons who habitually practice it and render them unwilling to undertake any other forms of manual labour. Unlimited facilities for chena cultivation thus tend to make the villagers neglect paddy cultivation which demands harder and more continuous work.

Debates on *chena* continue, but observations of the First Land Commission retain their validity even after sixty years. Areas under *chena* farming are still considerable. In 1952 the committee on the use of Crown Lands estimated about .7 million hectares of *chena* lands in the Dry Zone; fifteen years later the Land Use Committee (1967) reported *chena* at about one million hectares, and in 1984 the Land Use Division of the Irrigation Department estimated *chena* land at about 1.2 million hectares.

For Sri Lanka's forests the *chena,* and recent trends indicating its increase, are ecologically disastrous. Now *chena* cultivation concentrates on the remaining forest areas; as *chenas* spread, particularly in the Dry and Intermediate zones, forests diminish. As population increases in rural areas so does the intensity of chena cultivation. *Chena* cycles have become ever shorter, leading to rapid impoverishment of soil. The First Land Commission referred to some *chena* lands in the Kegalle District where farmers returned to the same plot after 20 years, and in Ratnapura District after 10 years. At present, however, *chena* cropping occurs every 2-3 years or less. Many farmers do not fallow their lands at all but crop it continuously. A recent survey of *chena* cultivation in some villages of the Anuradhapura District, shows that nearly 60 percent of the farmers have cultivated land that was used the previous season.

Chena lands produce about eighty percent of Sri Lanka's rainfed grains, pulses and vegetables . In any given year about 250,000 farm families depend on *chena* for their livelihood.

But environmental conditions and trends indicate that this situation is neither economically nor environmentally sustainable. The average *chena* land holding per cultivator family now is estimated at about one hectare. Population increases mean that this ratio cannot continue. With about 6.47 million hectares of arable land in the country, overall per capita land availability is well below half a hectare.

Even present *chena* cultivation practices are not sustainable. *Chena* cultivation was traditionally a system of low intensity land use with a cultivation intensity range of only 5 to 10 percent. However, the cultivation of lands with greatly reduced fallow periods has depeleted soil fertility and caused weed infestation, soil erosion, and crop-yield decline. The average yield of all *chena* crops during *maha* season is less than 50 percent of the potential yield, with possible exceptions for soya beans and gingelly.

By the mid-nineteenth century British colonial policies caused clearing of many of Sri Lanka's tropical montane forests in order to plant coffee and cinchona. Plantation coffee covered 20,500 hectares in 1847, increased to about 32,400 hectares by 1857, and to 110,500 hectares by 1873. Approximately 20,200 hectares were converted from *chena* lands (K.M. De Silva, 1981). By then the coffee blight was taking hold, and after 1880 coffee gave way to tea plantations. Tea cultivation was extremely efficient, and tea soon became Sri Lanka's single largest foreign exchange earner. In conventional business terms the transformation of natural forests to plantation agriculture was highly successful.

During the past decade, however, tea's relative economic importance has changed significantly. Government revenue from tree crops (tea, rubber and coconut) fell from 23 percent in 1981 to .04 percent in 1988 as the government reduced export duties and taxes. Further, the proportion of their export earnings declined from 49 percent in 1975 to 25 percent in 1988. After 1980 the value of industrial exports exceeded that of tea exports. However, tea remains Sri Lanka's highest net foreign exchange earner, bringing in twice the net foreign exchange earned by textiles and garments, although their gross foreign exchange earnings exceeded that of tea by 16 percent.

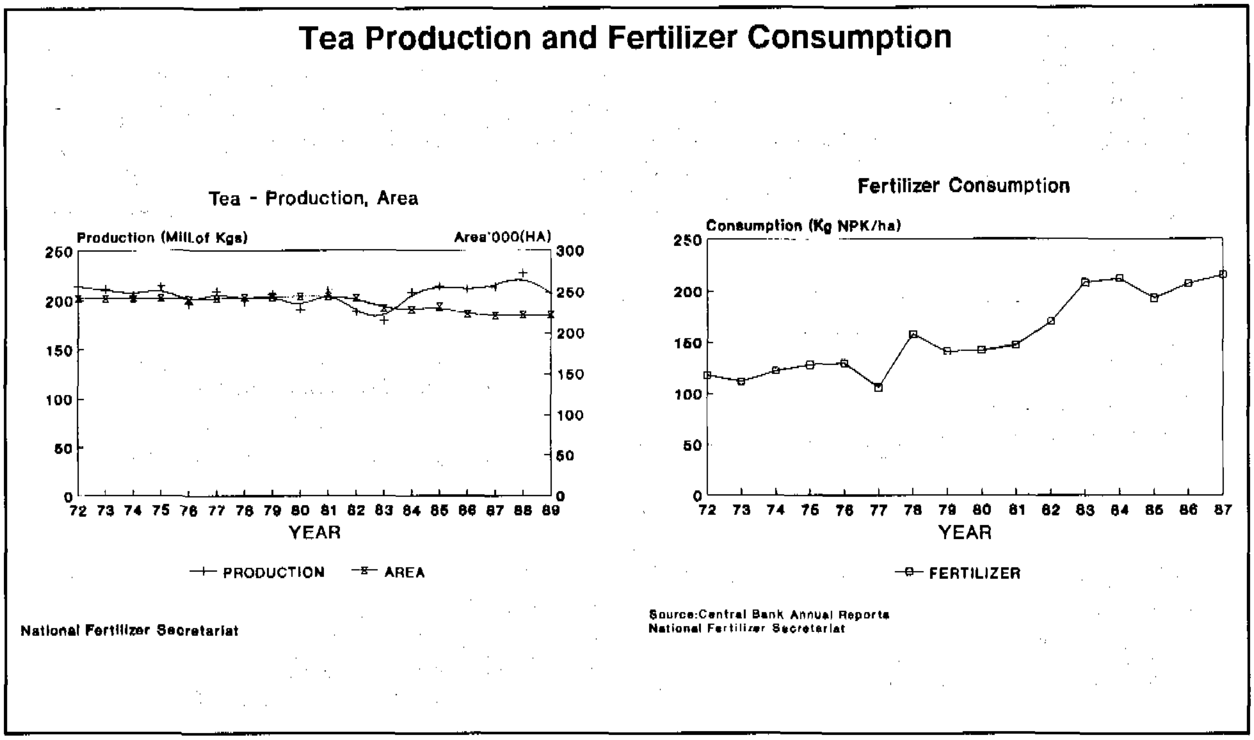


Figure 6.5

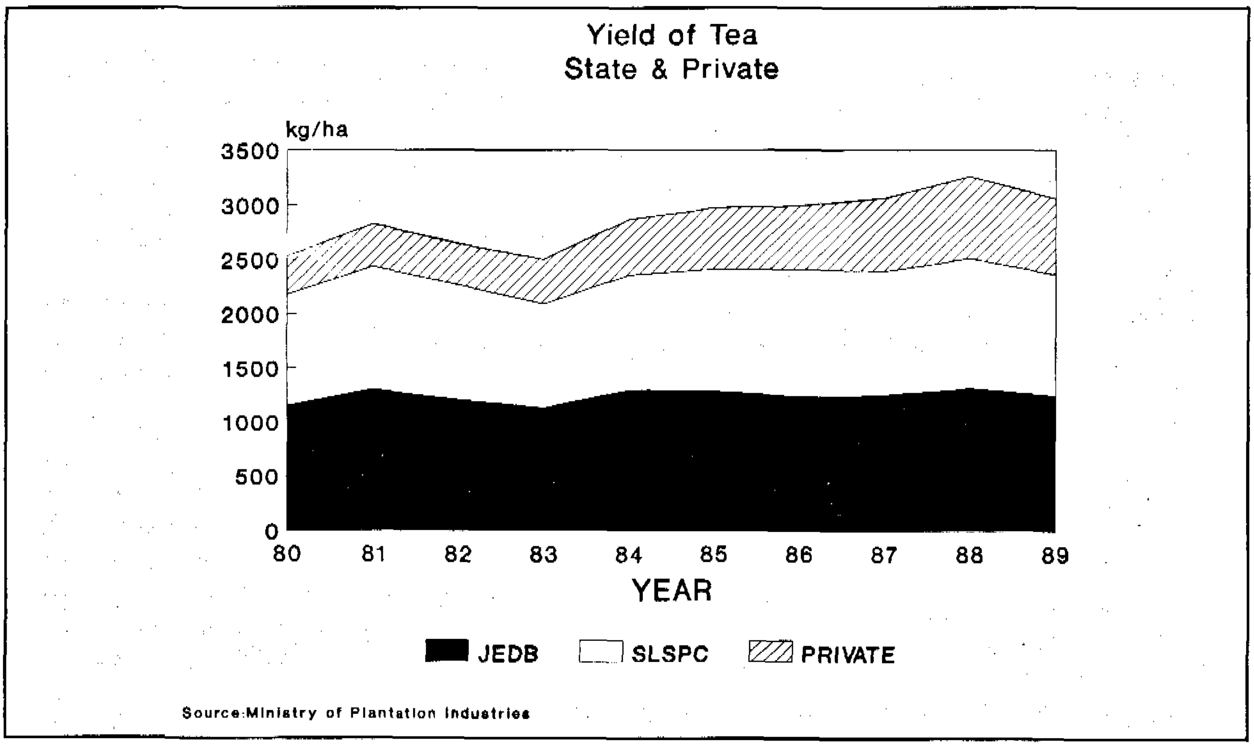


Figure 6.6

Production. Tea production peaked at 228 million kilograms in 1965 due to increased acreage and yields per acre. Since then production has declined. Between 1968 and 1982 production fluctuated but declined at an estimated rate of 1.87 million kg/ha/yr (Figure 6.5). In 1983 a severe and prolonged drought cut production to 179 million kilograms -- the lowest level since 1965. Although production rose to 208 million kilograms the following year and in 1988 production reached 227 million kilograms. In the absence of civil disruption in the Southern and Uva regions production might have exceeded that of 1965.

Various factors have contributed to production declines or stagnation: reduced acreage; adverse weather; inadequate replanting and infilling; poor management; nationalization following the Land Reform Laws of the 1970s; high taxation and depressed prices; increasing age and senility of tea plantations; and declining soil fertility.

Unfortunately there is no accurate information on the extent of tea. Area under tea, as registered by the Tea Commissioner's Division, remained virtually unchanged for at least the ten years up to 1982 (Figure 6.5), but data from the Agricultural Censuses show a 9.5 percent decrease in area between 1973 and 1982. Area under tea decreased by 20,031 hectares between 1983 and 1989, according to records of the Plantation Industries Ministry. Of this amount 63 percent occurred in the mid-country, in part because of land released for village expansion, diversification, and settlement.

Registered tea acreage in 1984 was 227,875 hectares but the Remote Sensing Survey, using aerial photographs during 1981-1984, estimated tea area at 201,630 hectares. Apparently because of this uncertainty official figures of national yield have ceased to be reported after 1980, even though tea is Sri Lanka's principal agricultural product and data on yield per hectare is a useful index of agricultural efficiency.

Yield data is nevertheless available for the two major state organisations, the JEDB and SLSPC, which together account for over 50 percent of the tea area and almost two-thirds of the country's production (Figure 6.6). Private sector yields have been estimated for comparative purposes, although four-fifths of the privately owned and managed tea estates are small holders (under 10 hectares). State sector yields have remained more or less stagnant, but smallholder yields have grown markedly, doubling within a period of eight years. While this is a remarkable achievement, private yield levels are still only 70 percent of the state sector.

In the private smallholder sector, the three lowest yielding districts are the midcountry -- Matale, Kegalle and Kandy. The three highest yielding districts are all in the low country (Matara, Kalutara and Galle) where average yields are higher than those of the state plantations (Figure 6.7). Tea growers in the low country have had the benefit of fertilizer on credit from TSHDA, private factories, higher prices, and higher proportions of clonal tea. Poor prices of mid-grown tea on the other hand, have led to a spiralling effect of neglect of lands, degradation, and poor yields.

Soil erosion. The most significant environmental cost of agricultural production is soil erosion, clearly evident for Sri Lanka's tea plantations. Tea is grown on red yellow podzolic soils (RYP), reddish brown latosolic soils (RBL), and immature brown loams (IBL) in the Wet Zone, of which most is the low-erodible soil RYP. However, because of the greater inherent erodibility and instability of IBL soils, which occur in the midcountry, tea lands on these soils are vulnerable to degradation. Even on low erodible soils, and despite low intensity rainfalls, tea in the mid-country and at high elevations grows on steep slopes. In the low country, where slopes are less steep, rainfall intensity is high. Thus all plantations are highly prone to erosion.

Soil erosion problems were recognised more than 60 years ago. The Administration Report of the Department of Agriculture for 1927 has a modern ring:

> The importance of soil conservation in the hill country is recognised by all and much has been accomplished in recent years. Much however, remains to be done and until every planter in the upcountry realises that this is his main agricultural problem the situation cannot be considered to be satisfactory. If soil erosion can be checked and general soil condition and tilth maintained, crop yields will be sustained without the aid of increasing quantities of artificial fertilizer and the incidence of pests and diseases will also be reduced.

Small Holding Sector Average Yields (1984)

Districts*	Average Yield (kg/ha)	Area (ha)
3 lowest yielding districts (Matale,Kegalle,Kandy	359	24,205
3 middle yielding districts (Nuwara Eliya, Badulla,Ratnapura)	661	23,406
3 highest yielding districts (Matara, Kalutara, Galle)	1,533	27,824

* Districts with over 500 ha

Source : Calculated data from Report of the Census of Tea Small Holdings in Sri Lanka 1984.

Figure 6.7

Little happened, however. Due to the importance of maintaining weed-free fields and the failure to adopt sound agronomic soil conservation measures, soil erosion continued.

Best available estimates suggest that as much as 30 centimeters of topsoil has been lost from upland areas over the last century since tea was introduced, equivalent to an average loss of 40 t/ha/yr. However, soil losses in well-managed tea estates have been reduced to as little as .3 t/ha/yr. Land under tea is most prone to erosion during planting and pruning when soil is exposed. With proper drains and the use of mulches and cover crops, soil erosion could be minimized (Figure 6.12). Weed management techniques are also very important, especially in land with low bush densities, and so is full coverage of the land by the crops. Annual infilling of vacancies in fields, one routine on estates, was neglected during the late 1960s and 1970s. The government introduced a scheme in 1978 to pay the cost of infilling.

Soil erosion and land degradation affect large areas of tea lands that are marginally productive and uneconomic, predominantly in the midcountry. These lands could be made economically productive again for mixed farming, including spice crops, if, as noted by the Land Commission, concerned agencies work together toward that end.

Fertilizer use. Artificial fertilizer is the single most important input in terms of at least short term productivity because tea responds especially well to nitrogen fertilizer. Tea receives the highest input of fertilizer of any crop in Sri Lanka with possible exceptions for upcountry vegetable cultivation and some other crops in the Mahaweli irrigation areas. Over the past two decades fertilizer consumption in terms of NPK nutrients increased from 118 kg/ha. in 1972 to 215 kg/ha in 1988, which is 79 percent higher than for paddy (Figure 6.5). Compliance with recommended use increased from 73 percent to 97 percent -- highest compliance rate for the three major plantation crops and paddy -- although cases of overfertilization still occur.

Yield in relation to other countries. The average yield of tea in Sri Lanka is low compared to other tea-producing countries. FAO statistics record in-

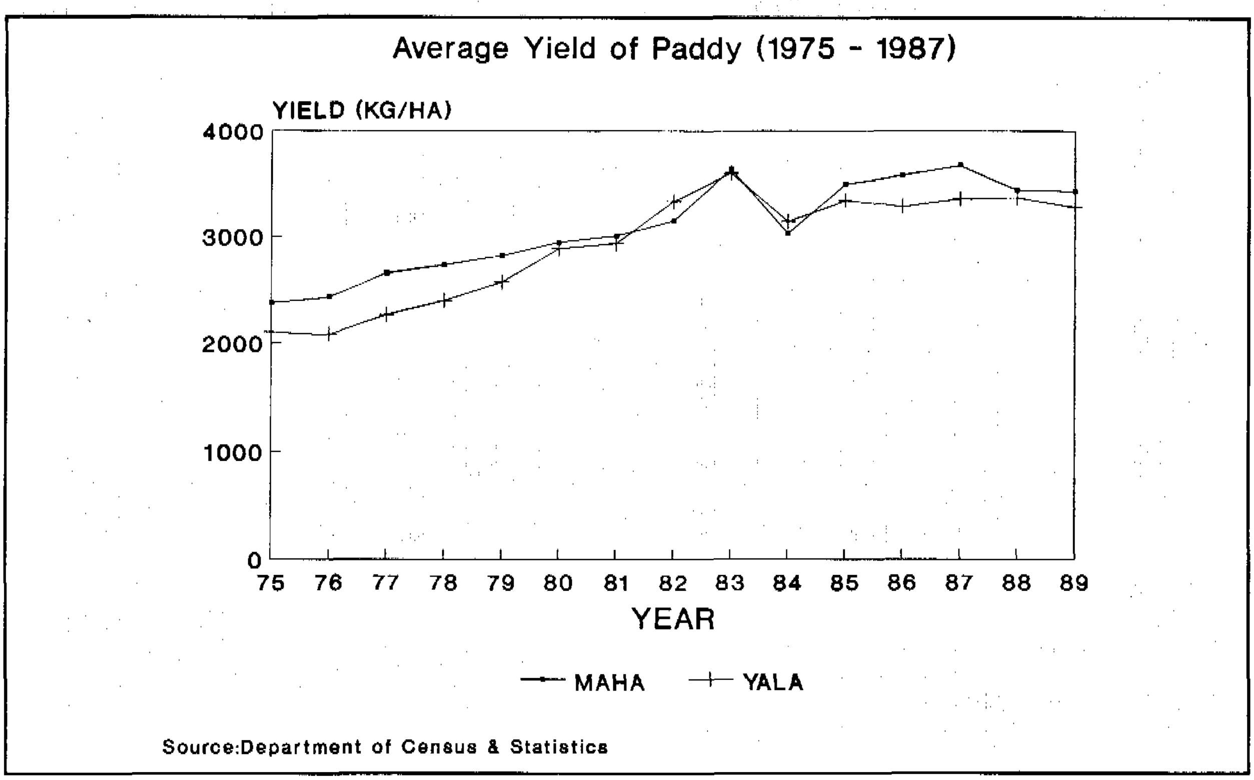


Figure 6.8

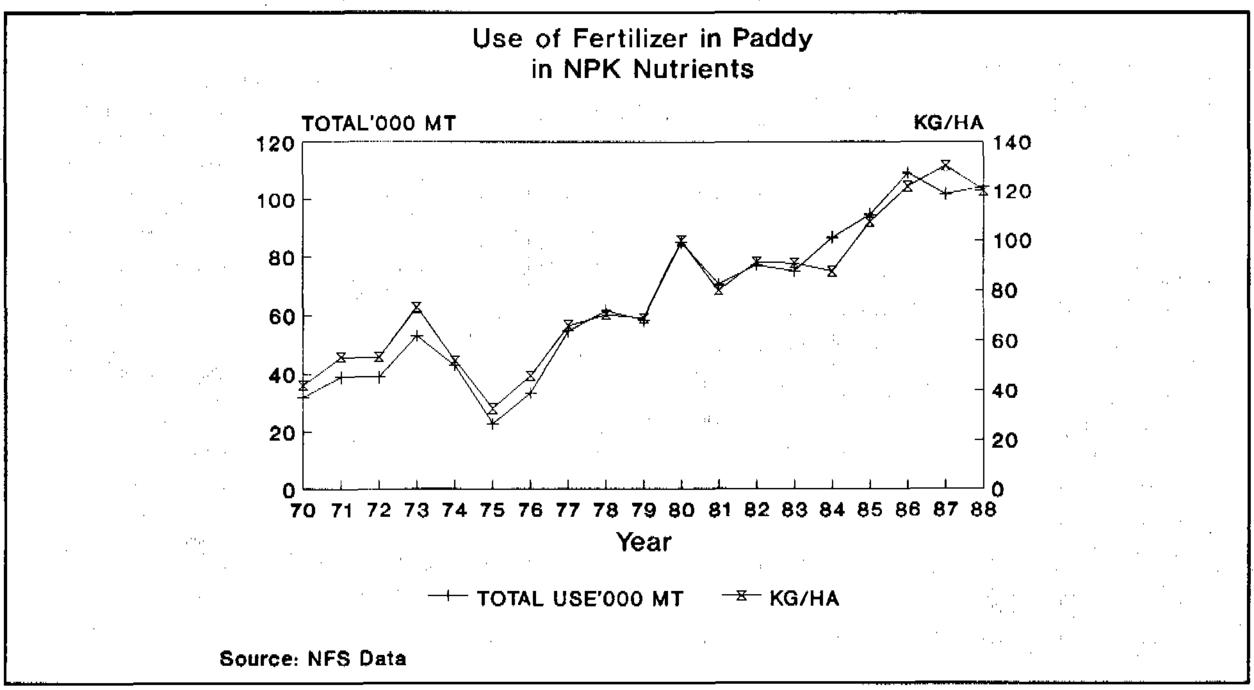


Figure 6.9

creasing yields for Sri Lanka from 1985 to 1988, but the yield in 1988 was only 52 to 64 percent of the yields of Indonesia, India, Malawi and Kenya. Of the countries reported, Sri Lanka only exceeded the yield of Bangladesh and Tanzania. The reasons for Sri Lanka's relatively poor performance:

- Many tea plantations are over 80 years old and beyond peak cropping potential;
- Low bush densities caused by neglected infilling;
- Slow rates of replanting with high yielding clonal material, well below the targets of 5,000 hectares per year;
- Low productivity of soils due to degradation.

These factors suggest a critical question: What level of investment can and should be put into rehabilitation of tea plantations to increase productivity over the long term?

Cultivation -- Focus on Paddy

In Sri Lanka, paddy is the dominant crop both in terms of land use and dietary importance. Efforts to achieve national self-sufficiency in rice have received high priority. In 1988 Sri Lanka's rice imports were only 10 percent of national requirements.

Production. Paddy output has grown remarkably in area and yield over the years. Large lands have been opened up for peasant colonization and settlements in the Dry Zone. From 1971 to 1982, increases in paddy area and yield per unit area contributed about equally to the increase in total production. During this period, particularly after 1976, paddy yields steadily increased, reaching a maximum in 1983. Between 1982 and 1986 changes in total paddy production largely resulted from increased yield, but after 1986 production increased mainly because more area was sown. Yields have also increased over the long term, but there appears to have been a levelling off since 1985 (see Figure 6.8).

A major factor contributing to increased yields is the breeding of improved varieties. The new improved varieties (HYVs) have a yield potential of 7 t/ha, compared to 4 t/ha for the old improved varieties. With the introduction of NIVs in the early 1970s they are now tending to replace older varieties.

Inputs. Use of fertilizers and adoption of better management practices such as weed control, pest and disease control have also increased yields. From 1965 to 1984 the area under weed control increased from 14 percent to 78 percent, and pest and disease control from 13 percent to 68 percent. Fertilizer use in paddy has increased threefold from 42 kg NPK nutrients per hectare in 1970 to 120 kg/ha in 1988, reaching a peak consumption of 130 kg/ha in 1987 (see Figure 6.9).

Agricultural development over the last 40 years has brought most available land and water resources into productive use. Given the limitations on increasing paddy lands, the only option for attaining and maintaining self-sufficiency is increased productivity, or the yield per hectare.

Cost and environmental factors constrain this option, also. Modernization of traditional practices of the farmer have invariably required costly inputs of tractors, fertilizers and pesticides. Since 1970 tractors have increasingly replaced buffaloes in paddy fields; an estimated 45 percent of Dry Zone paddy is cultivated by tractor. From 1977 to 1986 the cost of fertilizer and pesticides increased by 72 percent and 150 percent respectively. Imported inputs, according to data from the Hambantota district, amounted to approximately 50 percent of the total input cost in 1985.

Despite data problems, scientists have become concerned about long term productivity constraints associated with soils that have been farmed for many years with ever-increasing applications of chemical fertilizers. On one hand Sri Lanka clearly cannot return to the level of productivity of the ancient sustainable systems, estimated at only 1.5 t/ha (30 bushels/acre) at Independence. On the other hand input costs must be contained, and environmental externalities minimized. Increasing costs of tractor fuel, for example, may make it possible and desirable for more farmers to return to traditional reliance on buffaloes, assuming that availability of feed supplies make this economical. With improved data and analyses of long-term fertilizer and pesticide impacts on soils and sustainable productivity, changes in these inputs may be seen as economically necessary as well.

A potentially attractive move towards sustainability would be greater use of bio fertilizers (farmyard manure, green manures, compost) to substitute for chemical fertilizer. Research has shown that the use of rice straw at 3 t/ha could meet all requirements for potassium fertilizer and part of nitrogen requirements. The Department of Agriculture now recommends application of rice straw in all agroclimatic zones except the low country wet zone. Chemical fertilizer inputs can also be appreciably reduced when applied in combination with green manures such as Gliricidia, Tithonia, and Leucaena. The doubling of paddy fertilizer prices when fertilizer subsidies ceased in January 1990 is a strong incentive for greater use of biofertilizers by farmers.

Grass lands

Much of Sri Lanka's more than 500,000 hectares of grass and scrubland is used for livestock grazing. Only about 20,000 hectares of these lands, mainly in government farms, are under improved grasses with at least double the fodder yield of indigenous grasses. Yet only half the local requirement of milk is produced in Sri Lanka, the rest is imported. Cost of imported milk and milk products rose about eightfold from 1977 to 1986 (Gunasena, 1990 draft). Efforts to increase milk production from smaller areas can release grassland to other uses. Improved pasture can also be raised under coconut.

Forest Gardens

Forest gardens occupy almost a million hectares in rural areas and produce a variety of agricultural crops, timber, fruit, and fuelwood trees in multi-storey arrangements. The mix of crops varies according to climate, with the widest variety of crops in the Wet and Intermediate Zones. A fully developed home garden affords excellent conservation possibilities similar to that of a natural forest. However in most home gardens haphazard placement of trees and other crops denies these benefits; more careful, and more scientific arrangement of trees and management of canopies can increase production. (See box on forest gardens.)

ALLOCATION FOR SUITABILITY AND SUSTAINABILITY

Soils of Sri Lanka

Soil productivity remains a basic factor in determining good land condition and appropriate land use. It is essential to maintain the balance between forests (about one-quarter of Sri Lanka) and crop and livestock land (about one-third). Sri Lanka's soils are vulnerable to soil erosion, primarily from high intensity rainfall. Soil conservation is therefore a critical component of long term land management.

Soil is renewable in geologic, not generational terms. Although local data are not available, tropical research (Young, 1969) indicates a rate of soil formation of 46 milimeters in 1,000 years from consolidated metamorphic rocks, and in Sri Lanka erosion can remove up to 5 to 10 millimeters in one year. Thus soil lost in one year cannot be renewed or replaced within one human lifetime. Land and its soil may be reused, but not, for practical purposes, renewed. The economic costs of soils lost or degraded are therefore exceedingly difficult to measure.

General soil maps reveal the major soil groupings of the wide soil varieties present in Sri Lanka. Soil characteristics and capabilities vary as well, depending on climate and parent material. Some soils -- Immature Brown Loams, Non Calcic Brown and Reddish Brown Earths -- are highly erodible and need special soil conservation measures. But most stable soils like Red Yellow Podsolic and Reddish Brown Latosolic soils occur on steep slopes, so they too are prone to high erosion. The crops best suited to the various soils, and the management requirements, are presented in Figure 6.10. The 14 major soil groups are distributed among 4 topographic classes: (i) flat to undulating (0-8 percent slope); (ii) rolling to hilly (8-30 percent slope); (iii) hilly and mountainous (30-60 percent slope); and (iv) extremely steep (over 60 percent slope).

Suitability analysis

Wide variations and combinations of soils, climate and topography and susceptibility of lands to erosion, landslides, or loss of fertility, make evaluation of land capabilities for various uses exceedingly complex. The

Suited Crops And Specific Management Requirements Of The Major Soil Groups.

Soil Group	Suited Crops	Specific Management Requirement
Reddish Brown Earths	cereals,pulses,cassava,sugarcane, castor,onions chillies,cotton, tobacco,vegetables,fruit crops, pasture grasses,timber trees.	supplemental irrigation at 1-2 week intervals(furrow, drip, sprinkler); good drainage facilities (main drains 2 meter deep); timing of tillage to moist conditions; soil conservation measures; nutrient supplementation by organics or inorganics
Low Humic Gley	puddled rice, adapted pasture grasses	supplemental irrigation at weekly intervals (flooded basins); good drainage;nutrient supplementation
Non Calcic Brown	cereals pulses,cassava,sugarcane, castor,onions chillies,cotton, tobacco, vegetables, fruit crops, pasture grasses, timber trees.	supplemental irrigation at weekly intervals (furrow, drip, sprinkler); good drainage facilities (main drains 2 meter deep);timing of tillage to moist conditions; soil conservation measures; nutrient supplementation by organics or inorganics
Red Yellow Latosols	cereals, pulses, cassava, sugarcane, castor, onions, chillies, cotton, tobacco, vegetables, fruit crops, pasture grasses, timber trees, asparagus	supplemental irrigation at weekly intervals (furrow,drip,sprinkler); soil conservation measures; nutrient supplementation by organics or inorganics (small doses at frequent intervals).
Immature Brown Loams	conservation forestry for steep slopes; cereals, pulses, cassava, sugarcane, castor, onions, chillies, cotton, tobacco, vegetables, fruitcrops, pasture grasses, timber trees for gentler slopes	soil conservation most important; steep slopes to be undisturbed because of landslide hazard; nutrient supplementation; irrigation if available and possible
Solodised Solonetz	puddled rice after reclamation	reclamation by gypsum addition and flushing or repeated flushing by calcium rich irrigation water; supplemental irrigation at weekly interval (flooded basins); good drainage ; nutrient Supplementation, supplemental irrigation at weekly intervals (flooded basins); good drainage .
Grumusols	puddled rice	nutrient supplementation; soil conservation measures

Red Yellow Podsolic & Reddish Brown Latosolic Soils	tea, rubber, coconut, coffee, cocoa, cinnammon, pepper, mulberry, cloves, nutmeg, tobacco, vegetables, fruit crops, pasture grasses, forestry	
Alluvial soils		
a) Levee Soils	vegetables, cereals, pulses, tobacco, sugar cane, onions	supplemental irrigation at 1-2 week intervals (furrow,drip, sprinkler)good drainage facilities; nutrient supplementation by organics or inorganics
b)Back slope &	puddled rice, adapted pasture	supplemental irrigation at weekly intervals (flooded basins); good drainage; nutrient supplementation; flood control.
c)Back swamp soils		
Regosols	coconut,palmyrah,cashew	supplemental irrigation at weekly intervals (drip,sprinkler); soil conservation measures; nutrient supplementationby organics or inorganics (small doses at frequent intervals).
	medicinal products,mangrove	
Bog Soils	reeds for basket weaving, nipa palm for sugar & honey, sonneratia for fruit, cork & fuelwood, bacopa for vegetation for multiple use, rice if specifically adapted.	controlled drainage; flood controls; salinity control; flushing out of acidity; liming to correct acidity; nutrient supplementation including zinc and copper; prevention of subsidence and oxidation, conservation
Lithosols	conservation forestry	
Old Alluvial Soils	sugar cane, groundnuts, pasture, grasses, puddled rice	supplemental irrigation at weekly intervals (drip, sprinkler); soil conservation measures; nutrient supplementation by organics or inorganics (small doses at frequent intervals).

Figure 6.12

suitability of the lands for major land uses in Sri Lanka has been assessed using a generalized geographic information system. Data on soils, climate and topography have been analyzed to arrive at overall land suitability estimates for the entire country, regardless of present use. These data can be used only to obtain an overall notions of land suitability for national scale planning. They indicate, however, that thousands of hectares of agricultural lands are located on marginally suitable or unsuitable lands.

Land use allocation problems and needs

In Sri Lanka, as elsewhere, population and development pressures demand careful use of land management information and resolution of policy questions regarding land tenure.

Undeveloped lands. The Land Commission estimated that nearly two million hectares (4.9 M acres) of rainfed lands were available for agriculture, settlement, or other development in the Dry Zone. Most of this land is now under state forest or wildlife protection. Because of water constraints about one million hectares has been ranked low in agricultural potential. The Land Commission's report highlighted the important need to determine how this land should be allocated, to whom and under what conditions.

Wildlife habitat. With approximately 11.5 percent of the country allocated to National Parks or similar reserves, Sri Lanka devotes a higher proportion of its land to wildlife than any Asian country except Bhutan (World Resources Institute, 1986) -- three times the world average. Yetwildlife management faces significant problems of encroachment and still unprotected biological resources. Although the two largest wildlife parks, Yala and Wilpattu, are located within dry areas unsuited to agriculture, management problems arise from the presence of -- 2,000 families in Wasgomuwa and Uda Walawe. Meanwhile, development and demographic pressures in the biologically rich Wet Zone suggest serious needs for better wildlife protection there. (See biological diversity chapter.)

Forest lands. Allocation of forest lands presents similar questions. Forests constitute about 24 percent of the country, slightly above the Asian average (21 percent in 1965-1982), but these areas include "ecologically marginal" lands in the Dry and Intermediate Zones. Some of these forests are potentially suited to agriculture, whereas in the Wet Zone catchment areas natural forests may be desirable for long term protection of reservoirs, food and fiber for neighboring villages, and other forest uses, including protection of biological diversity.

Urban lands. Encroachment on state lands in urban areas usually occurs on lands least suitable for residential use, such as stream and canal banks and railroad embankments, but demands for affordable low-income housing are high. Efforts to protect water quality of urban lakes and streams, provide drainage, sewer connections, and the provision of clean drinking water from wells or piped supplies, require land management that accounts for encroachment problems and the housing and other needs that caused them. Areas considered open to development that might relieve encroachment problems are often low-lying lands subject to flooding. Options to anticipate and prevent worsening urban growth problems include relocation of industries to outlying areas, and planned low-rise housing developments with open-space.

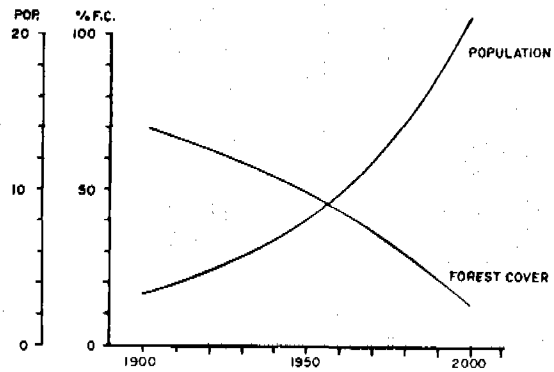
POLICIES AND INSTITUTIONAL RESPONSES

As with water resources, the laws and policies concerning land use are numerous and replete with problems of administration, coordination, and policy direction. Underlying Sri Lanka's land use and management practices, however, are policies, laws, and institutions affecting land tenure and the distribution of state land. These policies reflect concerns about how to allocate land fairly among competing interests -- the landless, land owners, business interests, religious interests, and interests of the community at large. Recognizing that the topic is large and all encompassing, a few key acts and policies are discussed below.

Land Ownership

State ownership has, on balance, remained steady since Independence at about 80 percent of Sri Lanka -- significantly higher than in most European or other Asian countries. Yet much land has changed into private ownership over the interim -- 1.3 million hectares under the Land Development Ordinance of 1935.

Trends in Human Population Growth and Forest Cover in Sri Lanka



Pop-Millions; FC Percent of Total Land Area

Source : Department of Census & Statistics; Nanayakkara (1982), Erdlen (1988)

About one-quarter of all Sri Lankans live on land alienated under that law, which reflected a policy favoring state land alienation. During the 1970s, however, with the Land Reform Acts, the state nationalized and acquired vast new acreage, mostly large tea plantations, but also, under new land ownership ceilings, many small parcels, even including 7,600 parcels (average size 1.2 hectares) in Colombo. Net state land ownership has increased about .4 million hectares (one million acres) since the nationalizations of the 1970s.

Complex law, custom, and policy, and various kinds of tenure restrictions resulting from disposition of state land, make it difficult to grapple with land tenure conditions and trends in Sri Lanka. Data is needed on the nature (restricted and unrestricted) and extent of land under private ownership by corporations (plantation, industrial, commercial), and individuals.

Major Land Tenure Laws

Land Development Ordinance. Following the recommendations of the First Land Commission of 1927 -- a commission of inquiry established to make findings and recommendations on specific land problems -- Land Development Ordinance No. 19 of 1935 (revised in 1946, 1955, 1961, 1969) sought "systematic development and alienation of Crown Lands in Ceylon." But the Act did not propose simple land sales to individuals. It provided for lands to be alienated first temporarily through a permit given upon payment of an annual rent. Once lands were developed the temporary permit could then be converted to a permanent grant. The single largest portion of the 830,832 hectares (2.05 million acres) of state land given to private ownership (nearly 1 million farmer families) since 1935 fell under this statute. This included the decision to make legal about half the encroachments identified in 1979, covering 205,762 hectares.

The Land Development Ordinance also provides for the Government Agent to "map out," carry out land use planning for, lands appropriate for village expansion, forestry, pasture, human settlements, prevention of soil erosion, buildings, or roads. Supplemented by provisions of the Crown Lands Ordinance No. 8 of 1947, it established procedures and responsibilities, under a permanent Land Commissioner, for administering, selling, and developing state lands.

Agrarian Services Act. The Agrarian Services Act 58 of 1979 (as an amendment to, and continuation of, the Paddy Lands Act No. 1 of 1958) sought to redress perceived land ownership inequities by giving more

FOREST GARDENS

As Sri Lanka's population increases and arable land becomes more scarce, young farmers from the hill country are moving up steep slopes into previously unsettled, marginally productive land, often belonging to the government. The phenomenon is fairly recent, with most settlers having arrived within the last decades. The farmers grow lucrative annual cash crops such as potatoes and tomatoes and rely on limited crop rotation or fallowing and heavy application of chemical fertilizers to maintain yields as topsoil erodes and fertility declines. These farming practices exacerbate soil erosion problems, reducing already marginal fertility in the highlands and increasing the silt load in dams for irrigation projects downstream. An alternative land use system for the deforested hills is needed to provide upland watershed protection and income for small farmers. One of the most promising options is forest gardens, planted to reforest the mountain *patana* grasslands while producing multiple crops for farmers.

Sri Lanka's forest gardens have been a dominant form of land use on the island for centuries. Similar agroforestry systems are known throughout the tropics. The gardens vary in structure and composition with climate and elevation. What little research has been undertaken on forest gardens in Sri Lanka has focused on those below 1,000 meters elevation -- the 'midcountry' Kandyan spice gardens (Jacob and Alles, 1987).

In the largely deforested Sri Lankan highlands - unlike traditional agroforestry systems in the forest or at the forest edge as in Indonesia and Mexico - forest gardens are begun on the degraded grassland hillsides. In much of the Uva Basin, the A horizon of the primarily red-yellow podzolic soil has eroded away. Yet, as villages expand, local farmers can create gardens of trees and shrubs on these very marginal sites in just a few years. As neighboring gardens blend together, a village, seen from above, appears as a forest island in a sea of grassland. The "village forest" provides vital refuge for native flora and fauna as the last remnants of natural forests in the highlands fall to illicit logging. As the gardens provide wildlife habitat, they may be appropriate models for nature reserve buffer zone areas, providing a gradual transition from reserve to agricultural land use.

In Mirahawatte, a slightly larger than average of 600 households, forest gardens account for nearly 50 percent of private land use. Located immediately around the owners' homes, the gardens are commonly one component of the larger farming system which may also include rice paddies, vegetable fields and/or plantation crops such as tea. Throughout the year they provide a wide variety of food, fuel, fodder, wood, medicinal and cash crops including coffee, bananas, avocados and palm sugar as well as a cool and pleasant living environment. Households gather 75-100 percent of their firewood from their gardens (the remainder supplied by prunings from nearby tea plantations). The gardens produce such a surplus of jak fruit, a basic carbohydrate component of the villagers' diet, that 75 percent of the fruit is left to rot on the trees. Individual timber and over-mature fruit trees are removed as wood is needed and various new seedlings are planted in their stead. The gardens are never clearcut and many predate living memory in the village.

On average the gardens are one-third hectare in size with over 250 individual woody perennials of 29 species (120 species of trees and shrubs were identified in the village). When compared with a typical agricultural field, the gardens' two-to three-tiered structure -- shrubs in the understory, medium sized fruit trees in a mid-level layer and large fruit and timber producing trees in the canopy -- increases the area for photosynthesis and thus production into vertical space. Structural characteristics of the gardens, including their high density and species diversity, are comparable to measures from natural forests in similar elevations and climates. Such characteristics may be used as indicators of vital functions of forest ecosystems, including nutrient cycling and watershed protection, suggesting that the gardens are partial analogs (Senanayake, 1987) of natural forest systems. The fundamental dynamics of the gardens, while guided by farmers' economic decision making, also follow processes of regeneration and vegetation change over time, like those of natural forests.

Farmers' knowledge of these processes of change makes it possible to modify the surrounding landscape with such agroforestry systems. If we can clearly grasp how the farmers use these forest garden systems, the principles can be applied to similar systems elsewhere. One area for further research is identification of more high value, sustained yield crops such as spices, fruits, medicines and ornamental plants and their markets from present garden species or from others which might be integrated into the existing systems and which for the small farmer on marginal land could compete in value with annual vegetable crops.

Prepared by Yvonne Everett, NeoSynthesis Research Centre, Mirahawatte, Sri Lanka from a paper presented at the American Association for the Advancement of Science (AAAS) meeting San Francisco, CA, January, 1989 - in press Warren, D.M., D. Brokensha and L.J Slikkerveer (eds), *Indigenous Knowledge Systems: The Cultural Dimension of Development.* Keegan Paul International.

secure tenure rights to tenant farmers in ways that would also increase productivity of agricultural lands. Sound management of agricultural activities was to be achieved through appointed Agrarian Services Committees and cultivation officers. The Act provided for various land use planning functions to ensure suitable crops or breeds of livestock.

The Act also required cultivation of only paddy during the paddy cultivation season on "paddy lands," interpreted as land presently or at any time previously cultivated with paddy. Hence, lands in irrigation projects that might be more suited to other crops that used less water or caused less waterlogging or salinity in soils must nevertheless be devoted to paddy. Similarly, poorly drained lands in coastal regions that were once unproductive paddy fields are, legally, required to stay in paddy.

Land Reform Act. The Land Reform Act of 1972 established limits on private ownership of agricultural land, stipulating a per capita ceiling of 10 hectares (25 acres) for paddy, and 20 hectares (50 acres) on other cropland such as tea, rubber, or coconut. Limits set for residences were .2 hectares (one half acre) for an owner, and .05 hectares (one eighth acre) for staff quarters per resident family. Amendments in 1975 included acquisition of the large tea estates. The result: state acquisition of 419,000 hectares (over 1 million acres), including the tea estates of 169,000 hectares (418,000 acres). The Act established a Land Reform Commission with power to acquire and dispose of property. Of the property acquired, only about 10 percent went to landless people, 4 percent of it tea land (Report of the Land Commission, 1990, p. 187).

Government Responsibilities

Management, disposition, and development of state land, and implementation of land use policies intended to foster small land owner prosperity, are highly fragmented. On one hand, custody of state land, traditionally with the Land Commissioner, has been given to a large number of private and public organizations, including ministries, departments and corporations. None has overall authority over land use decisions nor powers to enforce conservation measures. On the other hand, numerous agencies are involved in private sector land use activities, from agricultural technical assistance to the granting of permits for land development.

Land management complexity is indicated by the roughly three dozen agencies within seven or more ministries that directly manage land resources. Many other agencies affect land directly and indirectly through permits and other regulations. The following summarizes major governmental roles and responsibilities concerning state land management and private land use and development:

Urban land management and development, including disposition of state land, is carried out by the Urban Development Authority, the Sri Lanka Land Reclamation and Development Corporation, the National Housing Development Authority, the Ceylon Tourist Board, the Sri Lanka Port Authority, and the Sri Lanka Railways. Coordination of land development needs and proposals is difficult and often obscure.

The Ministry of Lands, Irrigation and Mahaweli Development is responsible for decisions on state lands not already allocated to other institutions. The Land Commissioners Department, Forest Department and Irrigation Department are Departments under this Ministry. New Divisions -- Water Resources Development, Forestry Resources Development, Forestry and Environment, Irrigation Management, and Land Use Policy and Planning -- have also been established. The jurisdiction of the new agencies, is often unclear and can conflict with the mandates of the older operating agencies.

The Ministry of Agricultural Development and Research is responsible for paddy, annual crops, sugar cane, horticulture, and export crop subsectors. Major organizations under the Ministry are the Department of Export Agriculture, Department of Agriculture, Department of Agrarian Services, and the Agricultural Development Authority. Overlapping responsibilities of several of these agencies, particularly among the latter three have caused confusion among local officials and residents.

The Ministry of Plantation Industries is responsible for plantation agriculture research, development and management. Major organizations involved in the Plantation Agriculture sector under this Ministry are the Janatha Estate Development Board, State Plantations Corporation, Sri Lanka Sugar Corporation, Sugar Cane Research Institute, National Institute of Plantation Management, Sri Lanka Cashew Corporation, Rubber Control Department, Rubber Research Institute and the Tea Research Institute. The Research Institutes do research and extension work on ways to improve crop productivity. Other agencies have regulatory or subsidy payment functions. The Tea Commissioners Department, for example, registers tea lands, factories, and regulates tea dealers, among other duties, and the Tea Small Holdings Development Authority issues permits for planting and rehabilitation, and gives funds for replanting and infilling. The Ministry of Coconut Industries, also within the Ministry of Plantation Industries, includes the Coconut Development Authority, Coconut Cultivation Board, Coconut Rehabilitation Board, and the Coconut Research Institute. The Coconut Research Institute carries out research and extension on conservation measures and production aspects. The Coconut Development Authority and Coconut Rehabilitation Board issue permits for planting, replanting, and rehabilitation of coconut plantations. It also grants subsidies to the private sector, part of which are set aside for soil conservation.

The Ministry of Policy Planning and Implementation controls development efforts in the districts financed by the Decentralized Budget and planned and executed by the District Development Secretariats. Integrated Rural Development Projects (IRDP) funded by bilateral donors and the World Bank in over a dozen districts are a major feature of the regional development effort. Projects include rainfed agriculture under small holdings, minor export crops, small-scale irrigation schemes, livestock enterprises, fuelwood and timber plantations.

The Ministry of Rural Industrial Development, recently took control of animal husbandry enterprises formerly directed by the Ministry of Agriculture. Primary departments are the Department of Animal Production and Health which carries out research, extension and veterinary services and the Livestock Development Board, which operates a number of livestock farms and promotes livestock development by individual farmers.

Findings of the Land Commission

The Report of the Land Commission (1990) evaluated the effect of these and other major land policies and the ways in which they have been implemented. Among its major findings that concern basic land resource policy:

- The long-standing authority of the Land Commissioner in administering and allocating state land has eroded by "increasing political interference in the selection of allottees for state lands. "(Land Commission Report). Once the sole custodian of state lands, the Land Commissioner has authority to issue directions to Government Agents or Land Officers, subject to general direction of Ministers in charge of the subject matter. Today management authority is diffused among a large number of state agencies.

- Devolution of land and land settlement matters to the Provinces under the 13th Amendment creates "an urgent need to develop a comprehensive land administration system" based on sound scientific policy guidance that can be administered by the provinces.

- Goals sought by the Land Reform Act have not generally been achieved. The Land Commission found that the Act did not result in significant land redistribution, increased employment, or boost total production, although by consolidating land ownership it did open new possibilities for more integrated planning and development.

The Land Commission conducted a survey of local level officials, based on a questionnaire, to determine their opinions regarding the present system of administration and management of state lands in their areas. The general response: it was not satisfactory. Among the reasons: lack of trained personnel, inability to control encroachments, and functional overlap among agencies. About 80 percent of those questioned recommended creation of a central coordinating authority for all land matters.

The Commission also found that no inventory of state land was maintained by local officials in charge of land, and virtually no land use planning was carried out before land was used or approved for a specific use. Despite reinstitution of the "mapping out" requirements in 1981, little information on scientific land capability and land use appeared to be applied to land development decisions.

Land degradation on steep slopes contributes significantly to costly earth slides.

PART II

LAND DEGRADATION

Land degradation denotes all natural or anthropogenic processes that diminish or impair land productivity. Natural processes include climatic changes and accelerated intensity of winds and waves. Among the anthropogenic factors, over-use of land and water, deforestation, excessive use of agro-chemicals, and careless disposal of wastes often degrade land. In Sri Lanka, man-induced land degradation is more significant than natural forces. It is manifested through high rates of soil erosion and siltation, landslides, floods, emerging problems of salinization, coastal erosion, and loss of productivity of agricultural lands.

Problems of land degradation in Sri Lanka have been evident throughout her history. *Chena* cultivation practised since prehistoric man undoubtedly contributed to deforestation and associated problems at least locally and temporarily. Abandonment of the ancient hydraulic civilization in the Dry Zone may have been caused, at least in part, by loss of soil fertility or the development of salinity in rice fields due to centuries of continuous use.

An early reference to land degradation during the colonial period concerned impact of Dutch canal construction on swampy rice fields and fresh water bodies along the western coast. Some claim that Muthurajawela, a flourishing paddy field during the time of kings, turned into a salt marsh as a result of such coastal development activities.

Significant land degradation began during the past 150 years, particularly after the advent of commercial plantation agriculture. In 1900, with a population of only 3.5 million, Sri Lanka had approximate forest cover of 70 percent. By 1953, when population reached 8.1 million, natural forest cover had diminished to approximately 44 percent, and when population doubled by the mid-1980s, the forest was cut by nearly half, to less than 25 percent. By that time the man/land ratio -- a rough measure of natural resource availability per capita relevant to an agricultural economy -- equalled one acre per person.

The well known inverse relationship between population growth and diminishing forest cover (see Figure 6.11) does not reveal the magnitude of the associated land degradation. Deforestation has caused the most significant impacts in the watershed areas of the hill country where forests are most needed. Estimated forest cover has declined to only 9 percent there.

Soil Erosion

Serious concerns about soil erosion in Sri Lanka have been expressed since 1873, when Sir J.D. Hooker stressed dangers of indiscriminate plantation agriculture. One result was the restriction on land cultivation above 1,525 meters. In 1931, a Committee on Soil Erosion documented the damage caused by plantation crops. The Soil Conservation Act of 1951, which followed devastating earthslips in the hill country, in particular in the Kotmale valley, has been largely neglected since. 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."

One critical measure of soil erosion and its impacts is sedimentation.In one of the earliest estimates of sediment transport, based on measured sediment yields, Joachim and Pandithasekera (1930), estimated 132,000-833,000 tons/year (giving a soil loss of 115 tons/hectare) for the upper Mahaweli catchment, 55 percent of which was under tea. The sediment yield of the Mahaweli Ganga was estimated recently by NEDECO (1984), in collaboration with the Irrigation Department. These studies indicated an average 15 million tons of sediment, calculated for the period 1952-1982, passed in the upper Mahaweli watershed through

Soil Losses from Cultivated Land

	tons/hectare/year
(a) Mid-country Wet Zone (Peradeniya)	
Soil type : Red Brown Latasol.	
Old seedling tea (no conservation)	40.00
Well managed tea (contour drains)	00.24
Kandyan mixed home gardens	00.05
(b) Up-country Wet Zone (Talawakelle)	
Soil type : Red Yellow Podsol	
Bare, Clean weeded clonal tea	52.60
One-year old clonal tea with much	00.07
(c) Mid-country Intermediate Zone (Hanguranketa)	
Soil type : Immature Brown Loam	
Tobacco (No conservation)	70.00
Capsicum (No conservation)	38.00
Carrots (No conservation)	18.00
(d) Low-country Dry Zone (Maha Illuppallama)	
Soil type : Reddish Brown Earths	
Sorghum/Pigeon Pea	21.30
Sorghum/Pigeon Pea (with mulch)	03.90
Cotton	22.20
Cotton with mulch	02.00
iii. Field estimates of soil under chena in mid-country	
Tobacco in 45 percent slope	200.00
Newly cleared chena plot on 45 percent slope at Panamure (Ratnapura District)	
Mean Annual rate of soil loss over a period of 40 years	100.0

Source : Stocking (1986)

Figure 6.12

the Peradeniya gauging station. The Polgolla barrage trapped about 70 percent of this load.

Almost 44 percent of the capacity of the Polgolla reservoir was silted by the end of 1988 (Perera, 1989), just 12 years after its commissioning. This same phenomenon is also reflected in the two-thirds reduction in sediment loads now passing below the reservoir through downstream gauging stations such as Weragantota.

Other estimates of soil loss due to erosion have been reported from different parts of the country. TAMS/USAID (1980) reports soils losses in the Maha Oya catchment (mid-country) in lands under tobacco on slopes ranging from 45 percent to 60 percent. Estimates range from 388 to 913 t/ha/year. Although generally considered overestimates, these demonstrate the dangers of cash crop cultivation on high slopes. Contrasts in soil loss from different locations have been estimated by the Soil Conservation Division of the Department of Agriculture (Stocking, 1986) based on small plots on slopes in the 20-40 percent range and for *chena*. Results are summarized in Figure 6.12.

PARTICULARS OF LANDSLIDES 1930 - 1985

YEAR	DISTRICT	LOCATION	MAJOR/MINOR	DEATHS	HOUSES DAMAGED
1930	Kegalle	Thalawela	Major	Not known	Not known
1947	Kegalle	Kadugannawa	Major	40	Not known
1947	Kegalle	Aranayake-Sela-wakanda	Minor	Not known	Not Known
1952	Nuwara Eliya	Udahewaheta	Minor	Not known	Not known
1957	Kegalle	Pahala Kadugannawa	Major	05	15
1964	Nuwara Eliya	Walapane	Minor	17 families affected	
1970	Nuwara Eliya	Walapane	Major	19	Not known
1973	Nuwara Eliya	Walapane	Major	13	Not known
1978	Kegalle	Bulath Kohupitiya Wegalla	Major	03	10
1979	Ratnapura	Kuruvita-Akurana Kanda	Major	05	10
1979	Kalutara	Bulathinhala	Minor	Not known	Not known
1981	Kegalle	Yatiyantota Polpetiya	Major	02	20
1981	Kegalle	Aranayake-Berawala	Major	Not known	30
1982	Kegalla	Mawanella-Heenalipana Kanda	Major	02	03
1982	Kandy	Pathahewaheta Paginiwela Kanda	Minor	Not known	Not known
1982	Ratnapura	Palmadulla Pathulpana Kanda	Major	08	15
1982	Matale	Pikakanda Pansalatenna Palindagama	Major	23	Not known
1983	Kegalle	Mawanella Elangapitiya Kolani	Minor	Not known	15

Figure 6.13

Particulars of Landslides 1930 - 1985 (Continued)

YEAR	DISTRICT	LOCATION	MAJOR/ MINOR	DEATHS	HOUSES DAMAGED
1984	Kalutara	Bulathsinhala Agalawatta Matugama	Major	42	Not known
1984	Badulla	Haliola-Beddegam	Minor	Not known	02
1984	Badulla	Bandarawela- Liyanagahawela	Minor	Notknown	21
1984	Ratnapura	Embilipitiya Ihala Anduliwewa	Minor	Notknown	21
1984	Ratnapura	Kolonnar Bulutota	Minor	02	05
1984	Ratnapura	Kuruwita, Ratnapura Eheliyagoda, Balangoda	(40 threats of Minor earth slips reported)		
1985	Nuwara Eliya	Norton Bridge	Minor	05	Not known
1985	Nuwara Eliya	Town Division	Major	Not known	40
1985	Kalutura	Matugama Uduwala	Minor	Not known	Not known
1985	Kegalle	Warakapola Thiyambarahena Kanda	Major	10	03
1985	Kandy	Galagedara Bodikulawa	Minor	Not known	Not known
1985	Kandy	Nawalapitiya Pemross Est.	Major	04	10
1985	Ratnapura	Elapatha Kohombakanda	Major	Not known	46

Source: Social Services Department

Figure 6.13

Several other estimates, mainly concerning soil erosion in the tea plantations, have been made by individual researchers (Manipura, 1972; Krishnarajah, 1985; Russell, 1980; and El-Swaify, et al., 1983). They seem to range from zero erosion rates in mulched and well-maintained clonal tea plots in the up-country to remarkably high losses of over 1000/t/ha/year in mid-country locations. Such extreme situations, while rare, demonstrate the importance of well-maintained ground cover in controlling soil losses, and how tea can be grown on steep slopes.

Soil loss occurs in all agro-ecological zones, although its intensity can vary according to the climate, slope, and ground cover. The worst affected area -- mid-country -- falls within elevations of 300-1000 meters. At higher elevations, although slopes are steep, rainfall intensities are relatively lower. In the low-country, where rainfall intensity can be high, slopes are less steep. Therefore, with Red Brown loamy soils erosion potential appears highest in the mid-country, where plantation agriculture began.

Erosion from house and road construction sites may be extremely high in localised watersheds near urban areas on steep slopes and at many civil engineering sites (Weil, 1981). Some examples are the Galata settlement near Gampola, and new road developments in the Victoria and Kotmale areas.

Landslides and Related Phenomena

Landslides and high soil erosion often occur in the same areas, but landslides cause more sudden and obviously damaging results. Landslides commonly occur following heavy rain storms, particularly in the hill country. Available evidence, though not quantitative or conclusive suggests that the frequency and magnitude of landslides has increased in recent years, causing serious damage to life and property (Jayawardhana, 1988).

Measures normally adopted for soil conservation will not usually prevent landslides. Some, like contour ditches, may even encourage landslides by allowing greater infiltration of water to the subsoil and lubrication of unstable soil masses.

Although records of past landslides maintained by the Social Services Department, are neither systematic nor comprehensive (Wijeratne, Banda, 1985), they are summarized in Figure 6.13. Records before 1970 appear sketchy, and many landslides have certainly gone unrecorded, like the Kotmale landslides of 1947. Small landslides that do not cause much significant damage to life and property are not recorded by the Geological Survey or the Social Services Department. In 1986, however, landslides in the Maturata area displaced over 1,500 families. The NBRO recorded some 136 landslides during that year, and the Remote Sensing Unit of the Survey Department detected many linear earthslips in 1986 through aerial surveys of affected areas. The landslides of 1986 left over 25,000 persons homeless, and many villages became totally inaccessible due to disrupted transport. The appearance of cracks in the walls of houses, observed along the perimeter of the Kotmale reservoir and at Maturata, indicated the potential for further slipping. Affected families had to be accommodated in special refugee camps and later to be relocated at great expense to the State.

In early June 1988, ironically on World Environment Day, Sri Lanka experienced perhaps its worst landslide damage, which caused over 300 deaths. In the Kegalle District 167 people died in the AGA Division of Galigamuwa alone (Madduma Bandara, 1989). From reports in Parliament some 225,000 people in ten districts were affected by floods and landslides that destroyed over 15,000 homes. Cost for rehabilitating these "environmental refugees" was estimated at about 120 million rupees at 1988 prices (Madduma Bandara, 1989).

Causes and Remedies. The devastating experience of landslides in the 1980s led to a search for reasons. In the public and academic debate that ensued the attributed reasons included cultivation of tobacco on steep slopes, impacts of the Accelerated Mahaweli project, high intensity rainstorms, geological instabilities, and aftereffects of the colonial land clearing in the hills (Vitanage, 1988; Priyasekera, 1986; Madduma Bandara, 1986; Dimantha, 1986; Dahanayake, 1986).

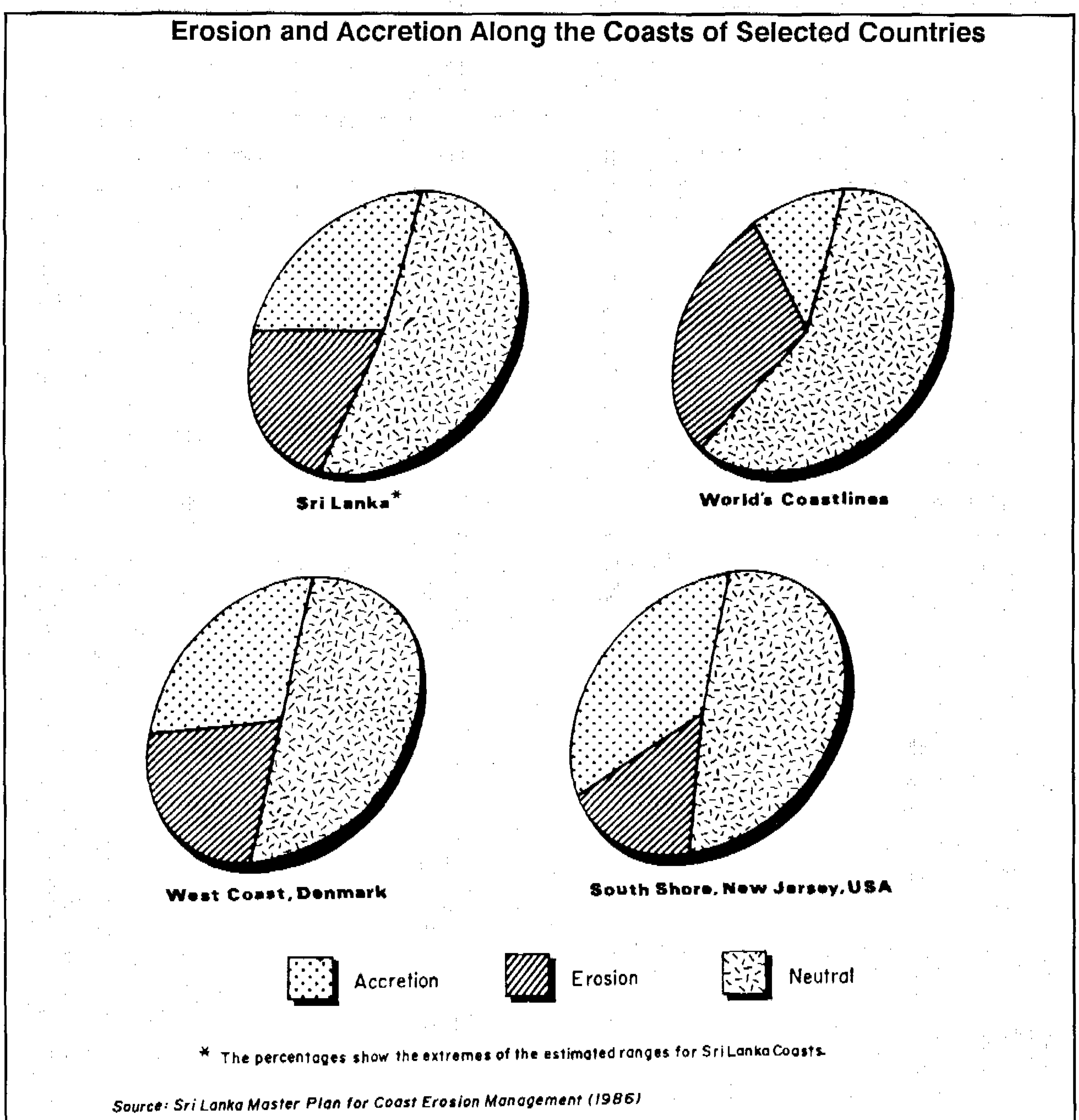
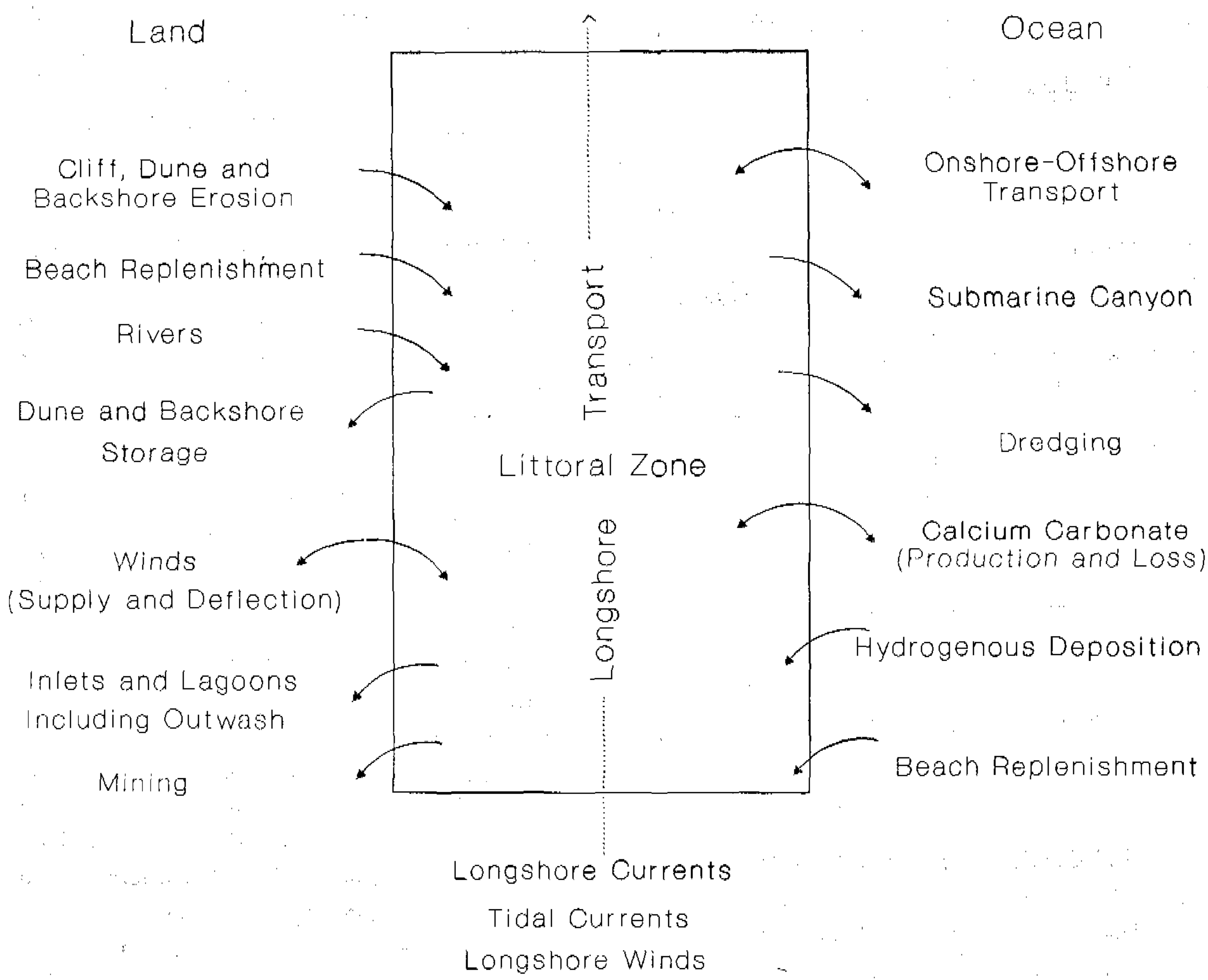


Figure 6.14

Conditions which favor landslides fall generally under two broad groups: First are the geological, structural, topographical and climatic factors of an area over which humans have little if any control; second are the conditions that humans impose on the land through destruction of watershed forests by fire or felling, obstruction of natural waterways and drainage lines, or construction of roads and buildings in vulnerable locations.

What "triggers" most landslides is saturation of the unstable subsoil layers and a build-up of water pressure 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 begin to appear when such rainstorms exceed a certain

Sources of Inputs and Losses to the Littoral Sand Budget
(Arrows Indicate Mean Net Transport of Sand)



Source : Shore Protection Manual (1973) Department of Army, U.S. Crops of Engineers

Figure 6.15

Although erosion has received public attention because of its impacts along the populous west and southwest coasts, comparatively little attention has focused on problems caused by accretion. These include obstruction of outlets affecting: escape of flood waters (the Kaluganga and Maha Oya), navigation (Negombo Lagoon, Chilaw Lagoon), migration of fish and shellfish species between an estuary or lagoon and the sea (Nandi Kadal, and Nayaru Lagoon in the Mullaittivu District), silting of harbors (Kirinda Harbour) and fishery habitats (Negombo Lagoon), outlets for urban and industrial pollutants (Lunawa Lagoon), and intake sites for seawater required for salterns. Seasonal accretion in Kandakuliya imposes restrictions on certain fishery activities, such as the Madel fishery.

Accretion is also caused by wind and aggravated by removal of dune vegetation. In certain areas close to Batticaloa and Potuvil, sand blown away during the dry season is deposited on paddy lands and coconut plantations.

Causes and Remedies. The major source of beach sand in Sri Lanka is sediment carried down by the rivers, but other sources include sediment from eroding coastal features and offshore sand brought onshore. Broken seashells and corals contribute to a very limited extent. Under the action of natural processes, such as waves, currents and winds, sediment moves on and off and along the beaches. If the sand supplied to a particular coastal sector is less than what is carried away, the shoreline will erode. Sources of inputs and losses on the littoral sand budget are illustrated in Figure 6.15.

Natural processes cause most shoreline erosion, but various human activities contribute. The most significant of these include sand mining from river beds and beaches, coral mining and destruction of reefs, removal of mangroves and other coastal vegetation, and improper location or construction of maritime structures, such as shoreline protection works, fishery harbors, or river outfall training schemes.

Of the human activities aggravating erosion, most widespread is sand mining in rivers, estuaries and beaches. Figure 6.16 indicates the removal of sand in the western and southwestern sectors in 1984. Demands for sand are high in and around areas where development pressure is high.

Coral mining, is not only a coastal or offshore problem. Although it has been restricted largely to certain parts of the southwest coast, has caused significant damage to the fringing reefs and is rendering the coasts more erosion prone. Figure 6.17 indicates the removal of coral along the southwestern coast in 1984. Coral mining was brought under control on the east coast in 1978, but with civil unrest in recent years it has reportedly become serious again.

Salinity and Waterlogging

Land degradation due to salinity and waterlogging is primarily associated with coastal areas and irrigated lands in the Dry Zone of Sri Lanka, which covers over half a million hectares.

Because irrigation has been practised in these areas since Sri Lanka's earliest history, salinity should have been a problem at least in patches of irrigated lands. The term 'kivula' or 'kivul bim' (or salinity affected lands) suggests that the problem did arise.

With development of modern irrigation networks, it was anticipated that salinity would become a problem over the years, as it has in many other countries with large irrigated areas. However, because Sri Lanka's Dry Zone is not as arid as most other areas of the world affected by salinity, salts that accumulate in top soils tend to flush out with the high intensity seasonal rains. Salts go deeper, as indicated by the increasing salinity levels in dug-wells in irrigated areas during the initial phase of the rainy season (Arumugam, 1970).

Unfortunately few systematic studies exist on land degradation from soil salinization in Sri Lanka; we have no records of the actual extent of lands affected by salinity or data that indicate its recent trends. Much of the available information comes from sporadic surveys. Thus Gangodawila (1990) compared soil salinity levels in the valley bottom lands of *purana* villages under minor irrigation with those in the 'H' irrigation system of the Mahaweli Project. These investigations were carried out in locations that the farmers themselves cited as being affected by waterlogging and salinity. Results of such studies undoubtedly indicate the gradual emergence of problems of salinity, particularly in areas of poor soil drainage like valley bottoms, and sites of old tank-beds converted to irrigated rice fields under the Mahaweli Project. However, it is difficult to predict the significance of long-range salinity from these data. The problem of soil salinity exists even in the *purana* villages, although not at the same scale as in the Mahaweli Project areas. There are serious drainage problems to be remedied in the Mahaweli systems.

Causes and Remedies. In contrast to salinity caused by irrigation, salinization of low-lying farming lands due to intrusion of sea water has always been a problem, stimulated by human intervention in Sri Lanka's coastal areas. Some development activities such as the construction of canals during the colonial period led to such problems (Brohier, 1935). At the same time a large extent of land was cultivated by providing pumping and drainage facilities in south-western coastal areas. These areas were neglected in recent decades due to high costs of fuel for pumps following the energy crises in the 1970s; it is no longer economical to grow paddy in once fertile lands. Paddy fields covering nearly 15,000 hectares in the Galle District are affected by salinity during high tides that extend their influence 10-15 kilometers into the interior in some places (Land Commission, 1989). Engineering structures built to contain saline intrusions have not been effective. In some cases, as at the Tangalu Welyaya fed by Kirama Oya in the Hambantota district (HIRDEP, 1989), they have made conditions worse.

Alternative land and water uses, including tourism and sustainable natural fisheries, can make these areas more productive. Over 70,000 hectares of low-lying marshy land around the island have been identified by the government for reclamation. Some areas located closer to urban areas are now being reclaimed by the Sri Lanka Reclamation and Development Corporation. Careful assessments of the hydrologic and environmental impacts of reclamation schemes will be necessary to help determine their costs and benefits.

EVALUATING IMPACTS AND PRIORITIES

Some causes of land degradation, such as intensified land use and over-exploitation of resources, appear destined to continue in spite of measures to control them. Policy makers need to identify the activities causing the most harmful long-term degradation and develop methods and incentives that can effectively reduce the impacts.

To establish priorities policy makers need adequate quantitative measurement of these significant land impacts that can help them compare the costs and benefits of remedial actions. Unfortunately, quantitative measures useful to policy makers are highly inadequate. There is hardly any information to quantify the precise impacts of soil erosion. Stocking (1986) made an attempt in this direction on the basis of field observations and anecdotal evidence. He believed that Wet Zone soils had a relatively high tolerance to erosion, and that the main limitations to land use were the eventual stoniness and limited rooting depth due to high rates of erosion.

A key question is how soil erosion reduces productivity from loss of fertilizers, organic matter, and available water capacity. Measurements have been difficult because effects are gradual and cumulative, and effects may vary with soil type and depth. The mid-country wet zone appears to suffer the greatest productivity impact, as reflected in the low productivity and even abandonment of some tea estates. Many Dry Zone soils display a concentrated nutrient distribution in the top soil and a critical water holding capacity. Any erosion of these soils can reduce the crop yields drastically, as is evident in areas where the *chena* cycle has become shorter over the years. More precise measurements of lost productivity throughout Sri Lanka, including production projections ten years hence, are needed, given continued erosion trends.

Sedimentation of tanks, irrigation works, and upcountry reservoirs directly result from soil loss in catchment areas. Experts have differed in judging the seriousness and costs of sedimentation. Although some consultant reports (TAMS/USAID, 1980) contend that the lifespan of new Mahaweli reservoirs will

Chena Cultivation With A Difference

Sri Lanka's Co-operative Reforestation, or Chena Reforestation, scheme is modelled on traditional *chena* cultivation. Similar to the Burmese *taungya* reforestation system it consists of leasing state land containing low quality or non-productive natural forest to local villagers for them to carry out the traditional slash and burn followed by cultivation of cash crops. It differs from the traditional *chena*, however, because lessees must also plant forest species as directed by the Forest Department; and cash crops are restricted to the intervening space. The Forest Department supplies nursery plants of the forest species.

Each lessee obtains up to two hectares and signs an agreement with the Divisional Forest officer to plant the forest species and tend them for three years, during which time he can raise several rotations of cash crops. If planting and maintenance attains the required standard, the lessee receives a modest reward by the Forest Department. After three years, the lessee leaves the area and the Department assumes full control over what by then is a young forest plantation. Because a lessee may obtain one area every year, he can, at any given time, be planting and maintaining three co-operative reforestation blocks.

This scheme gained popularity after the early 1960s and at its peak incorporated around 4,000 hectares per year. It operated only in the Dry Zone, and the forest species planted was teak. Nearly all of the teak plantations in the country (estimated at 40,000 hectares) were raised under this program.

Main advantages of the system:

- It attracted *chena* cultivators who would otherwise have practised traditional shifting cultivation and left behind weed-infested fallow land;
- Areas under co-operative reforestation can provide good harvests of vegetables and other food crops;
- Reforestation of low quality natural forests takes place at little cost to the government.

The program terminated in the late 1970s in the belief that the hundreds of thousands of hectares of deforested, derelict land in the Dry Zone required soil working, fertilization and other costly inputs that only the Forest Department could carry out using hired labor. Yet so far the results of this arrangement have not been promising.

The Forestry Master Plan recommends the resumption of the co-operative reforestation scheme. With the pressing need to expand the area under industrial wood species the Forest Department cannot ignore a scheme that produced singularly successful results in the past.

not be affected seriously during their first 50 years, such optimistic assessments have not considered continuing changes in upper watershed land use and catchment characteristics. Recent observations of high rates of siltation in the Polgolla reservoir emphasize this dynamic dimension to the problem. In the case of small tanks in the Dry Zone, a comparison of 1956 aerial photographs with those of 1982 brings out clearly the high rates of siltation resulting from the clearance of their catchments for agriculture and settlements. Experience elsewhere -- including substantial reductions in the lives of reservoirs in Pakistan, Colombia, and the Philippines -- indicates the high economic costs of unanticipated soil erosion and, correspondingly, the economic benefits of sound upper watershed management (Brown, Worldwatch, 1984).

Sri Lanka, like so many other countries, needs far better information on the economic and environmental relationship between soil erosion and land and water productivity.

Landslide impacts, being so obvious on the landscape, are most easily quantified. Figure 6.13 provides rough estimates of damage to life and property caused by landslides in the past. More comprehensive attempts to measure total costs of landslides -- including refugee relief, land rehabilitation, and lost productivity -- would reinforce the need to prevent or minimize landslide damage in the future through better land use practices.

INSTITUTIONAL RESPONSES

Allocation of Authority

Over 40 state institutions have functions or responsibilities pertaining to land management, allocation, and development that were identified by the Land Commission (1985). Analyses of their functions indicate the diffused jurisdiction and uncoordinated actions of individual organizations grappling with some aspect of land degradation.

Certain key institutions have significant shares of responsibility. The two key ministries dealing with land management are Agriculture and Lands. Nearly half of the 40 land-related institutions fall within these two ministries. The Ministries of Mahaweli Development and Plantation Industries play an important role in controlling land degradation and the newly created Ministry of Environment will also have a primary role in the future.

Despite the large number of institutions dealing with land management, when a landslide or flood occurs, no single institution takes primary responsibility to respond, or at least to coordinate the work of others. The aftermath of the 1986 and 1988 landslides and floods illustrates an interesting pattern of institutional responses. Initial reaction came from the Government Agents of the Districts and the Social Services Department, which rushed humanitarian assistance to the victims. Then many other institutions, including that of the Prime Ministers office, became involved: the Central Environmental Authority, the Geological Survey and the NBRO among them. Committees formed to investigate the problems and reports were prepared and presented (CEA, 1986; IFS, 1986).

Long-term Planning

By planning ahead these responses can be designed for greater efficiency. There are many instances where the victims of landslides and floods were accommodated in congested refugee camps for several months or years without effective action. Medium- or long-term planning is essential to mitigate adverse impacts. A single organization or an emergency management agency can be designated and equipped to handle all facets of such an exercise.

But further action, designed to anticipate and prevent or mitigate future events, will also be needed. As in so many other countries, when the floods recede and fair weather returns, enthusiasm tends gradually to fizzle out, and unpleasant events of the past are soon forgotten. Yet we know from Sri Lanka's history that natural disaster will strike again.

The rapid, often devastating landslides and floods should be viewed as symptoms of a wider, more insidious problem of land degradation. Unfortunately, despite high levels of public awareness, soil erosion and siltation receive much less effective institutional attention than they require, for several reasons.

Providing Resources

Institutions entrusted with soil conservation lack personal and financial resources. The history of the implementation of the Soil Conservation Act as recounted by the Land Commission (1985) and the "rise and fall" of the Soil Conservation Division of the Department of Agriculture provides an interesting case of institutional responses to the problems of land degradation. The Soil Conservation Division, resembling the same institution in the United States, remained vibrant until the 1960s, had a precarious existence in the 1970s and early 1980s, and finally ceased to exist after 1989. Serious soil conservation efforts are conducted by a few institutions such as Integrated Rural Development Projects, NADSA, the Ceylon Tobacco Company, and some plantation corporations.

An underlying problem has been an inability to gain voluntary participation of the affected farmers in soil conservation as a matter of enlightened self-interest. Subsistence farmers have immediate concerns and cannot be expected to initiate costly conservation measures. Government funds and technical assistance will be essential. Others, however, can be made more aware of the benefits of mulching, ground cover, and other measures to maintain productivity and control costs of fertilizer, pesticides, and labor. Good information, patience, and adequate budgets are essential.

Inter-agency Coordination

No less essential to soil conservation is coordination among existing agencies with overlapping mandates. Limited budgets and available expertise require effective agency management. One course is to strengthen Sri Lanka's many existing institutions concerned with soil conservation and coordinate their responsibilities. Considering this ineffective, the Land Commission (1985) recommended an overall rationalization of their functions and a powerful national-level authority for watershed management. Its proposal for a Watershed Management Authority was based on the premise that major restructuring or even liquidation of some existing institutions was necessary as well. Otherwise another institution with overlapping functions, would be pointless, ineffective, and costly (Stocking, 1986). Five years after the Land Commission's recommendations for reforming watershed management in 1985, nothing substantial has happened.

The same observations cannot be levelled against the institutions dealing with the problem of coastal lands. The Coast Conservation Department (CCD), has made some concerted efforts to plan and implement a variety of conservation measures. It has recognized that in many areas, erosion is a seasonal occurrence and becomes a problem only if the beach-fronted land is highly populated or contains heavy investment in terms of railways, highways, or buildings. It has also recognized the fact that the erosion is caused by natural processes which man can rarely control but can mitigate by avoiding costly human actions and planning wise ones. It has therefore gone beyond traditional shoreline protection programs to active planning for and management of development within the narrow coastal zone established under the Coast Conservation Act of 1981.

Much can be learned from Sri Lanka's coastal experience in designing workable approaches to inland problems. One option for control of land degradation in the inland areas and the hill country is a systematic development of watershed land use programs based on critical land use information. Gathering and use of information should include high hazard areas, erosion-prone slopes and soils, catchment characteristics, agricultural practices, land lot size and tenure rights, wood lots and forest characteristics, and suitability for small hydro or other developments. Public participation in the gathering and application of this information will be equally critical, because those with a stake in the planned outcome are more apt to support it. Similar plans for larger areas can be developed in conjunction with watershed plans. Ultimately, national level support will be necessary for watershed and larger land use plans. National support can be backed by government agency use of impact assessment mechanisms to evaluate the impacts of proposed development projects on local and regional land use plans.

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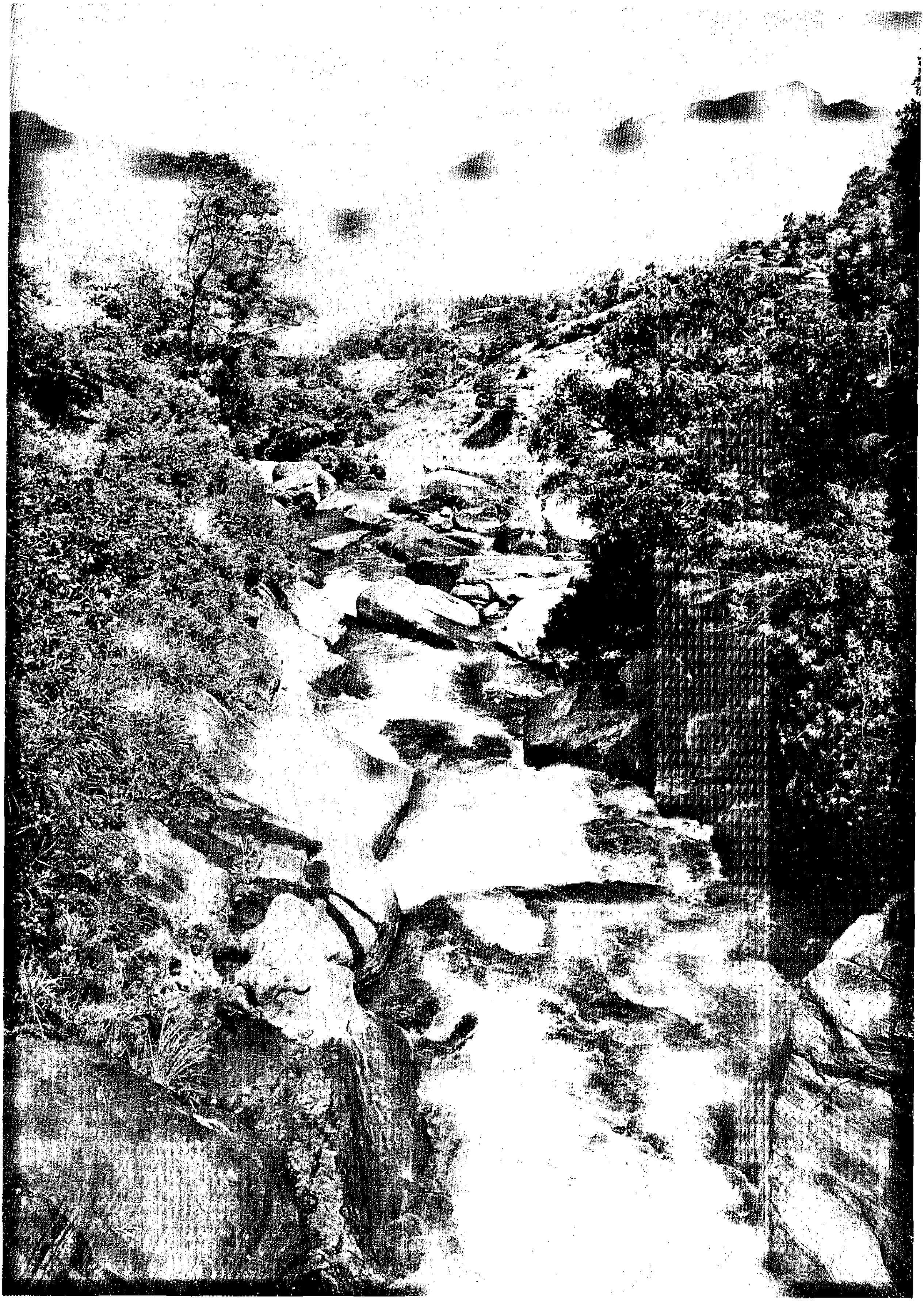


Sri Lanka's central hills that rise over 2,000 meters intercept moisture-laden monsoon winds and supply water to her major rivers and reservoirs.

7 Water Resources

Historians studying the rise and fall of Sri Lanka's ancient hydraulic civilization have marvelled at its engineering technology and water resource management systems. Arnold Toynbee noted that ancient Sri Lanka "once achieved the *tour de force* of compelling monsoon smitten highlands to give water and life and wealth to the plains that nature had condemned to lie parched and desolate."

Sri Lanka has relied on water resources during the last half century to produce staple food and energy, capped by the Mahaweli Development Project -- the largest development project in Sri Lanka's history at 38.26 billion rupees by the end of 1986. The medium-term investment plan (1986-1990) envisaged capital outlays of 27,626 million rupees (or about 20 percent of the total) on irrigation, power and water supply, equalling nearly 30 percent of the Government budgetary allocations for ongoing projects.

Sri Lanka suffers almost annually from droughts and floods. These and occasional cyclones and landslides are problems directly related to water resources. Total costs of these phenomena -- economic and environmental -- are high, but they can only be roughly extrapolated from disaster assistance expenditures. (See Figure 7.1) In recent years the contamination of Sri Lanka's waters has added new and still rising economic and environmental costs, which have not even roughly been calculated.

Part I of this chapter summarizes available information on the nature and extent of Sri Lanka's water resources, their present conditions, use, and trends, and current development policies and institutional responses. Part II describes the problems of water pollution in Sri Lanka, and what we have learned and need to know about its present impact and trends.

Average Annual Expenditure on Climatic Disaster Assistance, Sri Lanka, 1959 - 84

Period	Droughts (Rs. million)	Floods (Rs.million)
1950-59	01.91	0.73
1960-69	01.09	0.38
1970-79	00.03	0.04
1980-85	88.60	6.35

Source : Department of Social Services

Figure 7.1

PART I

WATER RESOURCES AND USE

GEOGRAPHICAL AND GEOLOGICAL BACKGROUND

Sri Lanka's location between 6 and 10 degrees North of the Equator, and close to the Indian subcontinent, gives it a predominantly monsoonal and tropical climate. As an island in the northern half of the Indian Ocean, Sri Lanka is exposed to moisture-laden winds from the southwest and the northeast.

Sri Lanka's highland massif in the south central part of the island, standing across the passage of monsoonal winds is undoubtedly the overriding geographical determinant of water resources. It creates high rainfall in the southwest and relatively dry regions in the east and north that cover over two-thirds of the country. The central hills that rise above 2,000 meters intercept the moisture-laden monsoonal winds, particularly on

River Basins

Basin No	Name of Basin	Catchment Area Sq. Km.	Basin No.	Name of Basin	Catchment Area Sq. Km
1.	Kelani Ganga	2278	53.	Miyangolla Ela	225
2.	Bolgoda Lake	374	54.	Maduru Oya	1541
3.	Kaluganga	2688	55.	Pulliyanpotha Aru	52
4.	Bentota Ganga	6622	56.	Kirimechi Odai	77
5.	Madu Ganga	59	57.	Bodigoda Aru	164
6.	Madampe Lake	90	58.	Mandan Aru	13
7.	Telwatte Ganga	51	59.	Makarachchi Aru	37
8.	Ratgama Lake	10	60.	Mahaweli Ganga	10327
9.	Gin Ganga	922	61.	Kantalai Basin Per Ara	445
10.	Koggala Lake	64	62.	Panna Oya	69
11.	Polwatta Ganga	233	63.	Palampotta Aru	143
12.	Nilwala Ganga	960	64.	Pankulam Ara	382
13.	Sinimodara Oya	38	65.	Kanchikamban Aru	205
14.	Kirama Oya	223	66.	Palakutti Aru	20
15.	Rekawa Oya	755	67.	Yan Oya	1520
16.	Uruhokke Oya	348	68.	Mee Oya	90
17.	Kachigala Ara	220	69.	Ma Oya	1024
18.	Walawe Ganga	2442	70.	Churian Aru	74
19.	Karagan Oya	58	71.	Chavar Aru	31
20.	Malala Oya	399	72.	Palladi Aru	61
21.	Embilikala Oya	59	73.	Nay Ara	187
22.	Kirindi Oya	1165	74.	Kodalikallu Aru	74
23.	Bambawe Ara	79	75.	Per Ara	374
24.	Mahasilawa Oya	13	76.	Pali Aru	84
25.	Butawa Oya	38	77.	Muruthapilly Aru	41
26.	Menik Ganga	1272	78.	Thoravil Aru	90
27.	Katupila Aru	86	79.	Piramenthal Aru	82
28.	Kuranda Ara	131	80.	Nethali Aru	120
29.	Namadagas Ara	46	81.	Kanakarayan Aru	986
30.	Karambe Ara	46	82.	Kalawalappu Aru	56
31.	Kumbukkan Oya	1218	83.	Akkarayan Aru	192
32.	Bagura Oya	92	84.	Mendekal Aru	297
33.	Girikula Oya	15	85.	Pallarayan Kadu	159
34.	Helawa Ara	51	86.	Pali Aru	451
35.	Wila Ara	484	87.	Chappi Aru	66
36.	Heda Oya	604	88.	Parangi Aru	832
37.	Karanda Oya	422	89.	Nay Aru	560
38.	Simena Ara	51	90.	Malvatu Oya	3246
39.	Tandiadi Aru	22	91.	Kal Ara	210
40.	Kangikadichi Ara	56	92.	Moderagam Ara	932
41.	Rufus Kulam	35	93.	Kala Oya	2772
42.	Pannel Oya	184	94.	Moongil Aru	44
43.	Ambalam Oya	115	95.	Mi Oya	1516
44.	Gal Oya	1792	96.	Madurankuli Aru	62
45.	Andella Oya	522	97.	Kalagamuwa Oya	151
46.	Thumpankeni Tank	9	98.	Pantampola Oya	215
47.	Namakada Aru	12	99.	Deduru Oya	2616
48.	Mandipattu Aru	100	100.	Karambala Oya	589
49.	Pattanthe Dephue Aru	100	101.	Ratmal Oya	215
50.	Magalawatavan Aru	346	102.	Maha Oya	1510
51.	Vett Aru	26	103.	Attanagalu Oya	727
52.	Mundeni Aru	1280			

Source :Hydrology Division, Irrigation Department,Colombo.

Figure 7.3

the steeper western flanks, causing rainfall patterns as shown in Figure 7.2.

The radial drainage pattern that carries surface water down from the high watersheds includes 103 distinct natural river basins that cover over 90 percent of the island (Figure 7.3); the remaining 94 small coastal basins contribute little to water resources (Arumugam, 1969). River basins originating in the wetter parts of the hill country are perennial, while many of those in the Dry Zone are only seasonal. Only a few river basins, such as the Mahaweli Ganga that drains 16 percent of Sri Lanka, carry water from the Wet to the Dry Zone.

Geological formations that largely determine Sri Lanka's aquifer characteristics can be grouped into four categories:

- Ancient crystalline hard rocks spread over 90 percent of the land. These Pre-Cambrian rocks have poor primary porosities and their groundwater is often found in their joints, fissures and cracks (Basnayake, 1981).
- Sedimentary formations, that characterize most remaining areas, which include Miocene limestone areas of the north and northwest;
- Surface alluvium, consisting of clays, sands and gravels in the riverine and coastal areas; and
- Weathered over-burden in hard-rock areas, which includes products of in *situ* weathering, such as soil and gravelly material that form localized aquifers.

Rates of ground water recharge from rainfall vary from one geological formation to another. In general it ranges from 10 percent to 30 percent in many areas of the Dry Zone (de Mel & Sumanasekara, 1973; Dharmasiri et al., 1985). At least 10 percent of the irrigation flow which seeps down may be available for recycling (Fernando, 1973, 1974; Madduma Bandara, 1980).

PRECIPITATION AND WATER AVAILABILITY

Rainfall supplies nearly all surface and ground water, supplemented by mist, fog and dew in certain areas. At higher elevations cloud-water also contributes to the surface water flow.

The mean annual rainfall of Sri Lanka is around 2,000 mm (Arulananthan, 1985) which, distributed over the surface area of 65,610 square kilometers, gives an average volume of 131,230 million cubic meters (m^3) of fresh water. What does not soon evaporate into the air runs off the surface or percolates into the soil to reach the sea as riverflow. Average annual riverflow, at 31 percent of the rainfall, equals 40,680 million m^3 (Bocks, 1959). The balance, 90,550 million m^3 is used and transpired by crops and natural vegetation or evaporates from the soil directly to the air.

This simple approximation introduces the considerable variations in time and space that affect Sri Lanka's surface water balance.

Average Rainfall

Average annual rainfall varies spatially from 1,000 mm to over 5,500 mm. Maximum rainfall occurs on windward slopes of the central highlands. A large area of high rainfall on the southwestern flanks (Figure 7.2) is influenced by the strong southwest monsoon (May-September) with a small area influenced by the north-east monsoon (November-March). These major river supplies are supplemented by the more widespread Inter-Monsoonal rains, (April-May and September-October). Tropical depressions and cyclones of high inter-annual variability also influence the rainfall during October-November.

Mean annual rainfall declines rapidly toward the northwest and southeast, yielding minimal average rainfall along these coasts. The same complex topography of the central hill country that attracts heavy rainfall on windward slopes produces "rain shadows" on the leeward flanks, such as the Dumbara valley and the Uva basin.

Wet and Dry Zones

Rainfall divides Sri Lanka into Wet and Dry Zones and an Intermediate Zone between the two. (Figure 7.2). The Wet Zone of the southwest and central hill country averages 2,500 mm of rainfall, mostly throughout the year, while the remaining two-thirds of the country in the north, east and southeast stays comparatively dry, averaging 1,500 mm, mostly the 'Maha' season (October-January). It remains dry during the five months of the 'Yala' season (May-September).

The southwestern flanks of the central hill country form the critical upper catchments of Sri Lanka's largest rivers. Over 65 percent of Wet Zone catchment rainfall is discharged into rivers, with Kalu Ganga showing maximum discharge of 77 percent. Rivers rising in the drier eastern half of the hill country have runoff/rainfall ratios of 20-40 percent.

Evapo-transpiration

Data on evapotranspiration are limited, being more difficult to determine than rainfall and riverflow. Best estimates in the Wet Zone indicate annual evapotranspiration of approximately 1,500 mm, with an upper limit at about 1,700 mm (Kayane, 1982). In the highest montane areas of central Sri Lanka, with greater cloudiness and lower solar energy, it declines to 1,000 mm.

In the Dry Zone, evapotranspiration attains similar rates to the Wet Zone during the *Maha* (October-January) season and lower rates during the dry *Yala* (May-September) season. But rates vary more than in the Wet Zone, the annual value being 1,000-1,400 mm. Evaporation values from Dry Zone tanks can reach 2,100 mm/yr., higher even than maximum Wet Zone values because the comparatively small water bodies are set in a dry climate.

Inter-annual variability

Elements of Sri Lanka's surface water balance are subject to substantial annual variability so that consideration of averages can be misleading. Variations are about 10 percent annually in the Wet Zone, 15 percent in the Dry Zone, and up to 20 percent on the east coast. *Maha* season rainfall is far more variable than *Yala* rainfall, due to the weaker Northeast Monsoon and irregularity of tropical depressions and cyclones during the *Maha* season. Maximum rainfall variability along the east coast results from landfalls of occasional tropical cyclones.Rainfall variations affect runoff and evapotranspiration, as illustrated by rainfall and discharge records of a Dry Zone basin between 1915-1961 (see Figure 7.4). Discharge is nearly absent in the dry years of 1934, 1946, 1951, 1955 and 1958. Inter-annual variability of the catchment is high and so the discharge varies even more.

Extremes: Floods and droughts

Floods and droughts constitute the extreme weather forms that disrupt Sri Lanka's economic and social life. During the last century two drought years, 1950 and 1974, and three flood years, 1891, 1957 and 1963, affected 50 percent or more of the country (see Figure 7.5).

Serious floods recur particularly in the Kelani, Kalu, and Mahaweli river basins, and occasional floods occur in many other major rivers. When intense rainfall from cyclones combines with normal monsoons, floods can devastate lowlands even in the Dry Zone, as occurred in 1957 in the Yan Oya basin. Data on major floods are provided in Figure 7.6.

Rainfall Probability

Rainfall variations are themselves unpredictable so agricultural planning has relied on simple probability levels. Annual surface water regimes of 25 agro-ecological regions of Sri Lanka, defined by a 75 percent probability of monthly rainfall, give expected surface water levels in three years out of four. This analysis has been particularly useful for planning paddy production.

Surface Water

Water that remains from rainfall after evapotranspiration and infiltration losses may generally be considered available surface water. Amounts are measured in terms of water discharged by the rivers, in cubic meters per year (m^3/yr) or as units of water depth distributed over the land surface as hectare meters (HM) or acre feet (AF). Information on surface water available for the whole island is given in Figure 7.7.

Although surface water estimates vary significantly -- 4.04 million HM annual runoff (IBRD Mission, 1952), 4.32 million HM (Walker, 1962), and 5.13 million HM (Bocks, 1959; Arumugam, 1969; Ranatunge, 1985) -- Sri Lanka's total annual runoff appears to be roughly 5.0 million HM. Much of this now serves irrigation and hydropower projects, and less than 3.3 million HM escapes to the sea. Over 60 percent of the water that

Secular Changes of Annual Rainfall and Annual Discharge for Kalawewa Catchment

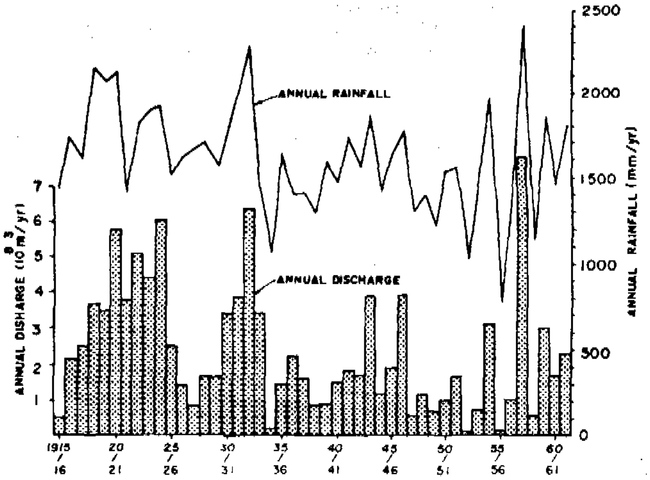


Figure 7.4

Climatic Extremes, Sri Lanka, 1971-1980

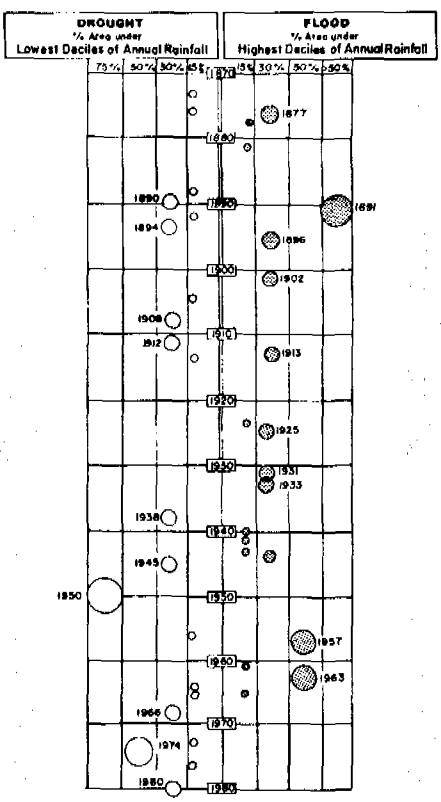


Figure 7.5

Maximum Recorded Floods in Sri Lanka

River	Station	Water Year	Peak Discharge (CU.m)
Kalu Ganga	Putupaula	1946/47	2547
Kelani Ganga	Glencourse	1966/67	3794
Kirindi Oya	Lunugamvehera	1966/67	1354
Maha Oya	Badalgama	1970/71	1982
Mahaweli Ganga	Randenigala	1955/56	1642
Malvatu Oya	Kappachchi	1948/49	2733
Menik Ganga	Kataragama	1957/58	1365
Nilwala Ganga	Bopagoda	1943/44	1692
Kuda Oya	Kuda Oya	1978/79	1852
Yan Oya	Pangurugaswewa	1957/58	6031

Source: Navaratne, 1985

Figure 7.6

Surface Water Resources of Sri Lanka

	Wet Zone	Dry Zone	Island Total
Mean Annual Rainfall (mm)	2424	1450	1937
Mean Annual Runoff (Hectare Meters)	2.58×10^6	2.55×10^6	5.13×10^6
Runoff rainfall ratio (%)	65.1%	35.8%	40.5%
Escape to the sea (Hectare Meters)	2.04×10^6	1.30×10^6	3.33×10^6
Escape as a % total runoff (%)	78.83 %	51.11%	64.91%

Source : Ranatunga, 1985

Figure 7.7

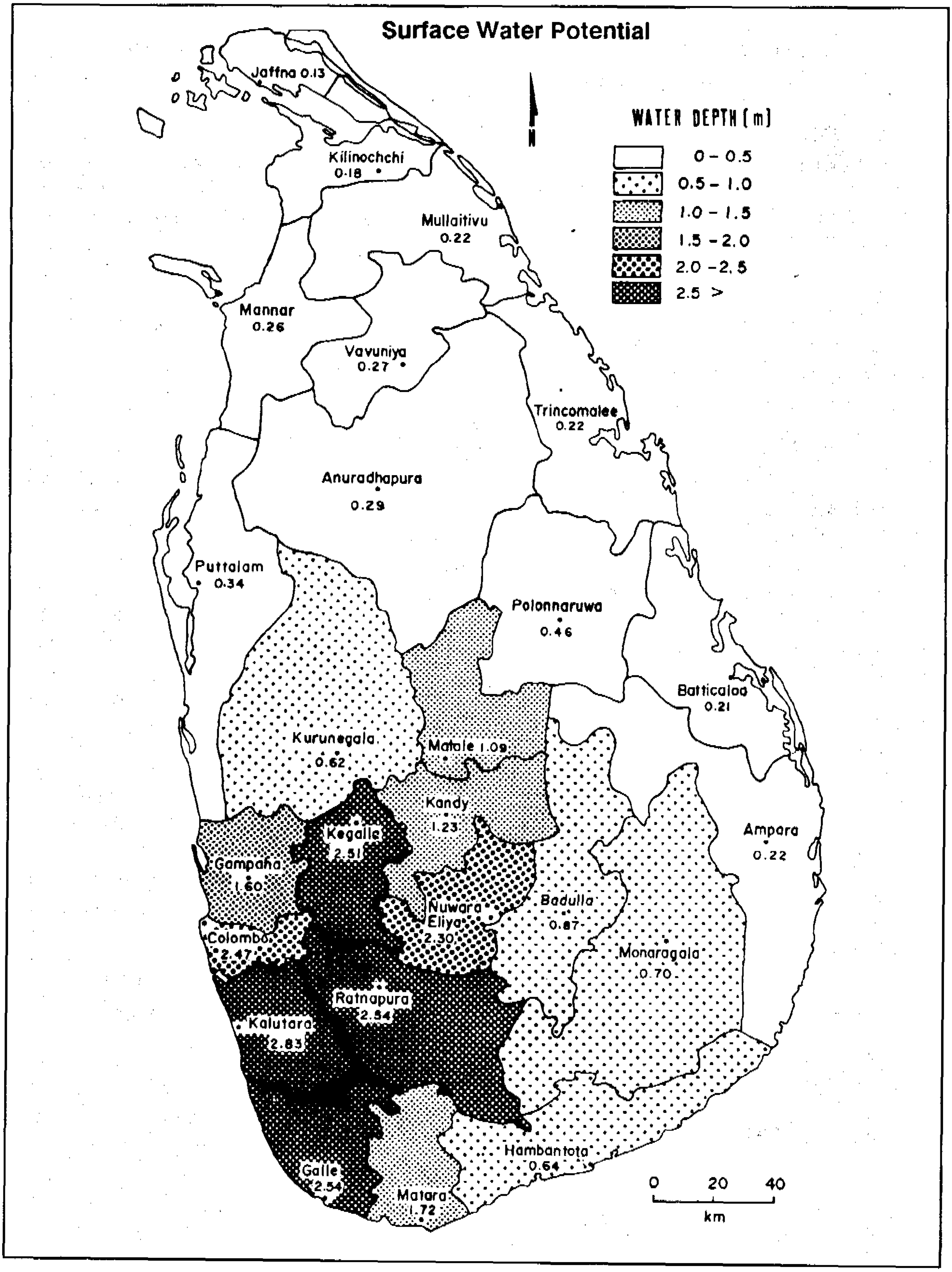

Surface Water Potential
N
WATER DEPTH (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 >
Jaffna 0.13
Kilinochchi 0.18
Mullaitivu 0.22
Mannar 0.26
Vavuniya 0.27
Trincomalee 0.22
Anuradhapura 0.29
Puttalam 0.34
Polonnaruwa 0.46
Batticaloa 0.21
Kurunegala 0.62
Matale 1.09
Kandy 1.23
Ampara 0.22
Kegalle 2.51
Gampaha 1.60
Badulla 0.87
Nuwara Eliya 2.30
Colombo 2.47
Monaragala 0.70
Ratnapura 2.54
Kalutara 2.83
Hambantota 0.64
Galle 2.54
Matara 1.72
0 20 40
km

Figure 7.8

does escape comes from the Wet Zone, which often creates flooding and waterlogging in lowlands. In the Dry Zone, however, over 50 percent of total runoff was used by 1972. Recent river basin developments, particularly the Accelerated Mahaweli Programme, have substantially reduced Dry Zone runoff.

Efforts to quantify Sri Lanka's surface water potential have been based on available rainfall, streamflow, and reservoir replenishment data. As summarized on a district basis, Figure 7.8 clearly shows spatial variation of surface water potential over the Island; while Kalutara, Galle, Ratnapura, Kegalle and Colombo record over 2.4 meters in water depth, most of Dry Zone districts have values below 0.03 meters.

Ground Water

Although information on available ground water in different aquifer formations remains incomplete, Sri Lanka's largest, most studied aquifers lie in the north and northwest. Research since 1966 indicates that the Miocene limestones of the northwest extend over 200 kilometers in the northwestern and northern coastal areas, with aquifers becoming increasingly thick as they reach the coast. They are karstic with a high degree of secondary porosity. In the Vanathavillu basin, which spreads over some 40 square kilometers, the confined aquifer creates artesian conditions. Estimates of ground water resources available in Vanathavillu basin vary between 5 -20 million cubic meters per year, with the higher figure indicating the ultimate potential (Henreck and Sirimanne, 1968; Wijesinghe, 1975; Foster et al., 1976).

North of Vanathavillu, in the Murunkan basin located between the stream courses of Malvatu Oya (Aruvi Aru) and Nay Aru, deep tube well technology has developed over the last fifteen years to supply water for irrigation and domestic use under programs of IRDPs and Water Supply Authorities. A relatively high yielding semi-confined aquifer system has been found from 15-25 meters below ground. The next major aquifer system, located in the Mulankavil Basin north of Mannar, lies between the Pali Aru and Pallavarayankaddu Aru, covering 180 square kilometers. Average yields from tube wells there range from 15-35 liters per second (Foster et al., 1976).

Within the metamorphic complex covering over 90 percent of the Island, regional aquifers underlie 1-2 percent of the land -- that underlain by quartzites or crystalline limestone bands within the metamorphic suite. In the extensive regions devoid of large aquifers, ground water resources depend on local long-term recharge from rainfall infiltration and irrigation seepage. Unfortunately, we know too little about groundwater in this large area. "[A]nyone attempting to formulate a national policy on groundwater development for the metamorphic regions of Sri Lanka is confronted with enormous deficiencies in hydrogeologic data" (Foster et al., 1977).

Estimates of well yields outside the north and northwest illustrate the modest ground water potential. In the Vavuniya District they range from 0.1 - 0.6 liters per second (l/sec). In the Colombo district at two sites laterites have yielded a total of 3.5 l/sec and 1.2 l/sec; tube wells drilled up to 25 meters deep in Trincomalee and Hambantota districts recorded yields up to 0.4 l/sec; wells sunk into quartzite formations as at Melsiripura (Kurunegala District) and Kebitigollewa (Anuradhapura District) have recorded yields of 0.5 l/sec for less than one meter of drawdown. Transverse valleys that dissect quartzite formations often create significant springs, as in the Matale District.

Ground water quality from limestone and metamorphic areas have been affected by chemical conditions. Figure 7.9 indicates the quality of water in tube wells constructed up to 1985. In many areas tube wells yield water of reasonable quality, occasionally affected by excessive salinity, hardness or fluoride content (Dissanayake et al., 1986).

WATER USES AND REQUIREMENTS

During Sri Lanka's hydraulic civilization in the first millenium, major population centers in the Dry Zone left the hill country watersheds largely undisturbed. Under colonial rule this pattern drastically changed; coastal waters became heavily used for navigation and other purposes and hill country forests were progressively denuded for plantation agriculture.

Development of irrigated agriculture in the Dry Zone gradually became the dominant state

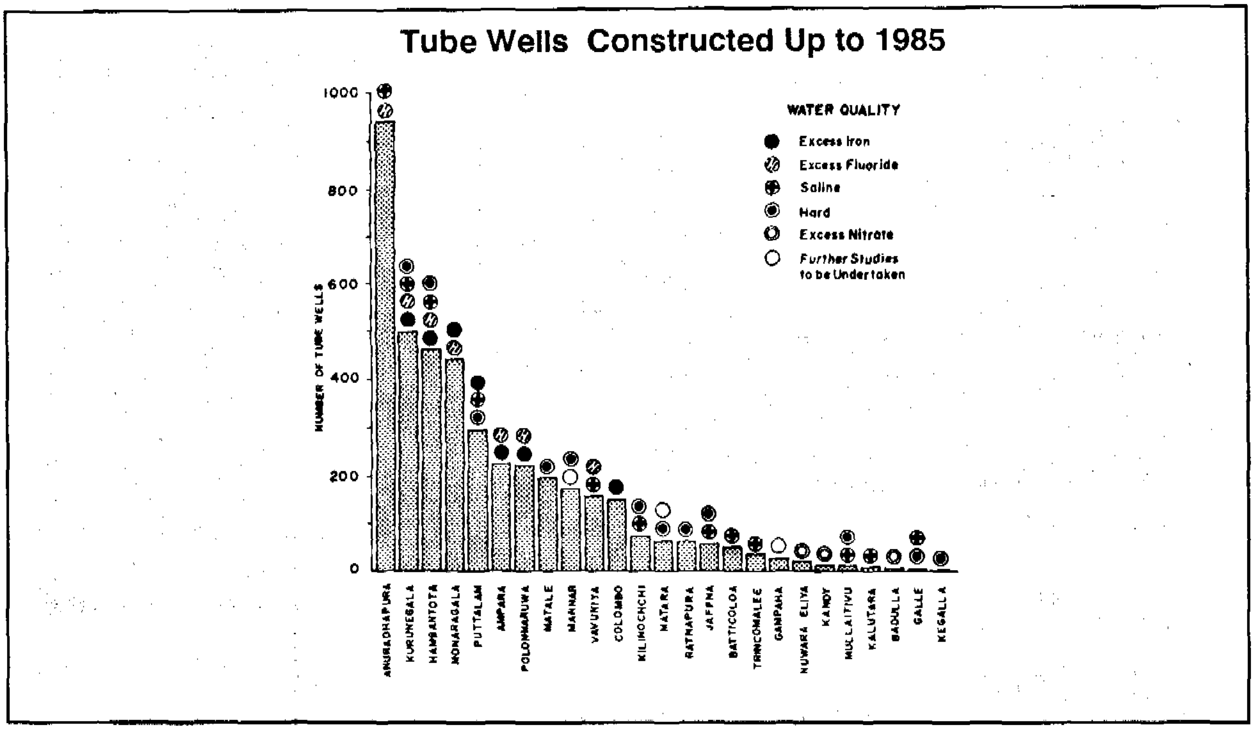


Figure 7.9

development policy in the latter period of British rule. The Irrigation Department, established at the turn of the century, assumed control over most water resource programs. Renovation of derelict ancient irrigation works and new land settlement around them became major concerns in the 1930s and continued virtually unchanged after National Independence. Large schemes such as Gal Oya and Uda Walawe culminated in the Accelerated Mahaweli Development Project. Nearly all major ancient reservoirs have now been renovated.

To facilitate macro-scale planning the island has been divided into four main regions (GOSL, 1977): the Mahaweli Project region; southeast Dry Zone region; western Wet Zone region; and northwest Dry Zone region. Today, Sri Lanka's only area with a water surplus is the Western Wet Zone (see Figure 7.10). Her most acute water deficit areas occur in the northwestern and southeastern Dry Zone. The Dry Zone region of the Mahaweli basin, however, with an estimated deficit of 199 million m^3, may nevertheless become self-sufficient under improved water conservation and management.

The Mahaweli basin discharges about 7,650 million m^3 annually which represents roughly one-fifth of all the island's river discharge from its watershed of 10,450 square kilometers. Development of these water resources occurred under the Mahaweli Master Plan (UNDP/FAO, 1967) and the Accelerated Mahaweli Development Programme, which commenced in 1978. All major Mahaweli projects except in the Moragahakanda are completed or nearly so.

With completion of the Mahaweli project few favorable sites remain for major irrigation development. The proposed Kaluganga Project may be able to convey water to at least some parts of the southeastern Dry Zone, but other river basin projects are possible only in the Kalu, Kelani and Walawe basins. In the Walawe Basin the only new project to be completed is the Samanalawewa reservoir and hydroelectric plant.

In the future Sri Lanka's water resource development must increasingly focus on augmentation, rehabilitation and improved water management. The village tank rehabilitation program has shown positive results, particularly where it has increased cropping intensities (Herath et al., 1988). Any future irrigation expansion will depend largely on small-scale schemes and exploitation of ground water.

Most major hydropower sites have also been developed, as discussed in Chapter 5. Small-scale projects may become economically attractive, but their long-term success will depend on sound watershed management.

Ground water can provide supplementary irrigation in many areas of the Dry Zone except the northern districts such as Jaffna and Vavuniya (Madduma Bandara, 1980). Ground water use has exceeded safe limits in most areas of Jaffna where sustainable irrigation depends on maintaining a delicate balance between recharge and extraction (Arumugam and Balendran, 1969). Heavy use of agro-chemicals threatens the purity and utility of the resource.

The quantities of water required for industrial and domestic uses are not so significant as for irrigation and hydropower generation. Total requirements stood at 665 million liters per day in 1973 and have been projected to increase to 2,820 liters per day in A.D. 2000. Quality and investment requirements of water supply projects for industrial and domestic water use will assume greater significance as demand increases.

WATER RESOURCES CONDITIONS AND TRENDS

Conditions and trends of water resources are determined by natural factors and the impacts of their use for human benefit.

Local Rainfall Decreases

Studies of island-wide rainfall trends have been attempted for several decades without conclusive results (Thambiapillay, 1958), but significant local trends have been observed in the annual rainfall or rainfall during agriculturally critical periods. For example, Nuwara Eliya has experienced significant decline in annual rainfall during the last 100 years. (Hamamori, 1968; Madduma Bandara and Kuruppuarachchi, 1988) (see Figure 7.11). The decline coincided with deforestation of the hill country for tea plantations, but this fact alone cannot explain a rainfall decrease of nearly 20 percent in a hundred years. Some still unknown meteorological change may be responsible for this rainfall decline, which also appears to have affected rainfall stations such as Abergeldie in the upper Mahaweli Basin.

Data do not support the belief of many Dry Zone farmers that rainfall has been declining over the past generation or more, adversely affecting agricultural production; analyses of long period rainfall at Anuradhapura do not indicate significant progressive rainfall decline in recent decades. On the other hand more drought years have occurred over the last 30 years than during the first half of this century. As Figure 7.12 indicates, between 1873-1974, 7 out of 11 years falling within the driest decile came between 1950-1974. Similarly 4 out of the 11 driest Januaries came in the eight-year period of 1973-1980 (Gooneratne and Madduma Bandara, 1990).

Increased Runoff

Available streamflow data cover shorter periods than those for rainfall and cannot provide meaningful time series analyses. Nevertheless, the few studies that exist (Abernathy, 1976) indicate a steady increase in the runoff/ rainfall ratios as expected from deforestation (Figure 7.13). For example, trends in Kirindi Oya basin streamflow (Madduma Bandara, 1977) revealed this increasing trend clearly (see Figure 7.14). Similarly streamflow data in the upper Mahaweli basin above Peradeniya (Madduma Bandara and Kuruppuarachchi, 1988) show an increase in runoff/rainfall ratios -- that is, an increase in discharge during the wet months and a decrease during dry months (see Figures 7.15 and 7.16). Also, average discharge of the Mahaweli Ganga over the long period (1944-1974) is 10 percent higher than the estimates of the UNDP/FAO Master Plan based on the twenty years 1944-1964 (Madduma Bandara, 1989). Such changes in river discharge trends stem largely from changes in catchment area land use. Although data available on sediment discharges in the rivers of Sri Lanka do not suffice for time-series analysis, in theory, increasing runoff/rainfall ratios indicate increased sediment transport from upstream and eventual increases in reservoir siltation.

High siltation rates are evident in many Dry Zone tanks (Gangodawila, 1988) as well as in such upcountry

Surface Water Requirements (in Million m3)

Supply / Demand	Mahaweli Project Region	South-East Dry Zone	Western Wet Zone	North Western Dry Zone
Total average annual yield	7375	2783	16,760	835
Current Requirements	1049	2165	-	216
Future demand for Agriculture by year 2000	6134	1534	-	1996
Surplus/Deficit	199	916	+2960	1377

Future demand is assessed on the basis of an average duty of 0.480 m/ha (10 Ac. ft/Ac)

Source: GOSL, 1977

Figure 7.10

Trend Of Annual Rainfall At Nuwara Eliya

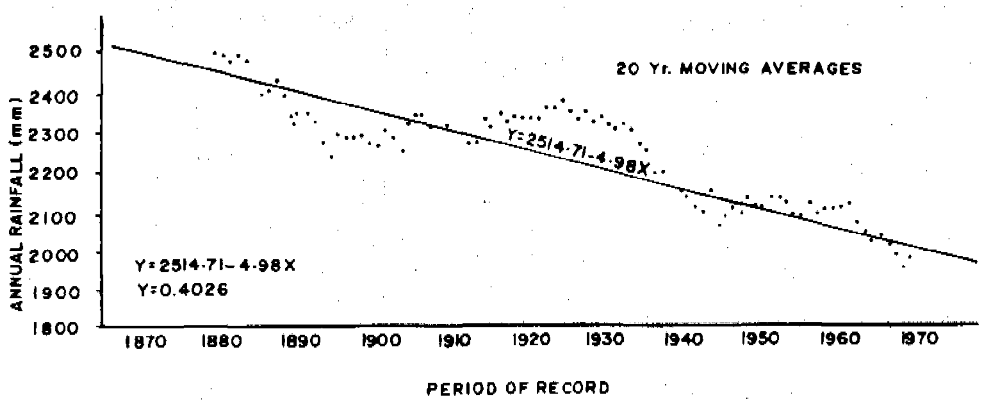


Figure 7.11

Occurrence of Years Falling within the Driest Decile at Anuradhapura (1870 -1980)

Driest in terms of Annual Total	Driest Januaries
1873	1873
1876	1877
1893	1888
1905	1898
1950	1916
1956*	1940
1958	1945
1967	1973
1968	1974
1973	1976
1974	1980* (* Driest on record)

Figure 7.12

reservoirs, as Kandy Lake and Lake Gregory in Nuwara Eliya. A recent study of Polgolla reservoir indicated that 44 percent of its capacity has silted up within less than 12 years (Perera, 1989). Hence, despite conclusions of the TAMS consultants (TAMS 1980), the new Mahaweli reservoirs, such as Kotmale, Victoria and Randenigala may well be seriously affected by siltation within their first 50 years.

Ground Water Exploitation

Temporal data for analysis of ground water resources trends are altogether lacking except perhaps in the Jaffna peninsula where a network of observation wells was maintained for some time by the Water Resources Board. Increased exploitation of groundwater for domestic use through large numbers of tube wells in hard rock areas of the Dry Zone requires careful monitoring to determine the impact on adjacent shallow wells and other surface waters.

DEVELOPMENT POLICIES AND INSTITUTIONAL RESPONSES

With the completion of the Mahaweli Project, government policies appear to be increasingly directed towards several new water resource 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;

- rehabilitation of minor irrigation systems;
- ground water development for agriculture and domestic use;
- development of small-scale hydro-power projects;
- drainage and flood protection improvement; and
- systematic watershed management.

Institutional Authority

Implementation of these policies rests with dozens of agencies and several ministries under scores of parliamentary acts. Some institutions began at the turn of the century, like the Irrigation Department, and others are more recent, like the Irrigation Management Division of the Ministry of Lands.

The Ministry of Lands and Land Development -- the single most important ministry responsible for water resources affairs in Sri Lanka -- covers all three major water resources development sectors, land, irrigation and forestry.

Within the Ministry the Irrigation Department had for decades primary responsibility for water resource planning, project formulation, construction and maintenance. Its groundwater exploration and development functions were later transferred to the Water Resources Board (established in 1964), which now coordinates government water resources functions and formulates national policies relating to the control and use of water resources.

Since 1979 the Mahaweli Authority has been responsible for water resources development in a large area of the country, not only coming within the Mahaweli project region, but also covering many other major river basins of Sri Lanka. The Water Management Secretariat of the Mahaweli Authority has the necessary technical resources to plan the distribution of water resources under the Authority's jurisdiction.

Other important government institutions include the Water Supply and Drainage Board -- the leading state agency on domestic and industrial water supply and sewage and surface drainage -- and the Ceylon Electricity Board, responsible for the generation, transmission and distribution of electric power.

But these are only the prominent state institutions concerned with water resource management. Scattered functions among departments, corporations and ministries have often resulted in poor coordination and wasteful duplication. The Water Resources Board has yet to fulfill its role as the single institution specifically devoted to water resource coordination and policy making. The Irrigation Department and the Mahaweli Authority have not yet made the fundamental changes in outlook, staffing and priorities to move from construction to water management responsibilities.

Water Resources Legislation

Scores of parliamentary acts cover different aspects of water resources in Sri Lanka. By 1977 there were 41 acts and ordinances related to water resources, administered by government departments, public corporations and local bodies (GOSL, 1977). Since then new acts have been passed, governing coastal and inland waters as well. Among them all, new and old, a few have retained central importance: The Irrigation Ordinance codified ancient customs pertaining to irrigation water management to suit changing agrarian conditions, while the Crown Lands Ordinance provides for the use and control of all waters in rivers and reservoirs.

The Crown Land Ordinance of 1949 defined a "private stream" as any river, creek, or *ela*, whose source and entire course lies within private land. All others are "public streams" under state ownership. In the absence of large landholdings, therefore, private ownership can only incorporate micro-catchments falling entirely within private property. Similarly, a private lake must be situated entirely within the boundaries of any private property. The right to use, manage and control water in any public lake or public stream vests in the State, subject to a few limitations. The Act gives a person who occupies land on the bank of any public lake or public stream the "right to use the water in that lake or stream for domestic use, livestock or agricultural purposes" provided that it is extracted by manual means. However, because all beds of public streams and lakes belong to the State they can only be used by permit. These provisions of the Crown Lands Ordinance are implemented through Government Agents and their deputies.

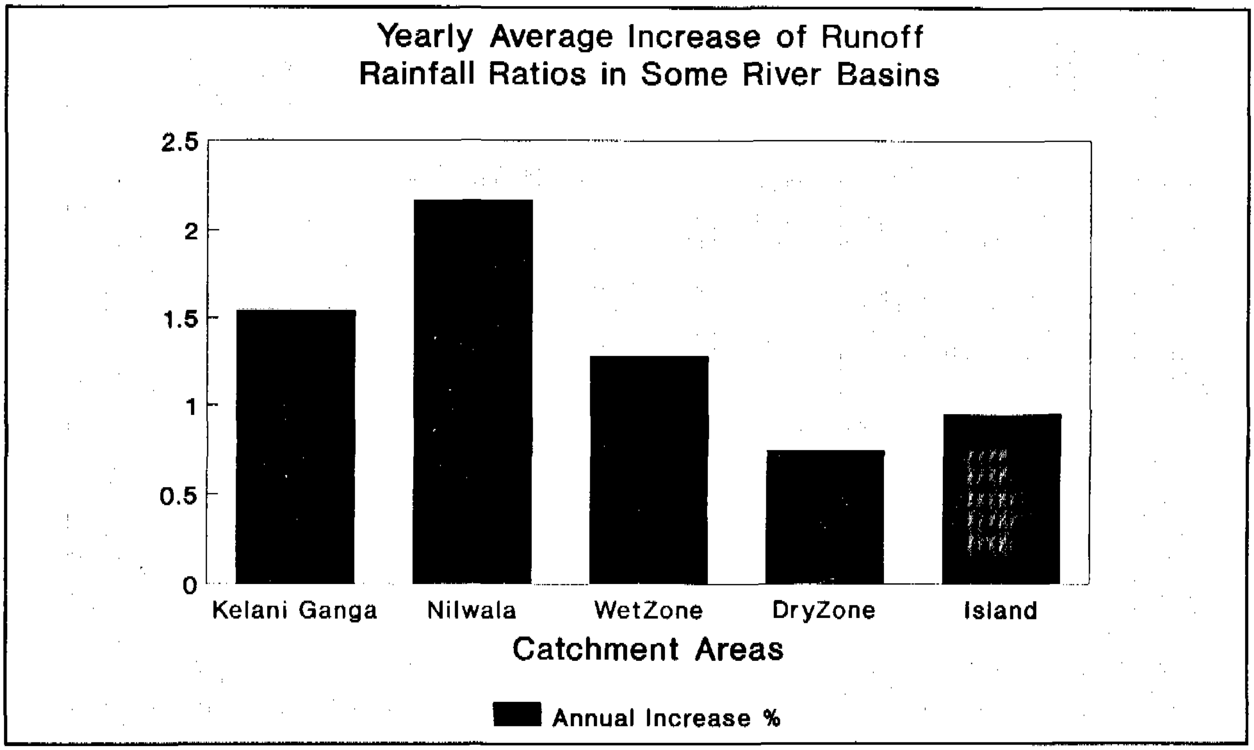


Figure 7.13

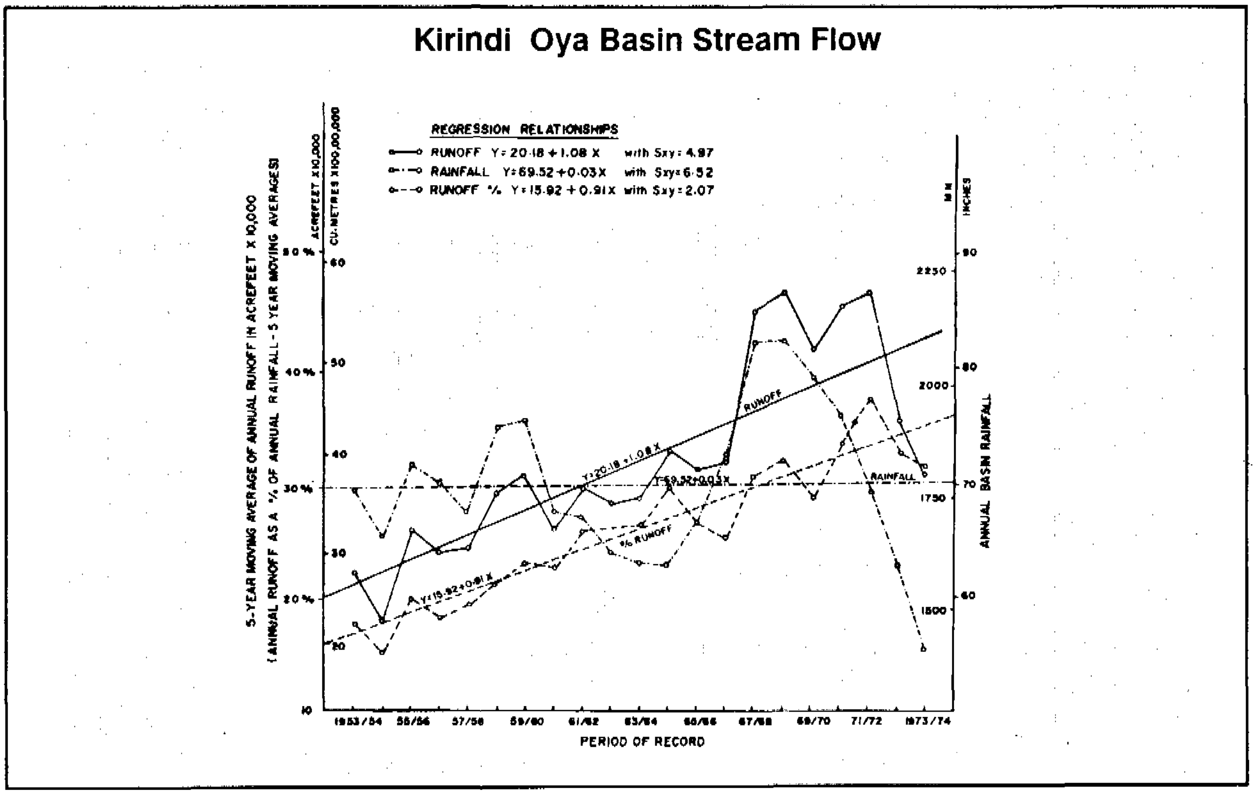


Figure 7.14

Changing Runoff / Rainfall Ratios of the Upper Mahaweli above Peradeniya

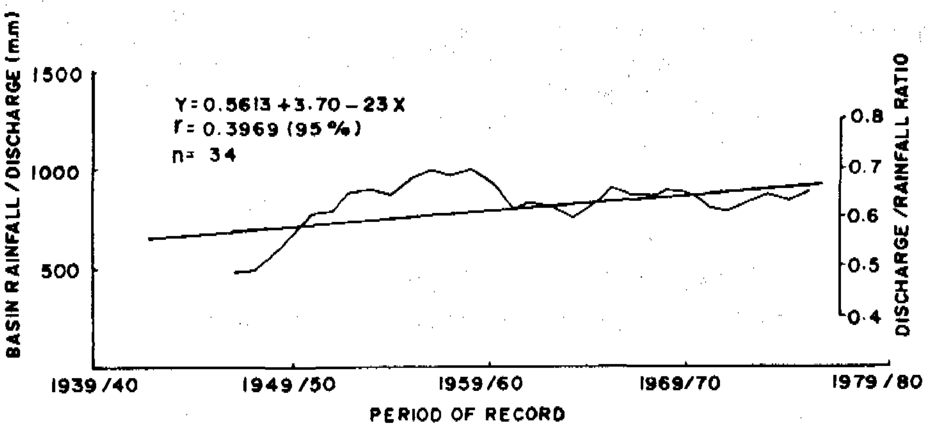


Figure 7.15

Mahaweli Ganga Monthly Discharge at Peradeniya

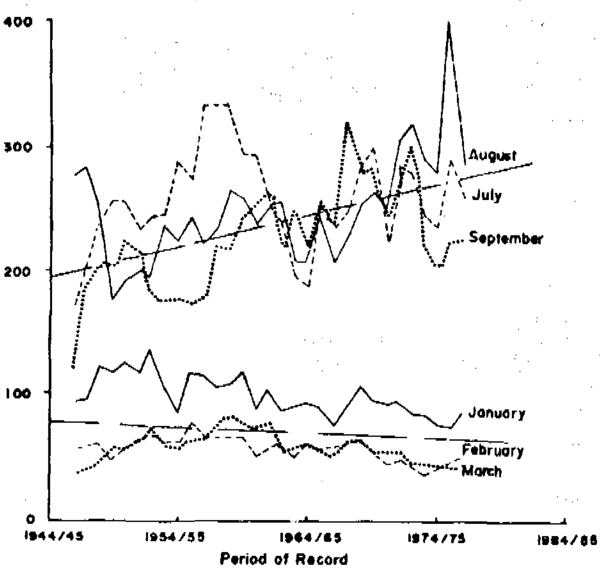


Figure 7.16

Need for watershed management legislation has been strongly recognized since the 1960s because the Soil Conservation Act of 1951 did not provide specific measures for water conservation. The Water Resources Board took some interest in formulating a draft Act on watershed management (Arumugam, 1969) over twenty years ago without results. Then in 1980, TAMS consultants, in their report on the Mahaweli development, outlined the legislation necessary for a Catchment Development Corporation. The Presidential Land Commission followed with its First Interim Report (1985), which cited needs for watershed management and provided draft legislation for a "Watershed Management Authority."

Since these largely unfulfilled recommendations little has been done to work towards sustainable watershed management in Sri Lanka. Only the Mahaweli Authority initiated watershed management, but on a limited scale in the upper Mahaweli basin, with help from the GTZ (West German) and ODA (British). In the meantime, the Soil Conservation Division of the Department of Agriculture and the Department's extension services for farmers have essentially ceased to function.

Clean surface water is essential to meet the needs of Sri Lanka's growing population in urban and rural areas.

PART II
WATER POLLUTION

With her small cities and industries and plentiful water to dilute wastes, water pollution problems in Sri Lanka are not insurmountable, but they are increasing rapidly. They will grow steadily more serious as urban communities grow, industry expands, rural areas develop, farmers use more pesticides and fertilizers, and forestry, mining, and other development projects unfold. In varying degrees Sri Lanka's waters will receive the unwanted effects of all these human activities. This section discusses conditions and trends of water pollution and what can be done to manage the problem before it gets out of hand.

SOURCES OF POLLUTION

Urban Wastes

About 21.5 percent of Sri Lanka's total population live in officially designated urban areas, which cover 0.5 percent of Sri Lanka's 65,610 square kilometers. Colombo, Jaffna and Kandy already have serious problems in disposing of urban wastes, which includes sewage, liquid waste from industrial processes, sullage water from kitchens and laundries, garbage and industrial solid waste, and urban storm water runoff that carries wastes of every description.

The Colombo Municipal Council area with its estimated population of 625,000 is the only municipality with piped sewerage. In 1986 it connected 60 percent of the inhabitants. Sewage disposal facilities within the city are shown in Figure 7.17. Yet this means that within the larger Colombo Urban Area -- population 1.4 million in 1981 and over 1.6 million today -- sewers serve less than one quarter of the population. None of Colombo's sewage is treated before discharge. By comparison, Bangkok treats only 2 percent of its sewage, but Singapore treats 80 percent (WRI, 1988-89).

Colombo's sewered area divides into two districts: the northern covers 2,100 hectares and until recently it discharged waste water directly into the Kelani Ganga at Madampitiya; the southern covers 1,000 hectares and now discharges directly to the sea through an ocean outfall at the mouth of the Dehiwela Canal. Sewage flow into the Kelani ranges from 67,500-90,000 cubic meters per day, equivalent to an estimated organic load of 10,000-26,400 kg BOD_5/d. Many of the effluents from Colombo's industries, although not connected to the sewer network, nevertheless reach the Kelani through the city drainage network.

Storm water and industrial effluents in the city discharge into a network of streams and canals (Figure 7.18). This drainage system divides into two parts. The north-flowing section discharges through the Mutwal tunnel to the sea near the harbor, and into the Kelani through the St. Sebastian canal north lock when its water level is low. At high water, however, this discharge is directed to the west-flowing sections that open to the sea at Dehiwela and Wellawatta. A number of overflows in the sewer system cause further pollution as sewage enters open water courses.

Problems of waste disposal in Colombo are compounded because 50 percent of the population belongs to the low income category, of which many are slum and shanty dwellers. Occupying marginal lands, they normally have little or no access to sewer services. Their sewage and garbage are dumped into the surface water, particularly where they occupy stream and canal reservations. A recent study identified 76 low income communities situated on canal reservations.

Approximately 10-15 percent of the estimated 625,000 inhabitants in the city of Colombo discharged sewage directly or indirectly into the surface water network in 1989. In addition, industrial and other domestic wastewater overflows from the sewer network regularly enter and pollute the canals. Organic pollution from sewage accounts for at least 50-60 percent of the total waste load (10,000 kg BOD_5/d) discharged into the canal network in Colombo.

The good news is that the sewer system is being upgraded and extended to minimize these overflows.

Profile of Water Pollution

Although water pollution is caused by hundreds of chemicals, it basically consists of nutrients from sewage or fertilizers, pesticides from croplands, sediments from cleared lands, and toxic metals from industry. In Europe and North America serious pollution of lakes and streams comes from the air through acid precipitation, but in Sri Lanka, so far as we know, the most significant pollution comes from the land.

It comes from either specific discharge points or diffused, non-point sources. Point sources, most easily controlled in theory, include industrial discharges of heavy metals, organic waste, and other pollutants, or discharge from urban sewers or sewage treatment plants.

Non-point pollution, more difficult to identify and manage, includes urban, agricultural, or any other land runoff. Urban runoff into lakes, streams or canals includes nearly every pollutant -- nutrients, toxics, oils, bacteria, and sediment. Agricultural runoff into streams and rivers usually includes pesticides, dissolved solids, nutrients from fertilizers, organic material, and pathogens. Runoff from forestry, road construction or other land-clearing introduces high levels of suspended solids and various oxygen-demanding loads. Runoff from mines can add sediment, acids, and heavy metal pollution.

We care about water pollution first and foremost because it makes people ill or causes death.

Lack of potable water and sanitation causes the most common tropical diseases, transmitted by mosquitoes, other insects, parasites, and other water-related disease vectors. About 80 percent of all illness in the developing world results from unsafe and inadequate water supplies. Contaminated water causes cholera in 10 million people each year, and diarrhea that kills 5 million children each year (WRI, 1988-89).

Pollution reduces food supply by killing fish and destroying aquatic habitat. Periodic fish kills in the Kelani River starkly illustrate the problem, but more gradual destruction of productive fisheries may be more difficult to control. In Asia alone, pollution seriously harms major fisheries in the Strait of Malacca, the Andaman Sea coast, the Bight of Bangkok, and Manila Bay. Heavy metal toxics from industrial effluent attack productive estuaries by concentrating in fish and shellfish, making them hazardous for humans to eat. Sediment from upstream agriculture and land clearing has caused turbidity in marine waters by blocking light and reducing fish habitat.

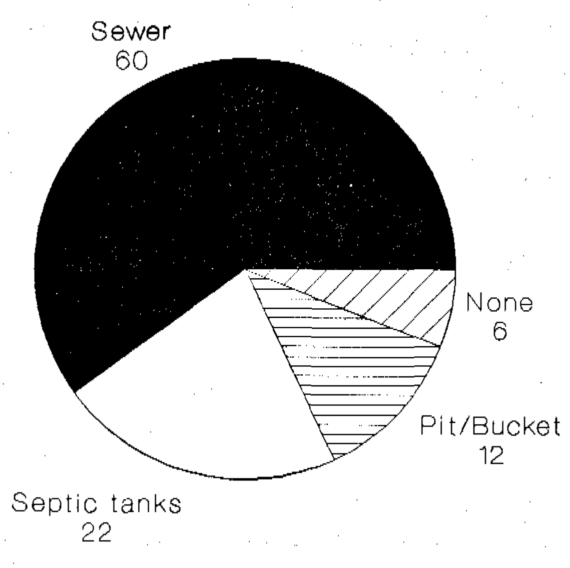
Excess nutrients from urban sewage cause lakes and lagoons to die by becoming eutrophic -- a common global problem starkly evident in Colombo's murky and greenish Beira Lake (see box). Nutrients from point and non-point sources cause an aging process -- eutrophication -- that stimulates plant production and algae blooms. As the plants die, settle, and decay, they rob the water of levels of dissolved oxygen needed for plants and fish, causing the death of formerly productive ecosystems. Eutrophication from human activities not only kills fish but makes waters unsuited to recreation.

To measure water quality we use various indicators.

Fecal Coliform Bacteria (FC) is a traditional, sanitary engineering measure of water pollution from feces of warm-blooded animals. They usually arise from discharges of human sewage, feedlots, and grazing lands.

- **Dissolved Oxygen** (DO) is one measure of water's ability to support aquatic animal life -- a necessary but not sufficient condition. Low DO levels may result from large amounts of decaying organic matter introduced by natural causes or from human sewage. Low levels may cause many aquatic organisms to die.
- **Biochemical Oxygen Demand** (BOD_5) measures the amount of dissolved oxygen that microorganisms consume as they oxidize organic materials over a given period.
- **Measurements of heavy metals,** such as lead (Pb), mercury (Hg), copper (Cu), cadmium (Cd), are important because they are toxic to plants and animals. They are neither readily soluble in fresh water nor usually found in high concentrations under natural conditions. High levels indicate industrial pollution and persistent hazards to humans who consume the water.
- **High levels of nitrates and phosphorous** (P) in rivers indicate pollution from domestic sewage, agricultural fertilizers, livestock wastes, and some industrial wastes. Nitrogen (N) and phosphorous are nutrients that help cause algal blooms and eutrophication. Nitrates are health hazards, especially to infants.

Sewage Disposal in Colombo City
Percentage of Households Served



Source:Central Environmental Authority; Tillakaratne

Figure 7.17

Further, because the ocean outfall at the harbor mouth has become operational, the northern sewerage system longer discharges into the Kelani river at Madampitiya.

Yet questions remain: will an ocean outfall solve the pollution problem, or simply exchange one problem for a new one in the ocean and along the coasts? Even with new ocean outfalls and new developments with sewage disposal, discharges from the drainage systems of Colombo will still cause serious water pollution.

Cities smaller than Colombo produce similar urban water pollution problems that often receive less notice. Kandy's population of 97,872 (1981 census) largely uses on-site disposal systems for sewage disposal, but only 50-60 percent of the houses use septic tanks or pit latrines. Low income settlements and high density mixed development in the city core discharge sewage and sullage directly into the surface drainage network.

This pattern recurs in all our cities and suburbs; canals and waterways have been turned into open sewers.

Urban waste disposal has affected not only surface water but ground water as well. Water pollution in Jaffna, which rests on miocene limestone soils, is one such example. Sewage disposal in Jaffna occurs through on-site systems, mainly pit latrines, and the permeability of the limestone, enhanced by its inherent crevices and channels, has caused widespread pollution of the water table.

In unsewered urban areas some major housing schemes and hospitals have waste water treatment plants. Yet many operate poorly due to lack of awareness, technical skills, or interest on the part of responsible authorities.

Large urban centers face rising problems in disposing of urban solid waste, both domestic and industrial. Generation of domestic solid waste within the Colombo Metropolitan Council region was 450 tonnes per day in 1987 and is estimated to rise to 470 tonnes per day in 1992. Disposal and filling is not always sanitary, causing pollution and clogging of surface canals and drains and pollution of ground water. The problem compounds when urban solid waste fills lowlands for development purposes -- a common occurrence given increasing demands for urban land. Housing developments on such sites, lacking piped water, may resort to ground waters that are badly polluted.

Industrial Waste

Industrial wastes in Sri Lanka undergo little or no treatment before discharge. Until recently the laws and by-laws relating to pollution and nuisance have been poorly enforced; liquid effluents are discharged directly into surface drainage networks or onto land, whence they reach the closest water body. Thus, textile dyeing and printing industries have caused widespread pollution in Ratmalana and Moratuwa. One study for the Central Environmental Authority estimates that in Colombo the total waste from industry discharged into the canal network is 70,000 person equivalents, or 3,900 kg BOD_5/day. A portion of this eventually reaches the Kelani Ganga.

Industries in Sri Lanka fall into two categories. One includes large-scale operations which have been established outside the main cities that have essential infrastructure and urban services. The second includes the smaller and medium-scale industries which of necessity are established in or near cities where infrastructure and urban services are, or can easily be, available.

Industrial estates are not numerous. The most well known are the Katunayake and Biyagama industrial estates in the Gampaha district within the jurisdiction of the GCEC. Both are equipped with treatment plants. From 1963 to 1975 only three major industrial estates were established by the government -- Ekala, Pallekelle and Atchuvely. During the late 1970s three mini-estates were developed in Horana, Pannala and Lunuwila. The Colombo district has two others -- the Ratmalana industrial estate and the LadyCatharine industrial estate, both established south of Colombo outside its municipal limits. Neither carries out any waste treatment. The Katuwana estate in Homagama, in the Gampaha district, will commence operations shortly. In addition medium-scale operations tend to agglomerate, creating areas of predominantly industrial development that are usually designated

Colombo North and South Drainage Canals

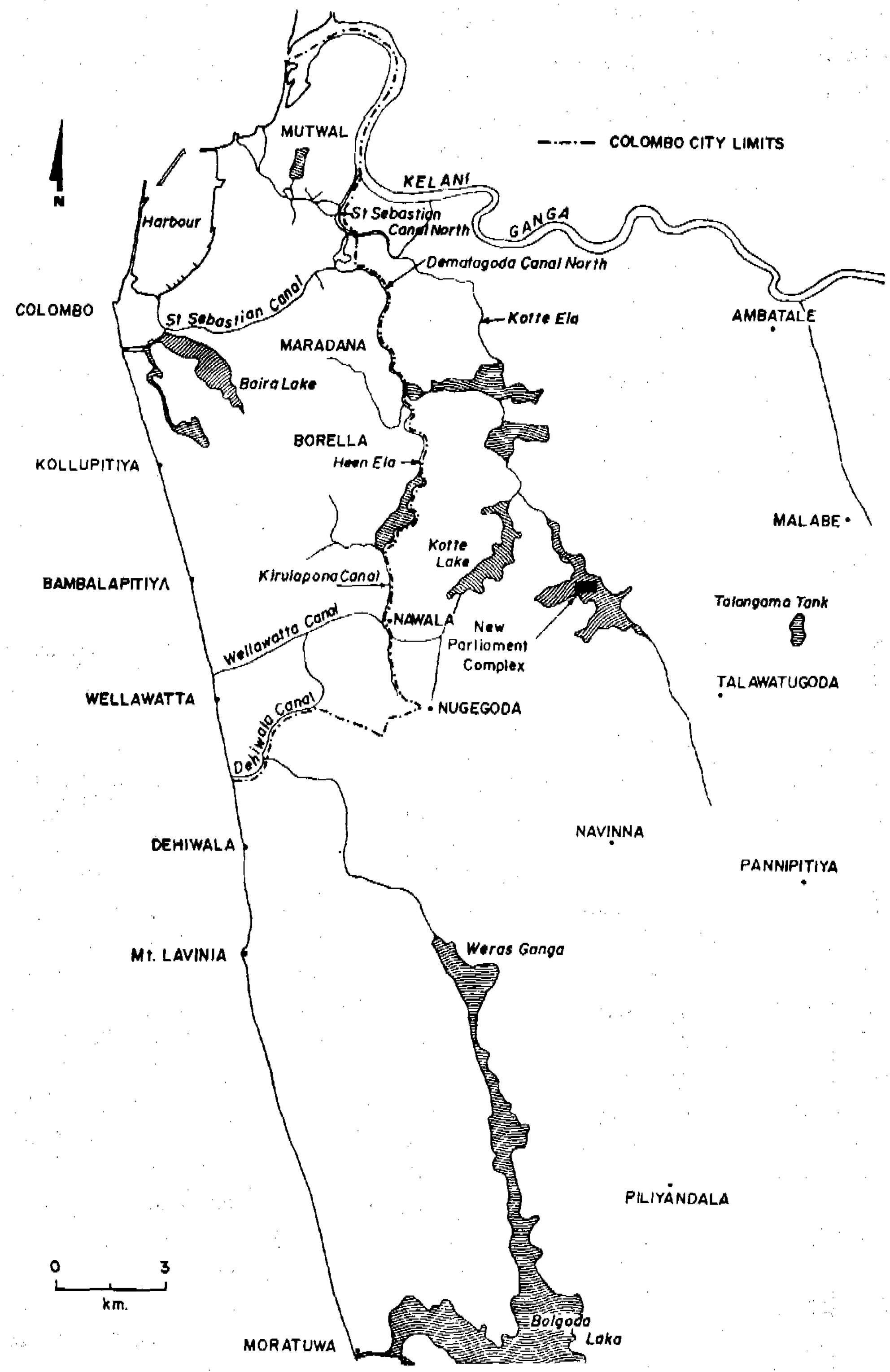


Figure 7.18

Waste Load from some Polluting Sectors

Sector	No.	Location District	BOD5 tons/yr	Waste Load SS tons/yr	HM tons /yr*
Textile dyeing	12	Colombo	1,564	472	
Printing	4	Gampaha	1,629	492	
	1	Kurunegala	480	145	
Leather	5	Colombo	734	510	11
Processing	6	Gampaha	767	533	12
Distillery	5	Kalutara	421	492	

* heavy metals

Figure 7.19

as industrial zones by the Urban Development Authority when it produces development plans for a particular local authority.

Data on industrial plants and pollution has been limited, but industrial pollution appears ever more serious as the information base improves. A 1989 survey indicated that 80 percent of manufacturing industries of all sizes are located in Colombo and Gampaha districts. Of the 7,610 medium- and large-scale plants it identified, 60 percent (4,600) were considered likely to have potential for pollution. Of these, 291 (6 percent) appeared to have a high pollution potential and 1,900 (40 percent) moderate potential. The 1989 survey identified 115 significant polluters, but the CEA staff now estimate (November, 1990) that well over 230 plants may be significant polluters, including state as well as private companies, and that the number of the industrial plants is larger than the original survey showed.

Figure 7.19 lists the process waste loads from highly polluting industrial sectors, both state and privately owned. Because of their high pollution potential, the extent to which even these small- to medium-sized facilities have already caused pollution is remarkable. Their size and scattered location makes pollution control costly and difficult. This is particularly evident in the case of local resource-dependent activities like rubber processing. By conservative estimates, up to 28,300 tons of BOD5 are discharged annually, polluting waters in the Ratnapura District.

Unlike many developed countries, however, Sri Lanka has relatively few severe pollution problems from chemical industries, because this sector is largely represented by manufacturers of paints, varnishes, cosmetics, and other chemical products estimated to have a relatively low potential for pollution.

Pollution from purely state-owned industries is most likely from the medium- to large-scale plants manufacturing paper, sugar, cement, steel, and petroleum. Individually these industries are highly polluting, as is the case with the cement factories at Kankesanthurai, Puttalam, and Galle, and the paper mills at Valachchenai and Embilitiya. In theory, being few in number, and having centralized operation, their problems can be easily controlled, if the state makes the effort to do so.

Rural Sanitation

The census figures for rural areas in 1981 revealed that only 5 percent of the rural population had access to piped water, 85 percent used wells, and the rest depended on streams and rivers (see Population Chapter).

Between 30 and 40 percent of the wells in the Hambantota, Moneragala, and Matale districts are unprotected and 25-30 percent of rural populations in Moneragala and Hambantota areas depend on rivers and tanks for potable water. If similar trends occur elsewhere, rural sanitation problems will assume growing importance. Lack of sanitation facilities and practices will largely determine the exposure of rural populations to waterborne disease.

Sanitation figures show that 44 percent of the rural population use pit and bucket latrines, while 36.5 percent use no latrine facilities whatsoever. In 7 of the 13 predominantly rural coastal districts, 60 percent of residents have no sanitary facilities. In these same districts over 90 percent of the population use wells, rivers, tanks and springs for water supply. Many water sources in rural areas are also unprotected. The result: a high proportion of the population is exposed to health risks associated with fecally contaminated water, either through ground water pollution or from surface contamination. According to one study, "the poor water supply and excreta disposal systems have resulted in 40 percent of the Sri Lankan population being affected by typhoid, amoebic and bacillary dysentery, infectious hepatitis, gastro-enteritis, colitis and worm infections" (Hydrogeochemical Atlas of Sri Lanka).

Agricultural Wastes

Agricultural waste results from agricultural practices and agro- and livestock-based industries in the rural sector.

Nearly one-third of Sri Lanka's land is cropped, and on it farmers put two to eight times more fertilizer than other countries in the region, reaching levels as high as 77 kg/ha. Certain districts show annual application rates for paddy in the range of 124 kg/ha. Fertilizer application rates for the country in general show an upward trend over the past decade (Figure 7.20).

Fertilizer pollution has become a potential hazard. Intensive agricultural patterns in the Jaffna and Nuwara Eliya districts have already caused pollution of ground and surface water by nitrates. Excess nitrates can cause bowel and other diseases in children. With its extensive sugarcane plantations covering an estimated 25,000 hectares, the Moneragala district is another potential recipient of fertilizer pollution. Seven river basins drain this district and monitoring of surface waters may well reveal the presence of agrochemicals in some of them.

Pesticide use has also risen steadily. Paddy is the highest consumer of pesticides (equivalent to 70 percent of the imports), and the average rate of application between 1977-1983 increased from 1,200 grams per hectare to 1,600 grams per hectare.Between 50 and 60 percent of the farmers use at least twice the recommended dose.

A further consequence of agricultural practices on hilly terrain is the silt carried through the run-off, along with the fertilizers and pesticides. Degradation of Lake Gregory has become notorious -- an oft-cited example of the impacts of seasonal crop cultivation with inadequate soil conservation.

Lack of data clouds our understanding of pesticides and fertilizer impacts on waterways. No systematic studies have been undertaken and little or no published data on monitoring are available on pesticides and fertilizer levels in the run-off from cultivated land. CISIR is presently involved in two monitoring studies in the Kandy and Batticaloa districts.

Nor have studies systematically measured the potential pollution impacts of agricultural and livestock-based industries here, such as pig and poultry farms. For example, paddy milling capacity increased by 60 percent between 1980 and 1987 due to new private sector mills. Although milling has caused localized pollution in the north central and eastern provinces we cannot yet determine the magnitude of the problem.We do know that mills consume substantial quantities of water during the milling season, and their high BOD_5 can cause pollution of wells and streams used for local drinking water.

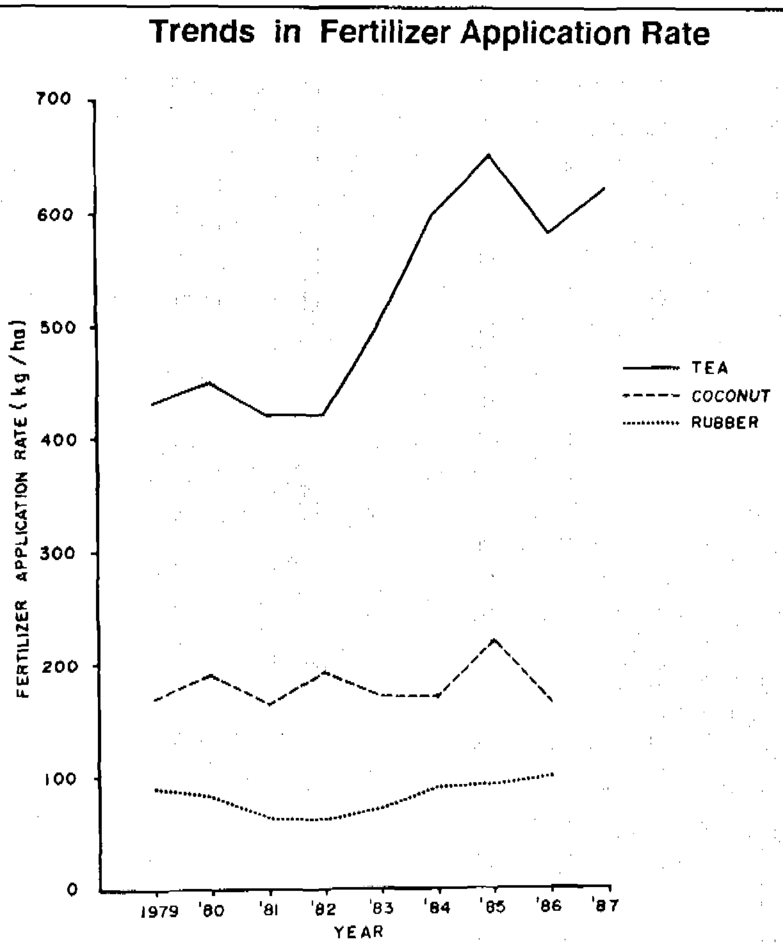


Figure 7.20

Natural Factors

Background contributions of geological factors to water pollution cannot be overlooked when analysing water resource constraints and environmental conditions and trends. Geological conditions cause high fluoride levels in water in parts of Sri Lanka. Too much fluoride causes dental fluorosis, and too little may result in high dental caries. Eppawela and Anuradhapura have the highest groundwater concentrations, reportedly as high as 9 milligrams per liter (mg/l). In Polonnaruwa district 15 percent of tube wells showed levels of fluoride above 2 mg/l. Excessive levels of fluoride that cause severe dental fluorosis among area residents result from fluoride leaching into ground water from the area's fluorine-rich apatite deposit. The Uda Walawe area is also high in ground water fluorine concentrations, due to serpentine deposits that contain 1000 to 2000 ppm fluoride. Pollution of ground water occurs through a process of ion exchange.

Oil Discharges

Oil pollution in Sri Lanka, although low level, is becoming chronic. The southern coast lies along the main east-west shipping routes that bring oil from the Middle East to Asian and other ports. Risks of a massive accidental spill are omni-present, but long term build-up from chronic pollution is more likely from discharge of ballast and bilge water.

Beira Lake Pollution - Causes And Remedies

Colombo's Beira Lake is one of Sri Lanka's most polluted waters. At 67.6 ha. Beira is twice the size of the well known Kandy Lake but it divides into four sections. The pollution problem is conceptually simple; too much pollution comes in and virtually none gets out. Flows out of Beira are restricted yet it receives city waste from an extensive catchment of 757 hectares and a thousand or more outfalls of varying sizes.

A recent study (NBRO, 1989) of 28 of these outfalls shows COD levels varying between 29 and 816 mg/l and SS in the range of 39-330 mg/l. The volumetric discharge in these outfalls varied between 7 and 40m ^{3}/ha in dry weather.

The lake is artificially maintained at a level of 1.8 meters msl by a system of lock gates opening into the St. Sebastian canal and thence north to the Kelani river. These gates allow drainage of lake water into the Kelani on certain occasions and vice versa. Early in the British period the entire Colombo canal network and Beira Lake were an integrated system used extensively for navigation. Then this system fell into disuse and the rapidly growing city used it as a natural drainage outlet.

Lake water quality began to deteriorate in the late nineteenth century. The decrease in quality became exponential and recent studies (NARA 1985) indicate that the "greening" of the Beira is due to algal blooms caused by the blue green algae microcyst. Beira Lake is a fine example of eutrophication!

After earlier efforts failed to improve matters a technical committee in 1989 recommended several remedial measures. One is a throughflow system to replenish and circulate the waters of the Beira, particularly in the south west section. The initial source of replenishment would be the waters of the east Beira, but pumping Kelani water through the St. Sebastian canal is a longer-term proposal, estimated at 62 million rupees in 1986. Controlling the pollution inputs is the other key remedy involving a number of difficult actions: connecting sewers properly so they do not overflow into the Beira; removing or eliminating all other sources; settling shanty populations away from the banks; dredging the lake bottom; and working with all major polluters to control their pollution. It will take time and money; both will be necessary to restore Beira Lake to the kind of urban amenity that can again please tourists and residents alike.

These discharges already pollute some southern beaches with tar balls. A different concern is oil and petrol washout from the 100-odd service stations and large garages in Colombo. These discharges may be carried to the Kelani estuary or the beaches around Colombo. Actual pollution loads must still be computed even to begin to understand the problem.

TRENDS IN WATER QUALITY

Comprehensive water quality data on surface water, ground water, estuaries and coastal waters are not available in part because of diffused resources management responsibilities. The Irrigation Department, Water Resources Board, National Water Supply and Drainage Board (NWS & DB), National Aquatic Resources Agency (NARA), Mahaweli Authority, and Coast Conservation Department (CCD) all manage water resources and collect data. Many independent water quality studies by universities and international agencies have also been carried out with no cohesive force guiding the search for information or its ultimate use. With data scattered, unpublished, or available in unprocessed form, analysis becomes onerous, when possible at all.

An attempt is made here to project some coherent trends based on data for the Kelani and Mahaweli rivers, several important urban water bodies in cities and health resorts, ground water in the Jaffna peninsula, areas subjected to pollution and salt water intrusion, and coasts and estuaries.

Kelani Ganga

The Kelani Ganga, the second largest river in Sri Lanka (144.3 kilometers), drains an area of 2,278 square kilometers in the west zone that contains some of the country's most densely populated districts. However most of its organic pollution comes in its last 50 kilometers before it flows into the sea at Mattakuliya.

Colombo receives most of its potable water from the Kelani Ganga. The intake point is at Ambatale, 14 kilometers from the river mouth. In turn, the Kelani receives a substantial portion of Colombo's sewage and drainage. Until 1990 the Madampitiya pumping station discharged 68,000-90,000 cubic meters of sewage and industrial waste into the Kelani each day. Characteristics vary between 250-500 mg/l COD and 16-45 mg/l TKN, which means that from this source alone the daily load entering the Kelani was 10,000 kg BOD_5/d.

Among the many water quality parameters that can be measured, most significant for the Kelani are organic matter from the large volumes of sewage and organic industrial effluent, and nitrates from sewage and fertilizer runoff. Heavy metal contamination also occurs mainly from tanning effluents in the lower reaches and to a lesser extent discharge from metal finishing and processing industries, but no precise discharge data are available.

Pesticide contamination may not be serious yet because much of the Kelani catchment drains through plantations where pesticide use has been much lower than in irrigated agriculture.

Estimated contributions from the major waste sources most likely to affect the Kelani are displayed in Figure 7.21 and Figure 7.22. Figures do not include non-point sources. The St. Sebastian canal, one of Colombo's drainage outlets, enhances pollution levels periodically when the Kelani is sufficiently low to allow the discharge of canal water through the North lock. Dissolved oxygen (DO) levels in the canal are zero, and the BOD_5 levels are around 350 mg/l. As can be observed, recent operation of the northern ocean outfall for the city sewage, diverting it from the Kelani, will vastly improve water quality.

Monitoring of water quality in the lower Kelani from 1973 to 1974 (see Figure 7.23) measured dissolved oxygen -- a good indicator of the river's health. Even in 1973 the last 12 kilometers of the river that drains the most industrialized section had DO values of only 20 to 30 percent saturation, whereas 60 percent saturation was observed at Kitulgala, about 96 kilometers upstream from the river mouth. Low values of DO downstream indicate how quickly a large influx of pollution can cause anaerobic conditions. Sudden fish kills that occur in the river illustrate one of the severe effects. The highest values of suspended solids and total nitrogen are also occurring in this stretch. More recent data from a single monitoring station 20 kilometers from the river mouth and upstream of the Ambatale water intake show water quality within levels deemed acceptable (Figure 7.24).

Heavy metals and pesticide levels have not been studied extensively in the Kelani. Levels in excess of tolerance limits for fresh water have been noted for cadmium (9 ppb), copper (11 ppb), and lead (9 ppb), which are the only elements monitored (Dissanayake, Weerasooriya, 1986). Discharges from local tanneries may well cause chromium pollution, but no data are available.

A reliable picture of the pollution conditions and trends requires sustained monitoring of sediment pollution as well as surface water pollution.

Impacts of sandmining in the Kelani have been extensive in the lower reaches. As a result, the Kelani's lowered river bed has allowed the intrusion of salt water. Conductivity and chloride measurements made by the Irrigation Department have shown that the saline plume is steadily extending further inland and will presently reach the Ambatale intake.

Mahaweli Ganga

The Mahaweli, Sri Lanka's longest river (325 kilometers), with an annual discharge of 7,650 million

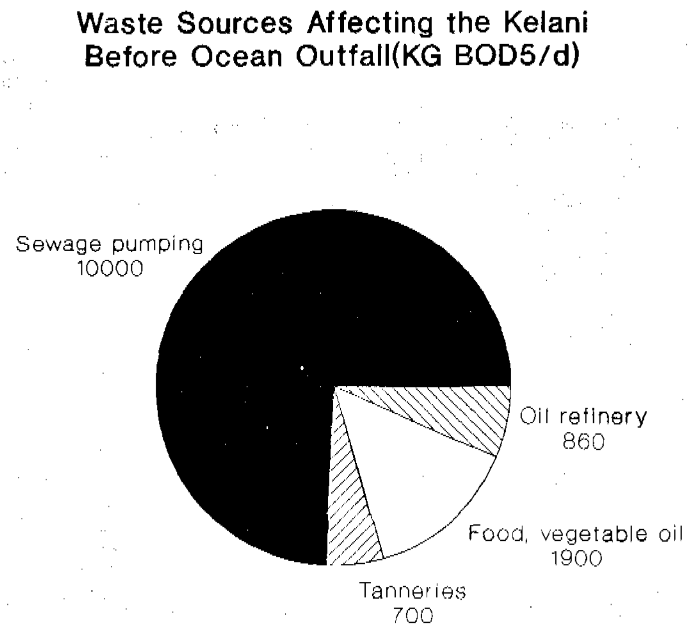


Figure 7.21

cubic meters also has by far the largest catchment area (10,327 square kilometers), covering one-sixth of the country. Under the Mahaweli development program over 16 percent of this catchment will be irrigated for paddy and home garden cultivation. By 1984 the Mahaweli water quality monitoring program was underway to assess project impacts of these and other changes.

For approximately half its length the Mahaweli traverses the Wet Zone, passing through densely populated towns, including Kandy and Matale. From Kandy alone it receives substantial untreated urban waste water through the two main waterways draining the city -- the Meda Ela and the Hali Ela, which together receive a load of 712-1,507 kg BOD_5/d from dense city center developments.

Low levels of industrialization have kept industrial pollution of the Mahaweli below that of the Kelani, yet expansion of the agricultural and agro-based industrial sector will require careful impact assessment. Results of a hydrogeochemical survey from August to December 1983 documented the variation in a number of metallic and non-metallic constitutents in the water. Monitoring data covered the area from Nawalapitiya to Gallela. Ranges for some of these parameters are shown in Figure 7.25. A comparison of heavy metals concentrations for the two major rivers indicates that levels are still well within the fresh water norms (Figure 7.26).

Nitrate concentrations have shown a definite increase along the direction of flow. Sewage also contributes to increased nitrate levels, but population in these areas is relatively low. The Mahaweli River is a clear case of agrochemical usage in the catchment contributing to elevated nitrate levels.

Without recorded data on pesticide residues we can only estimate the pollution caused by these materials. Increased pesticide levels may occur as the river flows downstream.

Other Rivers,Waterways and Water Bodies

Wastes from townships often discharge into small adjacent streams or rivers and ultimately reach the major waterways. Most of this waste is organic and could cause anaerobic conditions in some places. Rivers like the Uda Walawe have also been subjected to industrial wastes from a single factory. Such conditions can be corrected relatively easily, however.

Water Pollution Impacts on the Kelani River Before Ocean Outfall

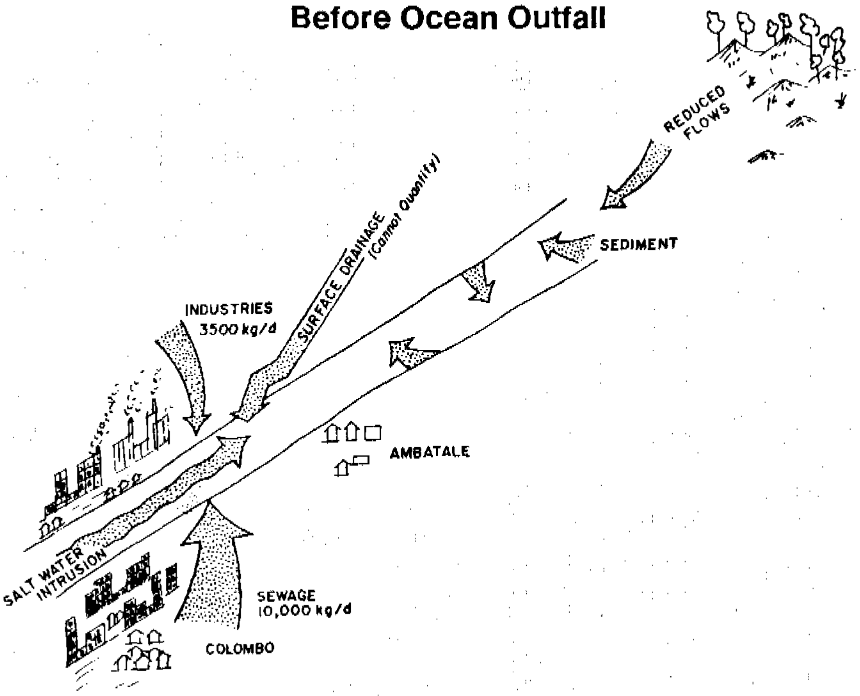


Figure 7.22

Water Quality of Lower Kelani River
Minimum values observed During 1973-1974

TSS mg/l	15.6	28	69	26	11.6	2.9
Total N mg/l	1.0	2.51	1.57	0.71	0.63	1.26
COD mg/l	0.8	1.9	1.7	1.12	1.2	1.0
DO% Sat	21	28	36	53	18	68
	Modera	Mattakuliya	Madampitiya	Kelaniya	Ambatale	Kitulgala
Distance from mouth	Mouth	1Km	1.5K	12K	14.6	96 Km

TSS = Total Suspended Solids

Total N = Total Nitrogen

COD = Chemical Oxygen Demand

DO = Dissolved Oxygen

Figure 7.23

Ground Water

Ground water is increasingly used for potable water, especially in small towns and rural areas. The ten year plan launched in 1980 envisaged drilling 20,000 deep wells and constructing or rehabilitating 25,000 dug wells. By this means 50 percent coverage for the rural population was to be achieved by 1990, although this target has not yet been reached.

Estimated ground water potential for the country is 780,000 hectare/meters per annum. For this water to remain safe, water extraction must not exceed the aquifer's replenishment capacity. Otherwise the well will run dry or, in coastal areas, invite brackish water intrusion.

This problem has occurred in northern coastal areas and the northwest agricultural belt where ground water irrigates rice and cash crops. Demand for domestic water from ground water is rising in Puttalam, Mannar, Paranthan, Kilinochchi, and Mullaitivu areas. To supplement surface water irrigation 130 tube wells were built over four years to tap the Murunkan limestone aquifer. Subsequent unregulated ground water use led to rapid salinity intrusion. Salt water intrusion into ground water has occurred in the Hambantota area due to seepage from rainwashed dissolved solids.

The most serious threats to ground water come from nitrate and bacterial (fecal) contamination. Nitrate pollution is due as much to extensive use of agrochemicals as to the disposal of sewage effluent from pit latrine soakaways and septic tanks, which causes bacterial contamination of ground water.

River and canal pollution also affects ground water; analyses of well waters from Tholalanga near a polluted stretch of the Kelani, and from the banks of the Meda Ela in Kandy, highlight the influence of polluted surface waters on wells. This problem is critical in urban areas where ground water provides most of the potable water.

Data on distribution of nitrate in ground water is available for the northern and northwestern coastal areas that largely comprise miocene limestone. Limited monitoring in the Kalpitiya peninsula, intensively cultivated and irrigated, has shown considerable aquifer contamination by nitrates in fertilizer. Peak seasonal concentrations there reached four times the WHO guideline; concentrations in the ground water beneath unfertilized land were substantially lower.

Similarly, in agricultural and non-agricultural areas in the Jaffna peninsula, nitrate concentrations over 200 mg/l of NO_3 have been recorded. Widespread water contamination in the peninsula results from agricultural washouts and pit latrine soakaways. Within the urban limits of Jaffna and Point Pedro high nitrate concentrations in some areas range from 122 to 174 mg/l, which can be attributed to sewage pollution from pit latrines. As noted above, the karstified limestone enhances the possibilities of such pollution. Of the wells monitored in one study 80 percent showed unacceptable bacterial quality due to sewage.

Leaching of pesticides into ground water may also occur in these agricultural areas, but no analyses have been carried out due to lack of facilities and funding for monitoring.

The Moratuwa urban council area, extending beyond Ratmalana, still uses ground water for potable water, although pipeborne water from Colombo reaches the town center. Sewage disposal is by septic tanks or latrines. The population of 135,000 inhabitants occupies an area of 13.1 square kilometers -- making the area second in density to Colombo (Figure 7.27). Not surprisingly, fecally contaminated ground water (95 percent of samples studied in an area covering 1.5 square kilometers) has been reported in certain localities.

Differences in population densities affect nitrogen levels in ground water. Figure 7.28 shows the nitrogen generated by different population densities and the concentrations likely to reach ground water in areas using on-site waste disposal.

Where towns are rapidly expanding and dense housing communities develop, on-site sanitation systems are often favored, even though their potable water comes from ground water. Water treatment systems are simply too expensive and ground water offers the most cost-effective alternative. Hence, ground water protection has become a development imperative.

Water Quality at Ambatale Intake

Parameter		1988-1989	1973-1974
	Average	Range	Range
Dissolved oxygen mg/l	7.2	6.2-13.2	1.5-8.7
Conductivity (microsiemens)	34.8	27-44	-
pH (acidity)	6.5	5.9-7.0	5.1-7.5
Suspended solids mg/l	9.1	0.4-40	11.6-180
COD mg/1 (chemical oxygen demand)	19.7	4.6-50.6	1.2-3.9
Nitrate mg/l	0.12	0.02-0.2	0.25-2.65
Free ammonia mg/l	0.61	0.04-6.07	0.08-1.8
SAR(sodium absorption ratio)	0.38	0.1-2.3	

Source : NBRO (1989)

Figure 7.24

Estuaries and Lagoons

Sri Lanka's 1,585-kilometer coastline is broken by extensive lagoons, bays, brackish water lakes, and wetlands. (See Coastal Resources chapter.) Brackish water bodies include 80,000 hectares of estuaries and large deep lagoons, and about 40,000 hectares of shallow lagoons, tidal flats, mangroves, and swamps. Of the small lagoons, especially along the southwestern, southern, and southeastern coasts, only a few are open to the sea and then only for short periods. Large-mouthed lagoons at Negombo, Puttalam, and Jaffna are perennially open to the sea, and a few others, like Batticaloa, Kokkilai, and Nayani, form sand bars across their mouths during the dry season.

Pollution monitoring data on the numerous lagoons and estuaries are virtually nonexistent. Lower reaches of the Kelani have received some attention, but no detailed pollution studies have been made of the estuary.The same can be said for the Mahaweli estuary and other lagoons and coastal water bodies. In part this neglect stems from priorities favoring study of areas most seriously affected by pollution from large populations. No major lagoons, except at Jaffna, are linked to urban centers with populations over 60,000, and no coastal towns are heavily industrialized except around the Kelani estuary. No other large riverine or basin estuary receives industrial waste. Consequently, with the assimilative capacity of the sea, pollution loads have so far been absorbed.

Pollution of the small lagoons and bay estuaries is much more serious, however. Lunawa Lagoon, the Bolgoda-Panadura riverine estuary, and Valachchenai Lagoon show how urban and industrial waste disposal affects the marine environment.

The Lunawa Lagoon receives water from streams and rivers and is opened to the sea by human intervention every three to four weeks to prevent lowland floods. On the average it receives 81 tons COD and 43 tons SS during each year from surrounding residential and industrial development. Sewage and industrial waste have made the two main feeder streams (five in all) completely anaerobic. The northern lagoon is eutrophic and exhibits higher levels of nutrients and pollutants (Figure 7.29) than in the southern section. Lagoon pollution has caused sediment buildup, although sediment quantity and quality data are not available. Eutrophication has set in and the lagoon has lost much of its value for recreation and prawn and fish culture.

Some Constituents of Mahaweli Water

Parameter	Range ppb
Copper (Cu)	4-37
Zinc (Zn)	2-270
Lead (Pb)	1-4
Cadmium (Cd)	1-2
Chloride (Cl)	11-27
Nitrate (as nitrogen) (NO3-N)	480-3100
Phosphate (PO4)	37-473

Source:Dissanayake and Weerasooriya (1986)

Figure 7.25

Average Metal Contents in Mahaweli and Kelani

Constituents	Mahaweli (ppb)	Kelani (ppb)
Cadmium	1	-
Cobalt	5	-
Lead	3	9
Zinc	58	53

Source : Dissanayake and Weerasooriya (1986)

Figure 7.26

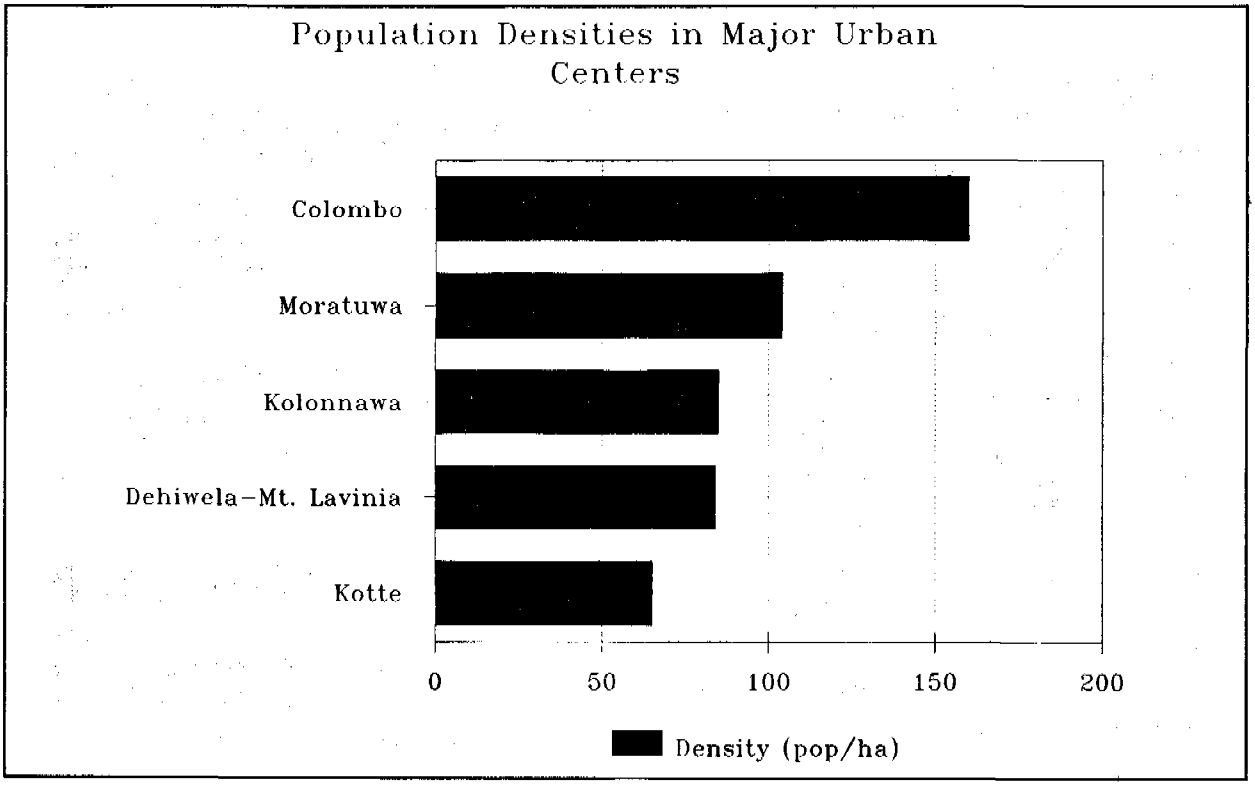


Figure 7.27

The Panadura-Bolgoda estuary, which also receives urban and industrial waste, showed BOD values ranging from 10-100 mg/l during spring tide. Background levels are relatively high even for marine waters.

The Valachchenai Lagoon receives its waste from a single industry -- a government paper factory whose discharge causes significant pollution. Waste loads of 18,000 kg suspended solids and 9,000 kg BOD_5 reach the lagoon daily.

Figures showing fishery declines caused by estuarine and coastal water pollution are not available but isolated cases of such pollution leading to economic losses have become increasingly common. The sea can assimilate large quantities of industrial wastes, but like every other recipient it too has limits. Coastal marine pollution has become an increasing problem around the globe, and Sri Lanka can be vulnerable, too. Rapid economic development envisaged for the future, with attendant rise in tourism, will require immediate attention to the impact of pollution o

Other Forms Of Water Degradation

Throughout the country, each watershed is likely to have its own peculiar mix of water degradation problems. Along with water pollution from industrial facilities and urban communities, other other adverse impacts on water quality may be significant as well. The mineral chapter discusses sand and gem mining impacts in riverbeds leading to bank erosion and deregulation of water flows. Land clearing, deforestation, and steep slope cultivation cause soil erosion and siltation that contributes to sedimentation and destabilized seasonal water flows in rivers.

IMPACTS

Economic, social, health, and biological impacts of water pollution interlink and cannot be viewed in isolation. All impacts cannot be quantified but efforts can be made to improve our ability to measure the long- and short-term economic costs of water degradation and the lost benefits of water quality.

The high economic costs of water pollution in Sri Lanka have not been, but can and should be calculated. Pollution of surface and ground waters requires costly treatment to meet potable water demands of expanding populations. Pollution of inland and estuarine waters supporting fisheries has resulted in heavy economic and social loss to fishermen. Pollution of water bodies and waterways in our cities contributes to a loss in aesthetic value, and may reduce diversity in plant and animal species in fresh and estuarine waters. (See Biodiversity chapter.) Most of these impacts can be quantified, and many can be put into economic terms: they include lost fisheries, lost income to fishermen, tourist companies and guides, costs of pollution controls, water treatment facilities, and so forth. Such measurements, however imperfect, offer rational ways to rank priorities for anticipating and preventing, as well as treating, water pollution problems.

Water-borne diseases caused by polluted water, although not precisely evaluated, have increased costs of health care in cities, small towns, and rural areas. Despite some improved health care, the numbers of people affected by water-borne diseases have increased. The frequent outbreaks of such disease are evidence of the increased water pollution.

LEGAL AND INSTITUTIONAL RESPONSE

Heightened concern about environmental pollution has come recently, but because water is one of humankind'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, from the purely advisory and coordinating scheme of the Water Resources Board Act of 1964 to the regulatory approach of the National Water Supplies and Drainage Board Act of 1974, dealing with aspects of pollution control. (See Figure 7.30.)

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. The National Environment Act of 1980 with its Amendments of 1988 stands as the most important single piece of legislation on environmental protection and management. Pollution control is to be

Ground Water Pollution In Jaffna

Beneath the Jaffna peninsula and the islands in northern Sri Lanka are sedimentary limestones more than 50 meters thick, and within these Karst formations are large quantities of ground water that serve the population and its agriculture. Pollution now threatens its long-term value and sustainability.

About 30 to 32 percent of Jaffna's rainfall -- 1,255 mm annually -- recharges its groundwater, while the rest evaporates or runs off. Recharge to groundwater in the peninsula depends almost entirely on rainfall percolation. The water table fluctuates in response to the rainfall, rising in the wet season and falling in the dry season. Fresh water forms lenses up to 24 meters thick, and these overlie the saline ground water that connects with the sea.

Ground water is the peninsula's only potable water source, exploited mainly through large diameter hand-dug wells. Of the more than 100,000 such wells, over 25 percent are for irrigation. Since introduction of mechanical pumps, largely in the 1960s, pumping in excess of safe yield has led to over-extraction. Most of the water pumped comes from the storage below sea level. As a result the fresh-salt water interface continues to rise. Storage is replenished during the monsoonal rains, when water levels rise and the fresh-salt water interface is lowered. If annual recharge to the aquifer is less than annual discharge the long-term position of the interface will be higher and wells will become increasingly saline.

The major problem with ground water quality is high chloride concentrations. Data from the Water Resources Board indicate a sharp increase in ground water chloride concentration as one goes deeper, from less than 400 milligrams per liter to more than 900 milligrams per liter. Areas of the peninsula experiencing high chloride concentration generally occur where pumping from wells has caused a rise in the lower boundary of the thin fresh-water lens that overlies saline water. About 23 percent of the peninsula now experiences or is prone to receive saline water in the dry season. This declines to 10 percent in December. About 15 to 22 percent of the peninsula receives moderately saline water.

Salinity distribution in the peninsula is very much related to population density and land use. Average population density of the peninsula is 430 per square kilometer, compared to national density of about 250 per square kilometer, and 1170 per square kilometer in the Western Province. About 60 percent of the peninsula is occupied by residences and home gardens, 13 percent is under subsidiary crops, and 12 percent lies under paddy cultivation. The island lagoons take up about 10 percent and the balance remains undeveloped and largely unused.

Intense urban development and agricultural activity in the densest western peninsula (800-1,200 people per square kilometer) has resulted in ground water overdraft far in excess of replenishment. The serious implications of these trends -- a peninsula essentially devoid of fresh water, at least in the dry season -- require restrictions on new wells including careful regulation of size, diameter and the distance between wells.

Intensive agriculture with increased chemical inputs also raises fears of ground water pollution -- a problem compounded by urban sanitary conditions. Most Jaffna residents lack sanitary toilets, and a large number of septic tank systems contribute to the deteriorating water quality.

Ground water of the Jaffna peninsula has the highest nitrate content in Sri Lanka. Nitrate levels directly relate to population density and organic pollution.

Jaffna's nitrate levels exceed WHO limits by 100-150 percent. A detailed study of the ground water contamination based on case studies in the Jaffna peninsula (Gunasekaram, 1983)found that 80 percent of the wells yielded water of poor bacteriological quality with high levels of fecal coliform. Among the major factors responsible:

- Discharge of human excreta. Soakage pit/septic tank effluents discharge directly underground. In densely populated urban areas the distance between soakage pits and wells is as short as 6 meters.
- Excessive use of agricultural fertilizers. Farmers mainly use urea, which contains 46 percent nitrogen. Excessive use of urea on crops such as chillies and onions is common everywhere. In addition cattle-manure is often used as a fertilizer, which adds more nitrogen to ground water.
- The ready solubility of urea. Urea easily reaches the shallow ground water table, and under normal conditions about 75 percent of the nitrates applied reach the ground water body.

The abundant nitrogenous waste from human excreta and synthetic and animal fertilizer easily percolates to the shallow ground water table through the cavernous limestone aquifer. Geological conditions are ideal for the excessive accumulation of nitrates.

Ground water pollution and over-pumping in the peninsula result from various activities. The increasingly urgent need to protect and enhance supplies of fresh water in the peninsula requires careful management that only peaceful conditions can create.

achieved through permit regulation under the Central Environment Authority (CEA). All stationary sources, existing and new, that emit any form of waste-causing pollution will require environmental licences to meet legally binding pollution standards.

The CEA's pollution control program has only recently begun. Polluting industries will be issued annually renewable licenses by CEA. Local authorities or Provincial Councils will be delegated the authority to license small- and medium-scale enterprises under the licence system initiated on 1 July 1990.

With proper enforcement, liquid effluents from industries and other stationary and point sources can be controlled through these regulations, but they will not control pollution from non-point sources such as runoff from cultivated or cleared land or urban streets. Other strategies will have to be adopted within the framework of a comprehensive environmental policy.

Water quality monitoring, analysis, and research will be essential to support the permit system and to identify water quality conditions and trends. Legal responsibilities for these activities vest in several different agencies operating in local or regional areas -- such as the Mahaweli Authority in its jurisdiction, Greater Colombo Economic Commission (GCEC) in its. Nationally, the CEA has water authority, along with its regulatory responsibilities. The Coastal Conservation Department (CCD) has authority to make water quality findings in the coastal zone and to regulate discharge within it.

NARA has the broadest national responsibilities for scientific, research on aquatic resources -- defined as "all living and non-living resources contained in or beneath the medium of water." Its authority includes the collection and dissemination of aquatic resource data, and the conduct of research on development, management and conservation of aquatic resources. It also has the authority to prepare an Aquatic Resources Management Development and Research Plan, although without any specified regulatory or management authority. NARA carries out water quality monitoring for industries regulated in the free-trade zone by the GCEC.

KEY ISSUES

Domestic Waste Management

Integrated environmental management for polluted waterways and water bodies in Sri Lanka's cities is essential. Urban areas cause and suffer from the most serious water pollution, although by Asian and world standards even Colombo is not a large city.

Chemical Pollution of Groundwater

Population per ha	Nitrogen kgN/ha/yr	Maximum leachate concentration mg/NO3/l assuming following % of N in Human waste are mobilized		
		10%	30%	70%
50	250	55	166	388
100	500	110	330	775
250	1000	220	660	1550

Source : Lawrence (1988)

Figure 7.28

Pollutant levels in Lunawa Lagoon

	Northern	Southern
DO mg/l	0.7-15	7-10
COD mg/l	20-140	50-100
SS mg/l	50-170	50-60
Nor-N mg/l	<0.1	<0.1
Total P mg/l	0.3-3.4	0.2-1.3

Source : NBRO (1989) Water Quality Monitoring Data at Ambatale

Figure 7.29

Urban management programs for sewage and garbage disposal require high priority, and relationships between water supply and waste disposal systems must be recognized in urban planning and project development. Impacts of urban commercial developments, housing, and roads on water pollution -- from surface run-off, canal drainage, and ground water seepage -- must become the concern of local authorities, central agencies, businesses and banks, and the donor community. Intergrated environment management plans for polluted waterways and waterbodies in the major cities is the first essential step.

The feasibility of sewerage schemes for major cities is being explored by the NWS&DB. Options like a city center sewerage network combined with on-site sanitation for peripheral areas can be studied to minimize cost only if urban authorities keep population densities below a critical level. Yet careful planning for high urban densities may be necessary to relieve pressures on critical rural resources, including forests, habitat, and prime agricultural lands.

All aspects of the problem must be incorporated into management programs. A common failing in the system of approving buildings is that issuance of certificates of conformity has become a mere formality. As a result many illegal sewer connections, and connections from household sullage drains to storm drains, eventually discharge into surface waterways. No less important are impacts from the informal sector. Sewage from low income settlements can no longer be considered negligible and ignored.

Industrial Waste Management

Industrial water pollution is within manageable levels because levels of industrialization have so far been low in Sri Lanka. For CEA's pollution control strategy to be successful, state-owned industries as well as large scale private sector industries must adopt pollution control measures. Small- and medium-scale operations will often need to control pollution through common facilities that bring economy of scale. Planning such facilities for scattered existing industries will be difficult but future siting of such industries in estates will facilitate common treatment. The priority for existing industries is to encourage as much low-cost primary treatment as possible prior to discharge.

Facilities must be provided for disposal of toxic industrial chemicals, including chemical sludge from treatment plants containing toxic wastes. Controlled landfills or incinerators must be provided.

Expertise on industrial waste treatment technology is badly needed. It is not readily available in Sri Lanka, and some must be imported.

Recognizing the limited funds available for direct government research and development, incentives must be given to the private sector to encourage investment in programs that will bring them, and the community at large, long-term benefits. Increasing numbers of environmentalists and economists emphasize the need to design legislation that not only sets optimal quality standards and allows careful monitoring and rigorous enforcement, but also incorporates economic incentives and allows industrial managers to determine how best to achieve pollution control goals. Pollution can be minimized by making it costly to pollute and profitable to change production processes or install pollution controls.

Economic incentive schemes to reduce pollution will require careful monitoring of effluent quality. Quality standards are necessary, based on the pollution levels a water body and its biological systems can assimilate and sustain over time, and what is necessary to protect human health. As in any approach, discharge of highly toxic pollutants will need to be prohibited entirely. To ensure that industries internalize the costs of their environmental impacts, fees might be established for industrial effluent, and penalties carefully set and rigorously enforced.

Agricultural Waste Management

Agricultural waste disposal and pollution from pesticides have not become major environmental problems because agro- and livestock-based industries have not yet fully developed. Problems need not develop so long as management and control of these impacts occur along with agro-industrial development. Strategies for agricultural waste management should depend on the type of expansion and activity planned. Small- and medium-scale livestock-based industries, for example, might stress size and dispersement criteria for waste management, because waste treatment technologies may be too costly. Large-scale developments may require centralized pollution control management made feasible through economies of scale.

A coordinated program for collecting data on various agro-industrial sectors, with particular emphasis on their water pollution potential will establish bases for future strategic planning. Similar data collection is needed on agricultural practices relating to land and chemical use.

Ground Water Management

Ground water assumes major importance in Sri Lanka because of its potential as an abundant, clean source of increasingly necessary supply, yet contamination threatens this development in urban and rural areas alike. Once polluted, ground water may be impractical to clean up. The economic and social costs of contamination are unusually high.

Long-term ground water management is already necessary. Systematic monitoring of ground water is a first, essential requirement, and a monitoring network must be established and coordinated by an agency. Ideally, the agency should also be responsible for ground water protection and use.

Research and Data Generation

Future pollution control requires much better generation and collection of all water-related data. Methods of identifying and obtaining environmental data require study and major reform. An idea worth

Environmental Legislation relating to Water

Name of Legislation	Pollution	Resource Management
Thoroughfares Ordinance and Act (1861)	x	
Irrigation Ordinance (1900)	x	x
Colombo Muncipal Council Waterworks Ordinance (1907)	x	
Crown Lands Ordinance (1947)	x	x
Water Resources Board Act (1964)	x	x
National Water Supply and Drainage Board Law (1974)	x	
Sri Lanka Ports AuthorityAct (1977)	x	
Agrarian Services Act (1979)		x
National Aquatic Resources and Development Agency Act (1981)	x	x
Coast Conservation Act (1981)	x	x
Marine Pollution Prevention Act (1981)	x	
National Heritage and Wilderness Act (1988)	x	
National Environmental Act(1980) and Amendment (1988)	x	x

Figure 7.30

exploring is the establishment of environmental units within each relevant agency, to provide such information to a centralized coordinating agency. Research requirments in the field of water pollution control will readily emerge from such an exercise.

Surface Water Quality Monitoring and Control

A surface water quality monitoring network is long overdue and must be established without delay. Unlike ground water, still a source of untreated water supply, surface waters have become heavily polluted and are secondary sources of untreated water even in village communities. Declines in surface water quality are increasingly neglected, perhaps because they reflect expected trends.But as the developed world has learned to its peril, most recently in Eastern Europe, surface water pollution can quickly become an uncontrolled major health and biological hazard. A network is essential to ensure that basic human health standards and ecological processes are maintained as law requires.

Within the framework of such a program, monitoringof the Colombo city sewage outfalls must also be undertaken. Only through such monitoring can changes in coastal water quality be recorded and remedial action taken.

Waste Reduction Technologies

For developing countries in particular, economic growth and environmental protection require cost-efefective waste reduction technologies. Many countries, including Sri Lanka, have experienced the adverse economic effects of expensive and complex pollution control equipment that cannot be well maintained and efficiently used. Small-scale industries with limited access to speialized skills require appropriate technological responses that may be unlike those often employed in developed countries, yet far too little attention has been given to these particular neds.

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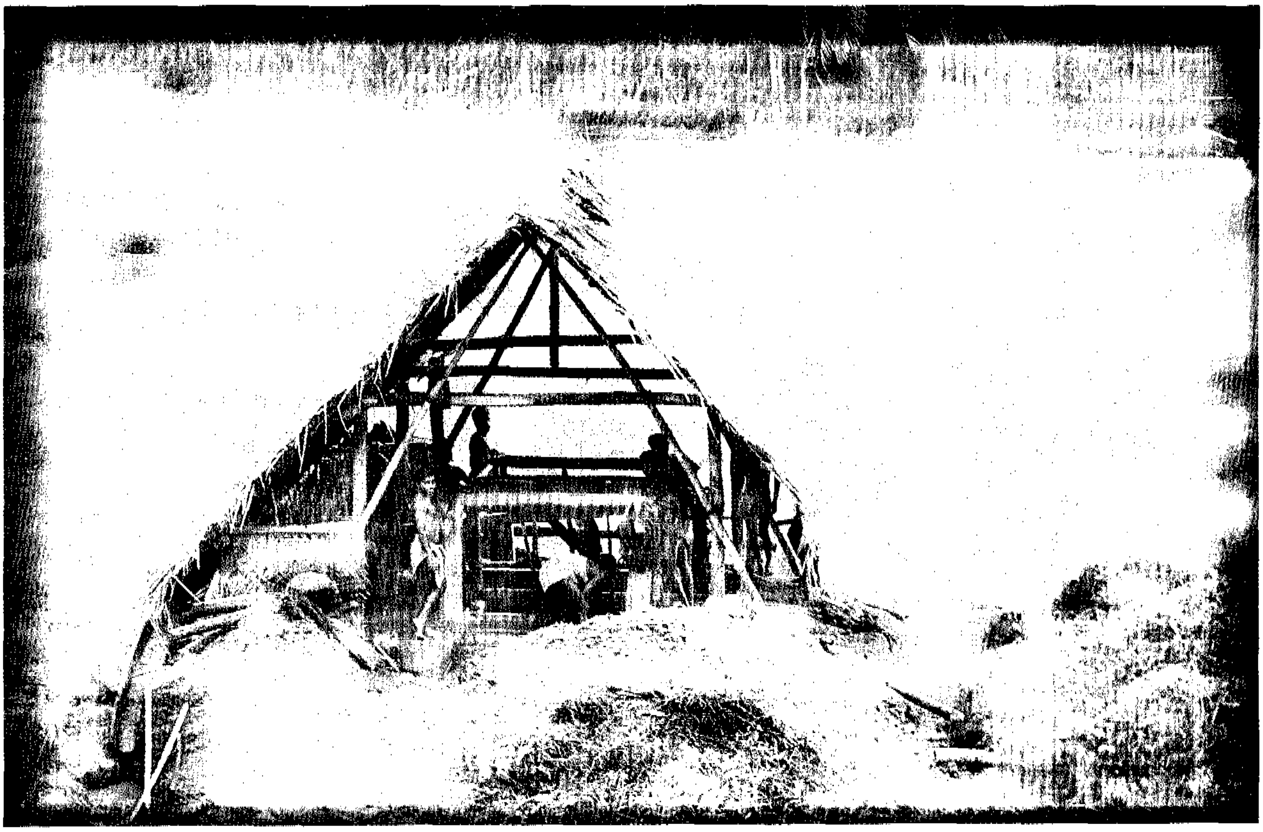


Small gem pits like this one produce gemstones unique in quality and variety. Gemstones are the country's most important mineral resource.

8 Mineral Resources

Sri Lanka, for its size, is reasonably well endowed with mineral resources (Figure 8.1), and mineral exports account for about 5 percent of the nation's export earnings (Figure 8.2). There are abundant gems, sufficient non-metallic minerals and modest quantities of metals.

The only fossil fuel consists of 50 million tons of peat, in the Muthurajawela marsh north of Colombo, whose low calorific value makes it uneconomic as a fuel. Exploration for offshore oil deposits beneath the northern continental shelf since the mid-1970s has, so far, yielded no promising results.

Many minerals are not presently economical to mine. These include several nuclear raw materials in the Ratnapura District and along the southwest coast, iron ores in Puttalam and near Trincomalee, and copper-magnetite-apatite at Seruwawila, south of Trincomalee.

Beach mineral sands in the northeastern, southern, and southwestern coasts form a major ceramic mineral resource: these include ilmenite and rutile, used to extract titanium and in producing light alloys; zircon, used for ceramics and many alloys; and monazite, a phosphate containing the nuclear raw material thorium.

Among non-metallic minerals are sizeable deposits of graphite, clays, mica, phosphate, and limestone. High quality graphite is still mined from veins in Bogala, Kahatahaha, and Kolongaha for export, to be used for such items as pencils, lubricants, electrodes and carbon rods. Sri Lanka has no significant graphite based industries. Clays for ceramic, paper, and cement industries are abundant. A deposit of kaolin (china clay), in the suburbs of Colombo is estimated at 1 million tons. Deposits of refined kaolin and ball clay have recently been discovered with 350,000 and 500,000 metric tons. Silica sands needed for the glass industry are found in reserves of about 6 million tons.

GEMSTONES

Sri Lanka has been known for over 2,500 years for gemstones unique in quality and variety, and today they are the country's most renowned and important mineral resource (Figure 8.3). Of the 5 percent mineral export earnings, 60 percent comes from gemstones (Figure 8.2).

Gemstone deposits lie within a geologically narrow zone (240 by 64 square kilometers). Recent geological surveys suggest that the potential for gemstones is about 50 percent higher than hitherto expected and many new gem fields have been located in the central highlands and southwestern geological formations.

Gem minerals are obtained from eluvial, alluvial and residual formations. The Sabaragamuwa Province, with Ratnapura as its leading center, contains approximately 80 percent of the gem mines, but gem potential is also high in the areas peripheral to its main gem fields.

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 bed rock termed "Malawa".

Gem Mining

Most gem mining has changed little in Sri Lanka since it began. The most common method is small-scale pit mining with lateral tunnelling. Riverbed mining is also common. Large-scale surface mining, using mechanized earth moving, was begun, but is not presently carried out.

Pit mining, by far the most common method, involves construction of vertical mines as deep as 30 meters, with horizontal tunnels averaging about 10 meters in length. Gem gravel is removed from the *illam* and washed and sorted it in wicker baskets placed in

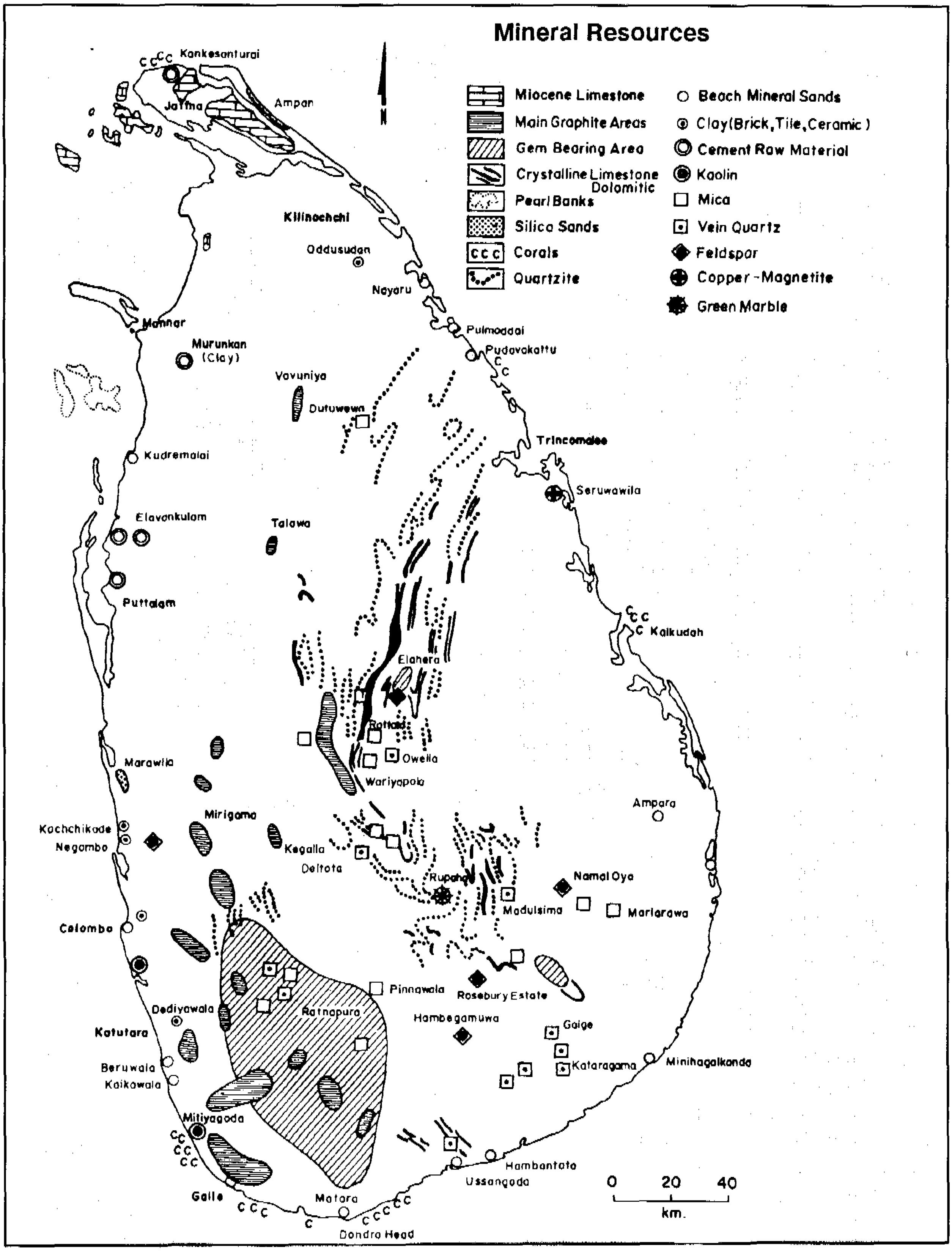

Mineral Resources
Miocene Limestone
Main Graphite Areas
Gem Bearing Area
Crystalline Limestone Dolomitic
Pearl Banks
Silica Sands
Corals
Quartzite
Beach Mineral Sands
Clay(Brick,Tile,Ceramic)
Cement Raw Material
Kaolin
Mica
Vein Quartz
Feldspar
Copper-Magnetite
Green Marble
N
Kankesanturai
Jaffna
Ampan
Kilinochchi
Oddusudan
Nayaru
Mannar
Pulmoddai
Murunkan (Clay)
Pudavakattu
Vavuniya
Dutuwewa
Trincomalee
Kudremalai
Seruwawila
Elavankulam
Talawa
Puttalam
Kalkudah
Elahera
Rattota
Owella
Marawila
Wariyapola
Ampara
Mirigama
Kochchikade
Negombo
Kegalla
Deltota
Rupaha
Namal Oya
Madulsima
Mariarawa
Colombo
Pinnawala
Rosebury Estate
Dediyawala
Ratnapura
Hambegamuwa
Galge
Kalutara
Kataragama
Minihagalkanda
Beruwala
Kaikawala
Mitiyagoda
Hambantota
Ussangoda
Galle
Matara
Dondra Head
0 20 40
km.

Figure 8.1

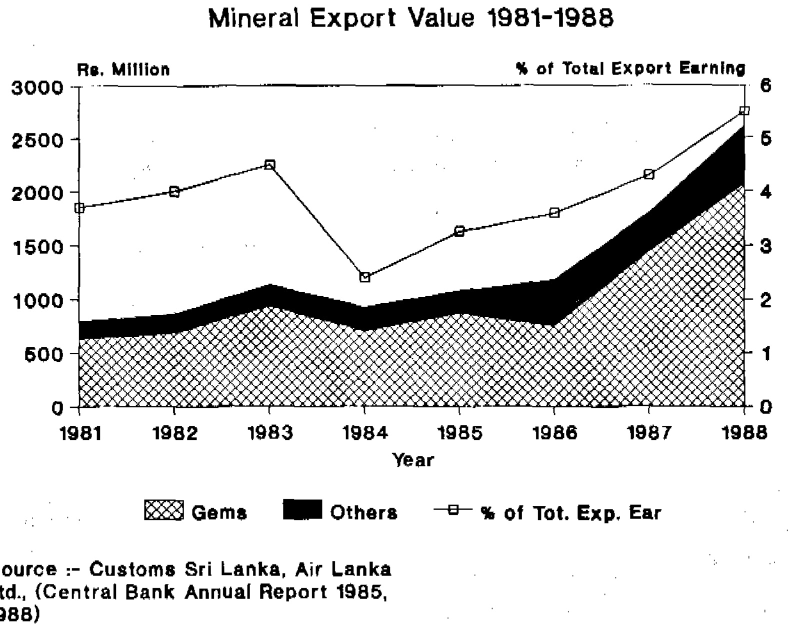


Figure 8.2

Varieties of Gem Exports

Year	Variety	Weight in carats	Amount in Rs.M.
1985	Blue Sapphire	47,260.71	126.0
	Star Sapphire	192,154.74	72.5
	Ruby	1,834.15	5.9
	Star Ruby	4,445.76	19.8
	Cat's Eye	24,486.83	79.2
	Alexandrite	832.12	14.4
1986	Blue Sapphire	53,917.19	173.2
	Star Sapphire	249,746.23	91.8
	Ruby	1,396.83	9.3
	Star Ruby	3,499.65	11.2
	Cat's Eye	28,371.09	126.4
	Alexandrite	624.40	19.6
1987	Blue Sapphire	51,191.14	363.3
	Star Sapphire	186,781.98	177.0
	Ruby	1,617.20	18.9
	Star Ruby	4,349.19	17.4
	Cat's Eye	27,978.63	221.0
	Alexandrite	585,2720.00	
1988	Blue Sappire	56,552.30	419.9
	Star Sapphire	191,431.19	231.7
	Ruby	2,14.19	25.5
	Star Ruby	5,694.23	36.0
	Cat's Eye	26,845.32	235.4
	Alexandrite	650.16	30.2

Source: State Gem Corporation

Figure 8.3

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 labor has made this simple, almost primitive mining method viable for many decades.

Streambed mining involves the damming of streams and small rivers by logs, sand bags and other materials. Workers use long shovels and *mamoties* to drag streambed material above the dam, there to separate out and store the heavy mineral fraction, which includes gemstones, for later washing and sorting. Stream banks are also subject to removal.

Large-scale mechanized mining was authorized by the Cabinet in 1985 on 666 hectares of state land in the Matale district, close to Wasgomuwa National Park and the Kalu Ganga. The mining plan allowed the lessee to mine separate blocks of 20 to 30 hectares carried out in long trenches of 100 meters by 20 meters, reaching a depth of 5 meters -- well above groundwater levels -- with separate removal and stockpiling of topsoil, subsoil, and gem bearing gravel (*illam*) layers. *Illam* would be mechanically washed with water from new reservoirs recycled through settling ponds and gems removed by a final manual sorting. Tailings -- 60 percent of the volume of the gravel layer removed for washing -- would then be placed back in the pit, followed by subsoil, topsoil, contouring and revegetation. Mechanical mining has evaded controversy over its environmental and employment impacts and has been carried out on a limited basis in Sri Lanka.

The Gem Industry

As highlighted by the National Export Development plan for 1983-1987, gems and jewelry -- the latter requiring imported gold or silver -- have high potential for foreign exchange and employment generation.

The State Gem Corporation, established by Parliament in 1971, regulates gem trade by issuing licences to miners, gem auctioneers, traders and lapidarists. The gem trade is largely carried out by the private sector.

Despite great potential for a thriving gem industry, export stagnation or decline has occurred recently, primarily due to smuggling and drops in tourism. Approximately 80 percent of the value of gems exported is not accounted for through official channels. Smuggling results from several factors: high demand for foreign exchange, desires to avoid income taxes, and the ease of transporting small gemstones that might bring a profit of 500 to 1,000 percent. An added incentive for gemstone exporters to engage in smuggling is to avoid cumbersome bureaucratic procedures for legal export.

Emerging Market Trends

The gem industry could benefit from an expanding market coupled with rising prices. Asia has emerged as the world's largest and fastest growing market for colored gemstones, with demand strongest in Japan and Taiwan. Expanding business in many Asian countries has prompted many dealers in Europe and the United States to establish centers in Asia. In 1987 Japan replaced the United States as the world's largest importer of colored gemstones. Japan buys at higher prices than buyers from the U.S.A. or Europe. Taiwan is also emerging as a leading gem buyer for rare and expensive stones, and in South Korea, Indonesia and the Philippines the prices of most colored gemstones have shown an upward trend.

With its adequate supplies the Sri Lankan gem industry can benefit from these markets if it can overcome a number of serious technical and policy problems, including environmental hazards. There appears to be a greater demand than supply for good quality stones, particularly for gemstones such as ruby, emerald, sapphire, alexandrite, aquamarine, pink tourmaline and blue topaz. Recent discoveries of topaz have opened up further possibilities for the gem industry of Sri Lanka because the blue topaz market has recovered from a slump in the mid-1980s caused by a radiation scare. (Topaz stones receive their brilliant blue color from radiation treatment, a process not carried out in Sri Lanka.)

There is a ready market in Japan for high and medium quality sapphires in all sizes, priced from 300 US dollars per carat, but supplies in Sri Lanka are low. The supply of fancy (non-blue) sapphires from Sri

Estimate of Average Annual Employment in the Gem, Jewelry & Lapidary Industry (1972-1984)

			Total
(1)	Licensed miners	60,000	
	Illicit miners	40,000	100,000
(2)	Licensed Gem Dealers	2,250	
	Assistants	11,250	13,500
(3)	Unlicensed Gem Dealers	30,000	30,000
(4)	Licensed Lapidarists	370	
	Assistants	2,230	2,600
(5)	Jewelry Manufacturers mainly connected with the gem industry	2,000	2,000
(6)	Staff of the Gem Corporation	500	500
			148,600

Figure 8.4

Lanka has increased, however. Another gemstone popular in Japan is alexandrite, but finds are rare.

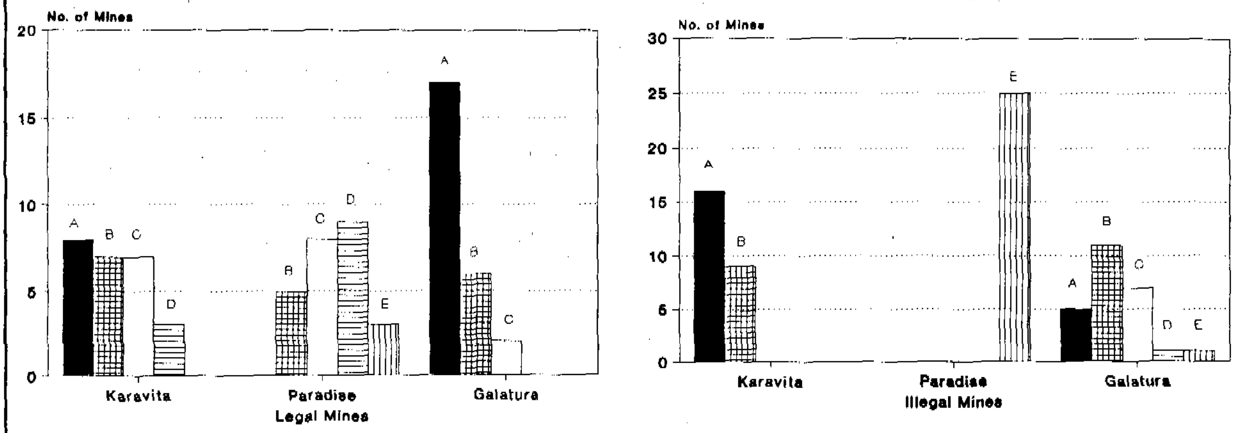
Geuda to Sapphire - The Addition of Value

If Sri Lanka can add value to its gems, earnings can rise even without more production. To realize the full potential of the gem and jewelry sector, the Sri Lanka Export Development Board has sought to reduce export of geudas in unprocessed, uncut form.

The term "geuda" refers to stones in the corundum family -- to which sapphires and rubies belong -- that have a smoky, milky or murky appearance and which can be heat-treated to improve color and clarity. They constitute about 30 percent of the stones in the corundum family, as do the "ottu" and silk yellow sapphires. Gemologists have observed that heat treatment can transform some geuda corundums into high quality blue sapphires, which could dramatically increase mining yield of exportable stones. Guneratne (1981) has described the variety most likely to produce good blue sapphires as those "having a very faint powder blue tint, display a milky white sheen and when held against a light source give the colour of clear thin honey."

The science of heat treatment of these geuda stones and high value addition has been mastered by Thais who buy them in Sri Lanka in massive quantities to be sent to Thailand for heat treatment. Implementation of the Thai-Sri Lanka Geuda Agreement in 1987 sought to regulate the geuda trade. During its first year the agreement brought in 18 million US dollars, which proved to be substantial, when compared to the earnings from gem export. However, in spite of the seemingly positive trends in the geuda export, smuggling continued and the better quality stones appeared to be illegally channelled out. Geuda trade undoubtedly helped Thailand to become the 'Gem Centre of the World' particularly in the blue sapphire market, and Sri Lankan geuda stones contributed enormously. Hence the Government decided in mid-1990 to terminate the Thai Geuda Trade Agreement and plans to establish a Gem Research Institute, entrusted with the task of carrying out research in the successful local conversion of the geuda to sapphire.

Annual Soil Extraction from Average Mine (Cubic Meters)



A = 1 - 28 B = 28 - 56 C = 56 - 84 D = 84+ E = Unable to Estimate

Source : Field Study, Ratnapura District 1985/1986 (Jayanthi de Silva - 1987)

Figure 8.5

Environmental Impacts

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 stream-bed mining involve different types and amounts of waste gravel, water use, and reclamation costs.

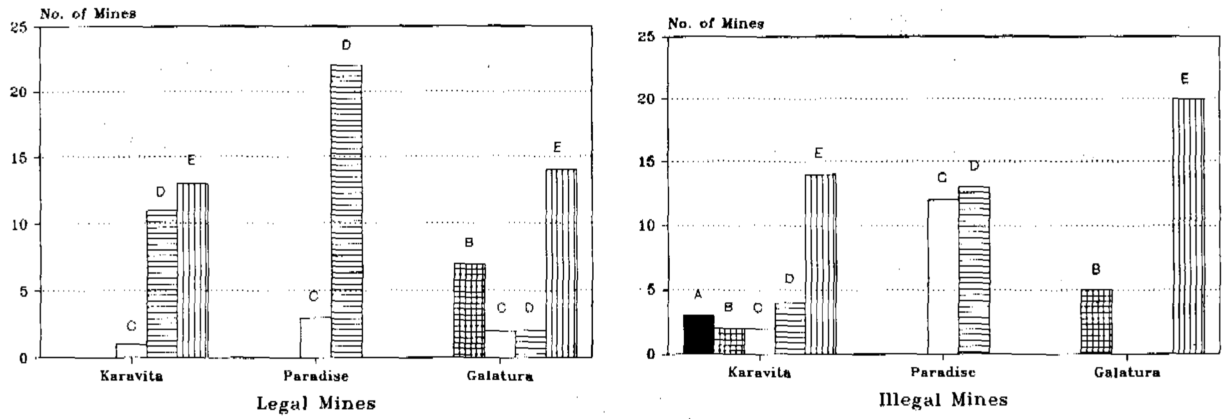
Large numbers of mines, contribute to the environmental problem of gem mining. The State Gem Corporation issues about 3,400 gemming licences each year, allowing each licence holder to dig from two to four gem pits at a time. Approximately 10,000-15,000 gem pits operate legally in the Island; an equal number are illegal. Traditional gem pits are worked by six persons so approximately 60,000-90,000 persons are engaged in gem mining. Adding the illegal mines, the total number of people directly involved in gem mining is about 135,000. Figure 8.4 gives an estimate of the employment in the gem industry.

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:

- stream bank mining,
- removal of vegetation cover for gemming,
- the process of washing gem *illam* in water bodies where clay and silt particles are added to rivers, streams or canals.
- deposit of sediments in rivers, streams and canals when mine waters are discharged from working mines, and
- erosion of soils from unstable soil heaps (mine spoils) that are accumulated around gem pits.

Estimates have been made and the quantities of soil extracted from an average gem mine in the Ratnapura District (Figure 8.5). Each mine in Karavita unearths over 56 cubic meters of soil annually. Nearly half the legal miners -- and probably most or all of the estimated 60 percent of local miners operating illegally -- leave most of their soils as heaps around the mines (Figure 8.6). Rain and floodwater carry this sand, silt and clay to nearby streams, rivers, low-lying areas, or paddy fields, causing sedimentation. Discharge of water pumped from mines adds to these impacts (Fig-

The Proportion of Excavated Soils that Remain as Soil Heaps Around Gem Pits

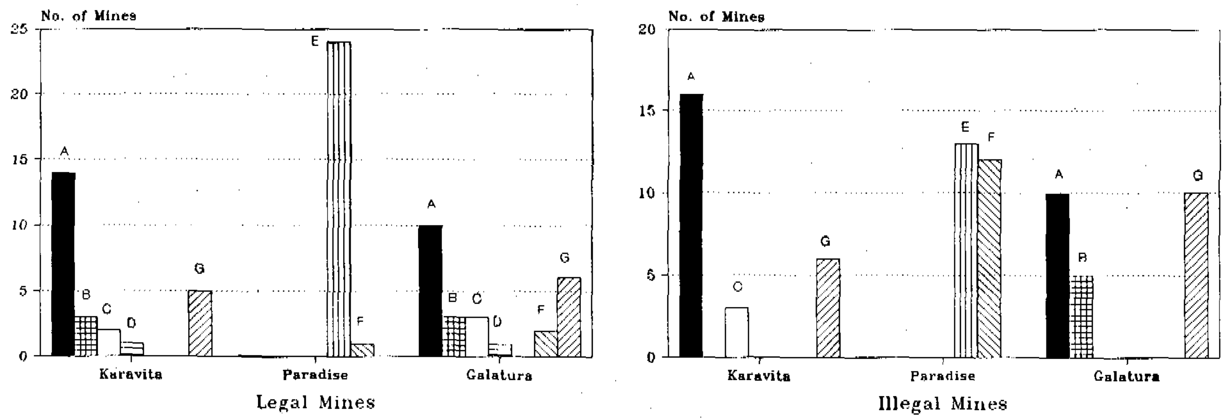


A =1 - 25 **B** = 26 -50 **C** = 51 - 75 **D** = 76 - 100 **E** = River Bed/River

Source : Field Study Ratnapura District 1985/1986 (Jayanthi de Silva - 1987)

Figure 8.6

Methods Adopted to Discharge Waters in Gem Pits



A = Directly To River
B = Via Canal
C = Via Drain
D = Along Paddy Fields
E = To Land
F = To Gem Pit
G = River Bed Mines

Source : Field Study Ratnapura District 1985/1986 (Jayanthi de Silva - 1987)

Figure 8.7

ure 8.7). The field study highlighted a number of adverse environmental effects caused by soil erosion and sedimentation during gem-mining:

- deposit of sediments in streams and canals,
- adverse effects on aquatic life,
- deposit of sediments in fish-spawning grounds,
- raising of stream beds that reduces the capacity of rivers to absorb flood waters,
- reduction of irrigation efficiency in canal systems, and
- water pollution.

Despite the unfortunate lack of comprehensive data on these environmental and economic effects, field observations testify to the environmental degradation caused by erosion and sedimentation from past and existing mines. It is clearly visible in muddy streams, eroded banks and increased flooding.

A highly visible environmental effect is the change of the landforms. Vast 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 meters in diameter. Stream banks in some instances have been expanded laterally by as much 38 meters. The extent and impact of these changes on land productivity need more precise measures to assess preventive and remedial action.

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 are still lacking, but resurgence of malaria in the main gem mining areas of Elahera and Ratnapura does not appear coincidental.

Regulation and Controls

Prevention and control of these environmental impacts suffer from many impediments. Environmental regulations for the large number of legal mines are inadequate and, in any event, unenforced. The State Gem Corporation's law enforcement staff of approximately 25 is clearly inadequate to enforce permit and bonding requirements. So is the level of public understanding of the problem by local residents, miners and officials, despite the fact that the locality itself incurs the costs of environmental degradation.

No less important is the proliferation of illegal, unpermitted, gem miners. Illicit mining continues despite enforcement provision, and there appears to be no sign of abatement. Among the major reasons for illicit gem mining are:

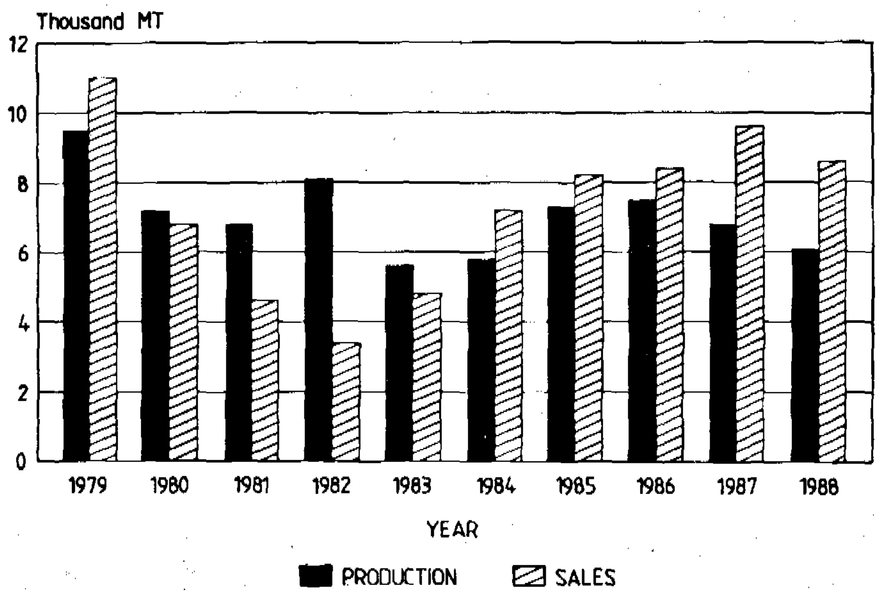
- Licence fees of 750 rupees per pit and 1,000 rupees for each additional pit. The fee for a pit in a rice field is 1,500 rupees.
- The need to share profits among participants, including the land owner, water pump owner, license owner. A miner very often receives about 5 percent or less from the total earnings of the pit. Illicit miners avoid many of these payments, along with environmental fines.

Among the measures that could bring about an effective and acceptable balance between gem mining and sustainable environmental management are conservation techniques to restore depleted gemming lands, incorporation of environmental factors into plans and permits for gem mining, continuous monitoring of compliance and of environmental conditions, and educating the local residents to the needs and benefits of environmental protection.

The best planning and management will fail where mining is illegal, so incentives to operate illegal mines must be removed or reduced. In other countries these kinds of abuses have been addressed through streamlined permit procedures, economic bonuses for legal mines, controls over corruption, community education, and high-level involvement in enforcement. Careful analyses may be necessary to assess the problem of illegal mining, and what can practically eliminate or reduce it.

Unlike traditional pit mines, large-scale open pit mining by heavy machinery disturbs large areas, but adverse impacts on soils and water can be minimized

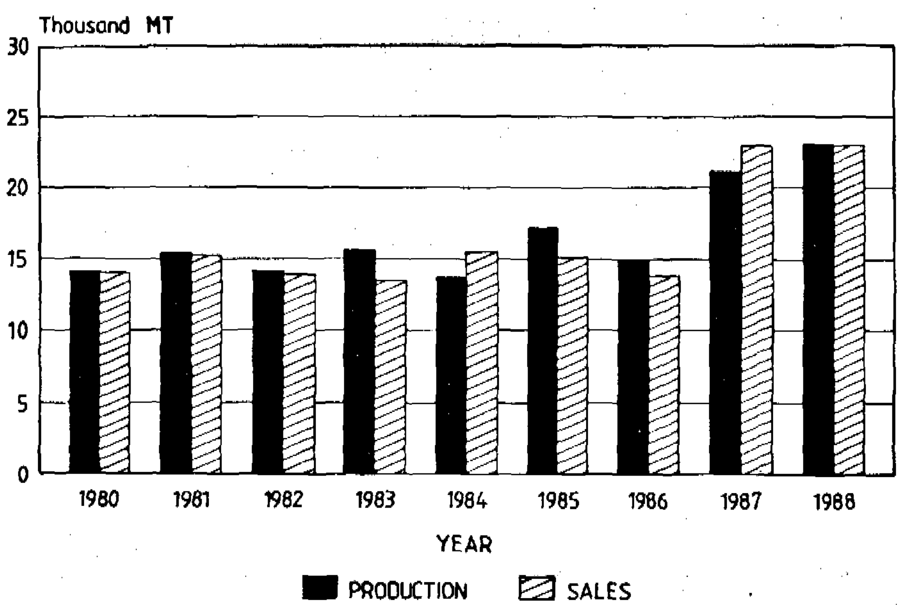
Graphite Production & Sales



Source : State Mining and Mineral Development Corporation

Figure 8.8

Phosphate Production & Sales



Source : State Mining and Development Corporation

Figure 8.9

through careful planning, monitoring, and implementation. At the outset, new access roads must be constructed to prevent erosion and minimize destruction of vegetation. Mining operators must control overburden disposal and drainage to arrest soil erosion and sedimentation, and ensure that water and settling ponds minimize surface and ground water pollution and water habitat for malaria-transmitting mosquitos. Reclamation requires precise replacement of overburden layers to reduce, if not prevent, future subsidence. To facilitate adequate moisture content for tree rooting, replaced subsoil must be carefully segregated from the gravel layer. Even after the surface is properly contoured it may remain, or become, uneven and unsuited to agriculture. Revegetation requires fast-growing cover crops and tree species, monitored and cared for to assure success. Long-term rehabilitation for wildlife or other uses may also become important.

Mechanized gem mining allows substantially more efficient exploitation of gems and potentially more effective enforcement of environmental requirements than traditional gem pits. On the other hand, its social impact can be more significant because it employs far fewer people and has been perceived as threatening gem miners' future employment.

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 the 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 tons, while a 1984 survey estimated the annual sand extraction at 916,000 tons.

Environmental impacts

Uncontrolled mining of river sand often leads to the collapse of river banks. Large-scale sand mining in the Badulla District has eroded river banks and affected the stability of bridges. In coastal areas the deepening of the riverbed below mean sea level creates conditions for an 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. A National Sand Study with Netherlands assistance has been proposed to ascertain the amount of sand which can be safely extracted annually, with minimal environmental impacts, covering river systems of Kalu Ganga, Kelani Ganga, Maha Oya and relevant adjacent coasts.

GRAPHITE

Sri Lanka has also been renowned for its graphite - the world's major source of high quality microcrystalline carbon material. The purity of Sri Lanka graphite is unparalleled at over 99 percent. The occurrence of graphite as massive veins occupying natural fissures in rocks allows relatively easy mining. Nearly 6,000 shallow pits and small mines operated during the two World Wars, and about half that number operate today, scattered throughout the country, particularly in the central and southwestern regions. The State Mining and Mineral Development Corporation (SMMDC), which controls the graphite mining industry of Sri Lanka, now depends on two main underground mines at Bogala and Kahatagaha.

Graphite mining has existed for about 165 years and was once perceived as of equal importance to tea, rubber, coconut and other exports. During the last few decades, graphite exports declined and since 1983 it has dropped to sixth place among Sri Lanka's exports. Graphite exports peaked during the two World Wars at 14,000 metric tons in 1916 and 28,000 metric tons in 1942, but in the last eight years production has averaged about 7,000 metric tons In 1982 traditional buyers of Sri Lankan graphite switched to other sources causing heavy losses, particularly in 1984. With the subsequent reduction in graphite prices, demand increased and net profits increased marginally.

Graphite production of a mine depends heavily on the width of the vein encountered in mining. Lack of proper equipment needed for this purpose results in poor prediction of vein width and subsequent drop in production. A major reason for low production of graphite in 1988 (Figure 8.8) was the destructive subversive activities in the months of November and December.

MINERAL SANDS PRODUCTION (MT) 1984 TO 1988

Year	Ilmenite	Rutile	Zircon	Monazite	HITI Ilmenite
1984	97,040	6,467	3,708	147	5,008
1985	114,954	8,605	4,061	80	7,734
1986	129,907	8,443	910	18	3,966
1987	128,490	7,238			3,938
1988	74,305	5,255			3,702

MINERAL SANDS EXPORTS (MT) 1984 TO 1988

Year	Ilmenite	Rutile	Zircon	Monazite	HITI Ilmenite
1984	130,957	4,612	3,329	606	
1985	147,666	8,374	4,548	397	
1986	95,298	7,249	34(Bags)		17,625
1987	106,722		1,700(Bags)		
1988	91,879	13,759			5,207

MINERAL SANDS EXPORTS VALUE (Rs.'000)

Year	Ilmenite	Rutile	Zircon	Monazite	HITI Ilmenite
1984	52,686	34,038	6,827	2,492	
1985	86,911	73,076	10,921	1,691	
1986	102,098	75,531	471		20,511
1987	146,627		10,255		
1988	145,783	147,353			9,103

No production of zircon and monazite from March 1986 due to lack of fresh water

Source : State Mineral Sands Corporation and Ministry of Industries

Figure 8.10

Despite high purity levels, Sri Lanka's graphite production activity is limited to sorting, grinding and screening to different particle sizes. Production of articles of value such as crucibles, carbon brushes or colloidal graphite have failed due to inadequate technical competence and lack of suitable markets.

ROCK PHOSPHATE

Sri Lanka imports its required fertilizers at a cost of about 40 million US dollars annually. Fifteen to twenty percent are phosphates -- rock phosphate and super phosphate. In 1986 26,000 metric tons of rock phosphate and 55,700 metric tons of triple super phosphate were imported. Local production of rock phosphate was 15,000 metric tons in 1986.

Sri Lanka discovered a major phosphate reserve at Eppawala (see Figure 8.1) in 1971 with a firm reserve of 30 million tons of high quality phosphate rock (average of 38 percent $P_2 O_5$) and inferred reserves of 60 million tons. Figure 8.9 illustrates the production and

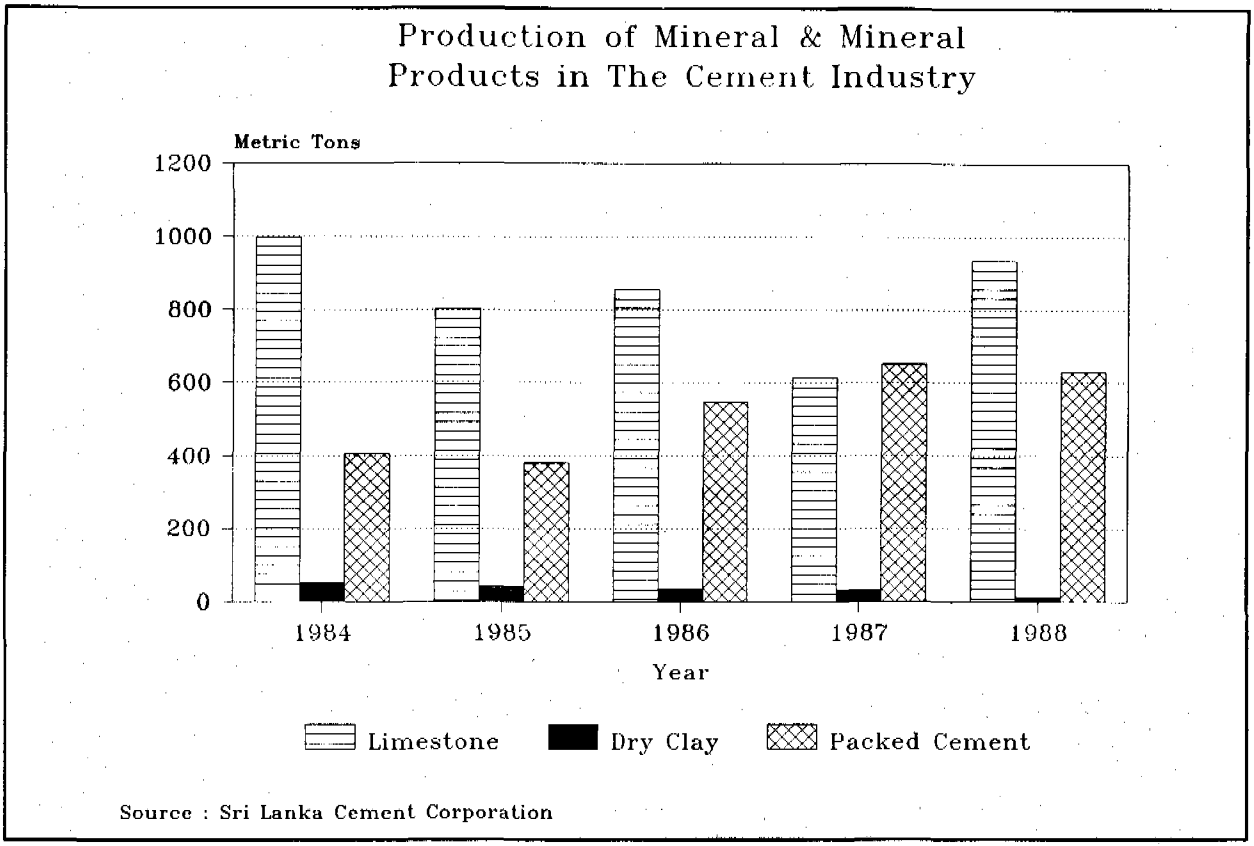


Figure 8.11

sales. Despite the high potential of the phosphate deposit, optimum use has still not been obtained, mainly due to the lack of technical know-how and machinery to convert it to soluble phosphate that plants can absorb. Chemical research is now underway in Sri Lanka to address this need. Analyses of environmental impacts of phosphate mining and processing will need to proceed in conjunction with any development plan.

CERAMICS

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

Sri Lanka has an old ceramic industry where the earliest products were unglassed items made from plastic clays, such as bricks, tiles, crude earthenware and ornaments. The state-owned Ceylon Ceramics Corporation mines and processes kaolinite and operates refineries at Boralesgamuwa near Colombo, and Mitiyagoda (Galle District). The Corporation also includes four subsidiary companies: Lanka Porcelain Limited (producing 1,500 tons of porcelain tableware per year for export), Lanka Wall Tiles (Pvt) Ltd and Lanka Tiles Ltd. (15,000 tons and 10,000 tons for export) and Lanka Refectories (Pvt) Ltd (1,500 tons). The Ceylon Ceramics Corporation also has one ball clay plant, one lime plant, a quartz-feldspar mine, nine tile factories (25 million tiles per annum) one ornamentalware unit and two ceramic factories (earthenware -- 3,700 to 4,000 tons (crockery); -- electroporcelain -- 350 tons; and sanitaryware -- 1,300 tons per annum). A modern Ceramic Research and Development Centre (CRDC) has also been established by the Corporation with UNIDO assistance (Herath, 1988).

A cottage industry provides much of the country's brick and roofing tile needs. About 100 small units produce 80 million tiles per year. Over 85 percent of Sri Lanka's brick requirement is produced by 2,000 units scattered throughout the country.

The state supports the cottage ceramic industry by the establishment of pottery centers, and incentives for the export of ceramicware and manufacture of ornamentalware in the Free Trade Zone. The public sector ceramic industry records revenue of around 700 million rupees compared to private sector revenue of around 500 million rupees per annum. To realize further development the ceramic industry will require remedial measures. These include:

- Detailed geological survey aimed at locating raw material,
- Reliable estimates of individual deposits,
- Further research into the nature, quality, properties and feature uses of these mineral materials,
- Proper analysis of marketing aspects,
- Analysis of environmental impacts of all aspects of the ceramic industry and,
- Development of practical operating, monitoring and enforcement measures to ensure environmental management.

MINERAL SANDS

The beaches of Sri Lanka are rich in sands containing minerals such as ilmenite, rutile, monazite and zircon. At Pulmoddai, 77 kilometers north of Trincomalee, a beach place deposit along about 8 kilometers of the coast contains about 6 million tons of raw mineral sands containing 70-72 percent ilmenite, 8-10 percent zircon, 8 percent rutile, 0.3 percent monazite and 1 percent sillimanite. Among several other concentrations of mineral sands scattered along various beaches in the country, the most significant are at Kailawela, 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 by NARA.

The production and export figures of the Ceylon Mineral Sands Corporation, which is responsible for the exploitation of mineral sands, are shown in Figure 8.10. Lack of a constant supply of fresh water has hampered production, particularly in 1986.

Despite these valuable mineral sands Sri Lanka has no extraction industries that use them. Ilmenite contains 50-60 percent of the oxide of titanium, and rutile has nearly 95 percent, but this material is exported in its raw state mainly to Japan and Europe.

Environmental Impacts

Although we have no comprehensive assessment of environmental impacts of sand mining, coastal erosion is one danger. A 27-meter shoreline recession was noted during operations of the Mineral Sands Corporation at the large extraction site at Kokilai in the mid-1970s (Second Interim Report of the Land Commission).

CEMENT

Sri Lanka has seen considerable growth in many new development programs. To meet high demand for cement the Ceylon Cement Corporation has two major cement factories, at Kankesanthurai in the north, and at Puttalam on the west coast. The two plants manufacture about 600,000 metric tons of portland cement per year using the dry process. A grinding plant at Galle uses limestone derived from Kankesanthurai or imported material. A joint venture between a local private firm and a Japanese company has developed a cement complex for exports at China Bay, Trincomalee. After additional facilities are installed at Kankesanthurai, cement production should reach 1 million metric tons.

Limestone resources are available in the Jaffna Peninsula and in a belt stretching to Puttalam, Southwest Aruwakalu, and the Dutch Bay region. Inland coral limestone, suitable for cement manufacture exists in the southern coastal areas that could, if properly managed and reclaimed, support the Galle cement plant. No living coral is needed and none is permitted to be used. Figure 8.11 shows the production o mineral and mineral products in the cement industry.

Environmental Impacts

At the Puttalam cement factory, environmental degradation occurs during mining of limestone and processing of cement. Significant air pollution has resulted from poor maintenance of the installed electrostatic precipitators, which were out of order for many years. Discharge of large quantities of dust into the surroundings has caused poor crop yields in nearby coconut plantations and damage to other trees and plants from the settling of dust on the leaves.

FUTURE MINERAL PROSPECTS

The discovery of a copper-magnetite deposit at Seruwila in the Trincomalee area, the first base metal find in Sri Lanka, has opened up a new area for exploration. Location of these base metal ores between two major lithological zones -- the Highland Series and Eastern Vijayan Complex -- indicates that this boundary is a potential target area for further base metal investigations. There are also promising indications of uranium mineralization in certain areas. With the extension of maritime boundaries following the Law of the Sea convention Sri Lanka now has a vast offshore territory that can be explored for high mineral potential.

Mining and quarrying contribute 3.5 percent of the GDP and account for one-tenth of total employment and one-seventh of export earnings. Lack of technology and expertise has retarded development and efficient use of valuable mineral resources, including phosphate, salt, ceramic, cement, graphite and mineral sands. Political stability, a favorable economic climate, and integrated environmental planning at every step of the way, can, however, open new possibilities for mineral development.

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This pinus is among tens of thousands of hectares of forest plantations.

9 Forest 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 most 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. Deforestation has now seriously diminished timber supplies, made soils less productive, water supply more erratic, and floods more frequent and severe. Management of what is left, and reestablishment of new forests, will require concerted planning and strong political will. These actions depend on broad public understanding of the benefits of reforested watersheds, mixed farmland forests, village groves, shelterbelts, and sustainable natural forest ecosystems.

Forest Cover Today

Climate, the main determinant of forest distribution, does not preclude the presence of forest in any part of this island. Except in a few locations limited by soil factors, the entire land area of Sri Lanka 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 southwestern region and the central highlands have the most luxuriant plant cover. The lowland area, up to an elevation of about 900 meters (m) has a climax vegetation of Tropical Rain Forests, where the crowns of dominant trees form a closed canopy at 25 m to 30 m with emergents rising to about 45 m. These forests have a relatively sparse undergrowth but are rich in epiphytes and lianas. They gradually give way through Sub-Montane Forests, at 900 m to 1,350 m, to Wet Evergreen Montane Forests at the higher elevations. The latter have a lower canopy and a denser undergrowth. Their stems are often covered with lichens, bryophytes and other epiphytic plants.

The transition zone between the Wet Zone and 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 mostly of thorny shrubs.

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 result is formation of *damanas,* savannah with fire resistant trees, or *talawas* and some dry*patanas,* which are dominated by coarse grasses.

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 even-aged monocultures of teak, eucalyptus or pine. A few mixed plantations of broad-leaved tree species, such as jak and mahogany, have also been established.

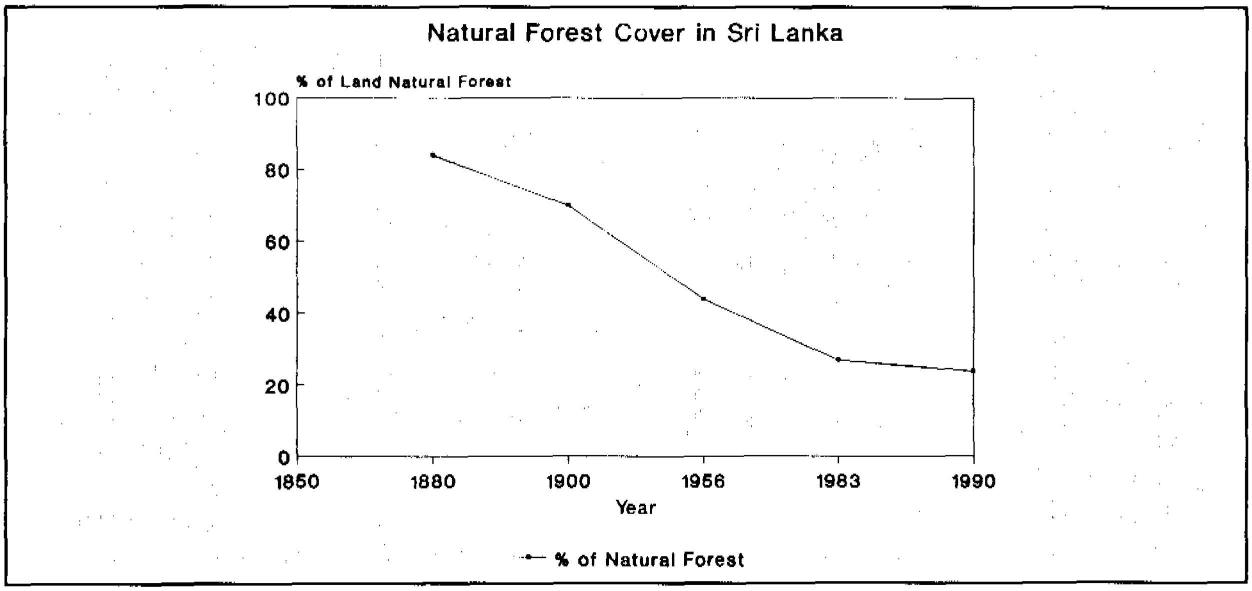


Figure 9.1

NATURAL FORESTS

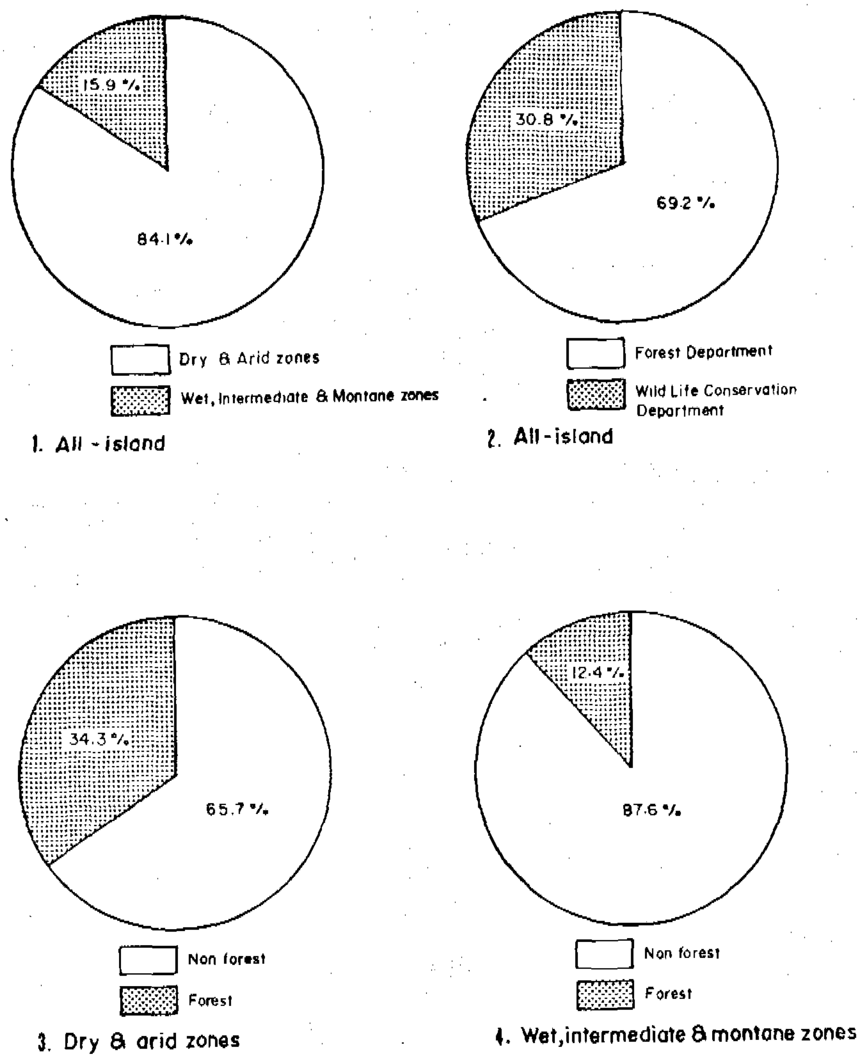
During Sri Lanka's hydraulic civilization beginning more than 2,000 years ago, agricultural development in the Dry Zone required transformation of natural eco-systems to agro-ecosystems. Wetlands in valleys and flood plains became rice fields, and clearings on high ground became multilayered home gardens. From about A.D. 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 sharply increased. By 1881, the forest cover was estimated at 84 percent of the land area, and in 1900, 70 percent.

The first comprehensive forest survey of the country was conducted after Independence in 1956-1961. The survey found that the total area of forest was 2.9 million hectares, or 44 percent of the land area. Even then over-exploitation had so spread that as much as 42 percent of all natural forests were classified as non-productive. In 1982-1985 the FAO carried out a second inventory to obtain data for the Forestry Master Plan. According to this inventory Sri Lanka's forest cover was 1.76 million hectares and the area of scrubland was 625,000 hectares. The aggregate figure of 2.385 million hectares, or 36 percent of the land area, is often cited as the area of forest land. However, this figure includes scrub that consists mainly of early secondary growth after deforestation, and hence these areas cannot rightly be classified as forest. The aerial photographs on which the FAO survey was based were taken in 1983. Assuming that deforestation has occurred at the rate of 30,000 hectares per year since then, the 1989 estimate of forest area should be 1.58 million hectares, or 24 percent of the land area as natural forest (see Figure 9.1).

In addition to high forest and scrub, *chena* cultivation occupies a large area, mostly 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 hectares, or 15 percent of the country's land area. Since then *chena* areas have been absorbed into permanent agriculture or otherwise developed, while more forests have been cleared for *chena*. At present, shifting cultivation covers about 1.2 million hectares, or about 18 percent of the country, forest 24 percent, and scrub 9.2 percent of the country. Figure 9.2 gives more information on the natural forests, based on the 1982-1985 forest inventory.

The Natural Highforest Area of Sri Lanka - 1983 Position



1. Zonal Distribution
2. Controlling Agency

3 . & 4. Forests As A Percentage Of The Land Area.

Figure 9.2

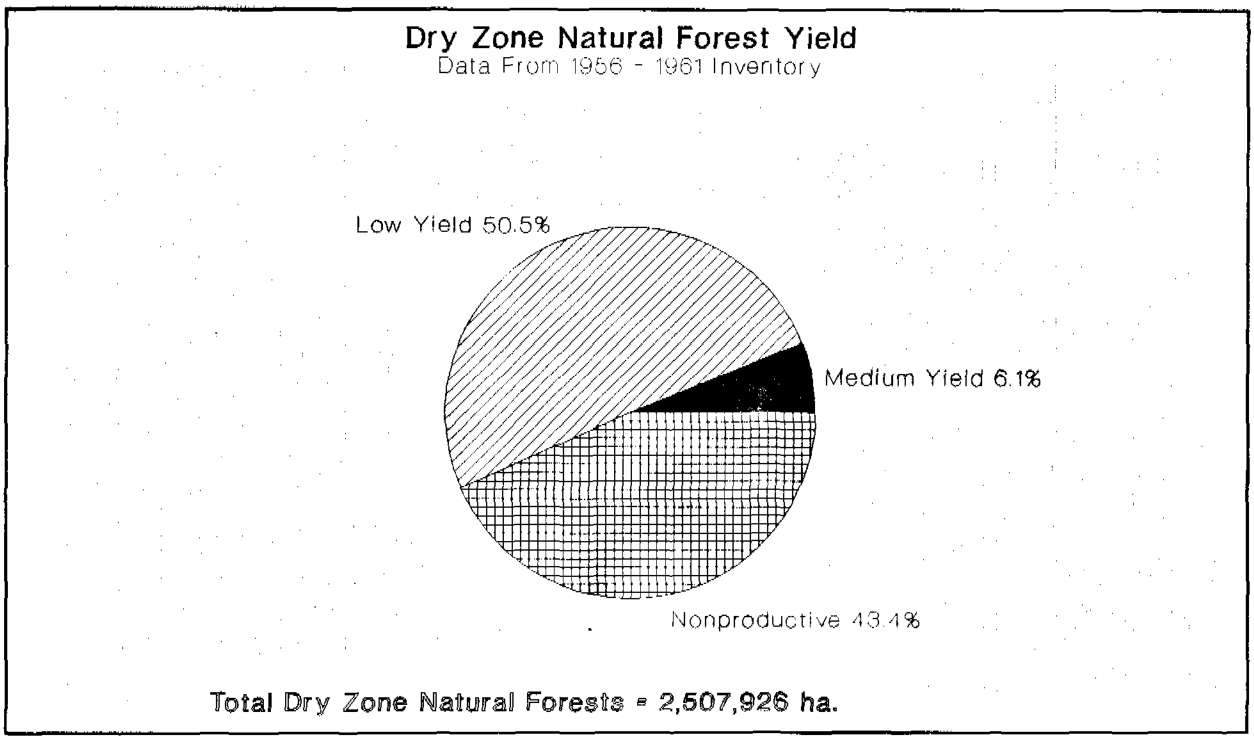


Figure 9.3a

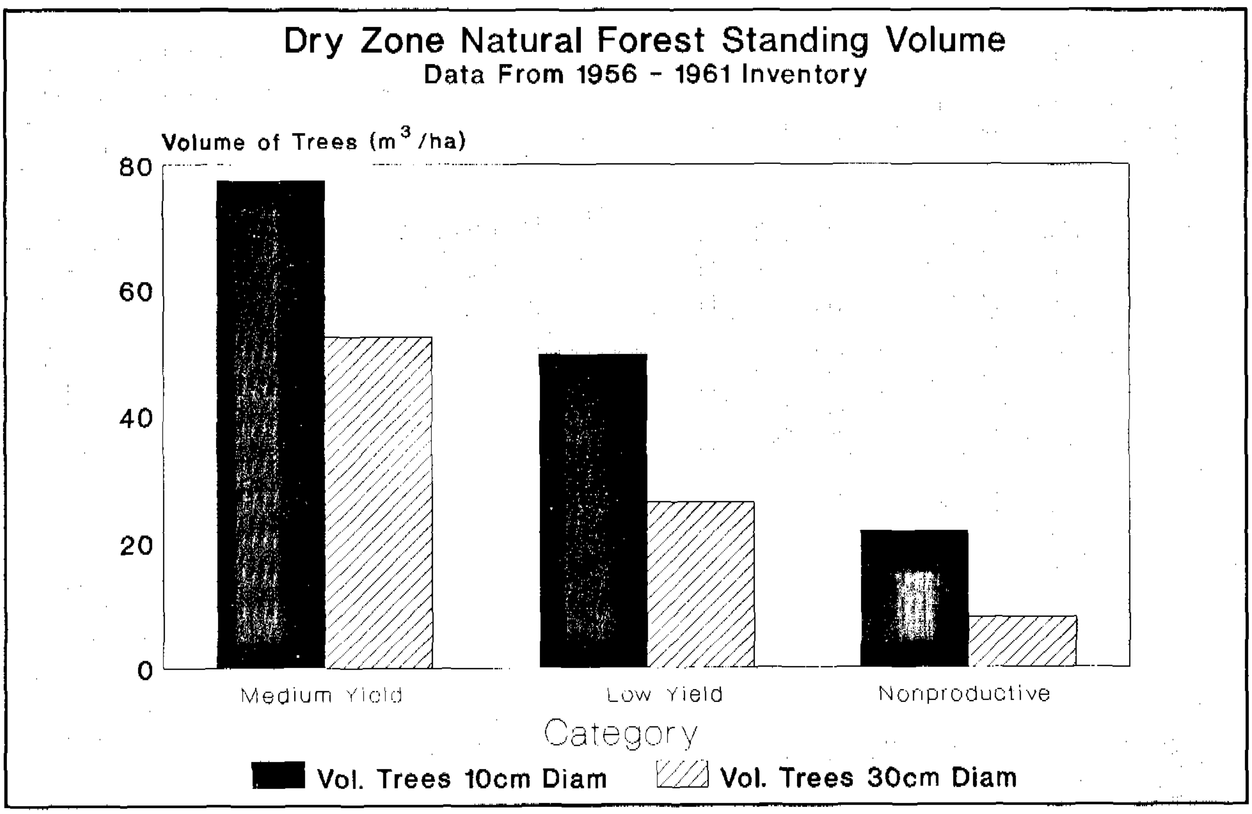


Figure 9.3b

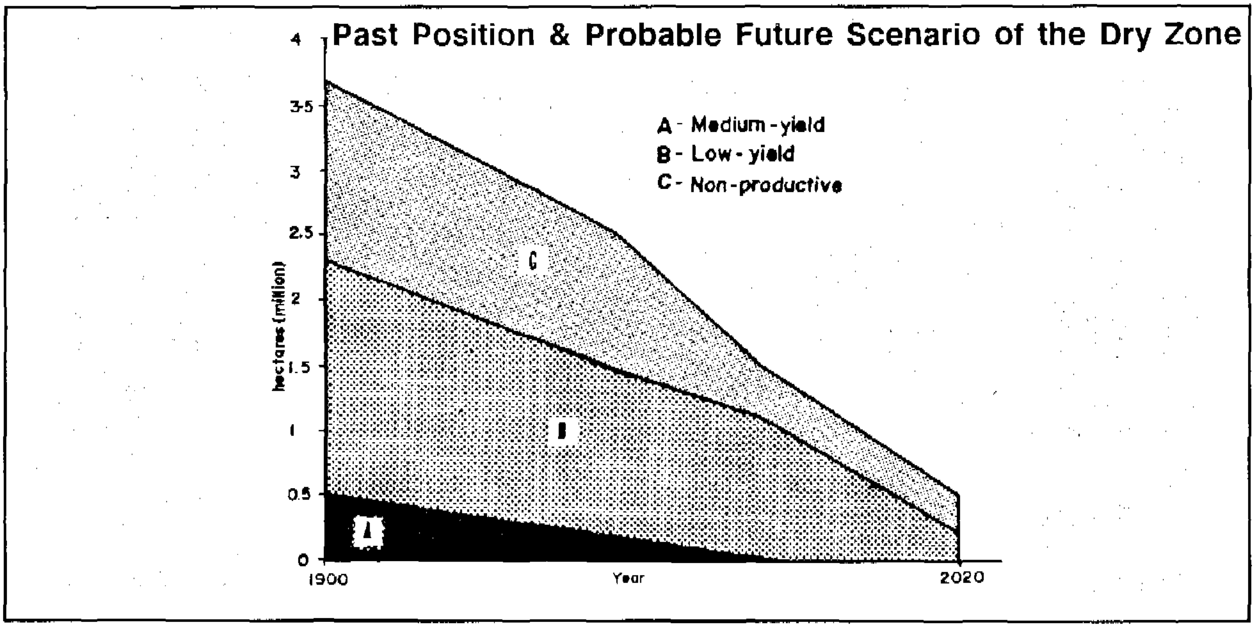


Figure 9.4

Forest Ownership

Over 95 percent 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 more areas were set apart as Proposed Reserves, also under jurisdiction of the Forest Department. Village Forests were placed under the district Government Agents, and other Crown Forests were at various times transferred from the Forest Department to Government Agents and vice versa.

In addition to these categories, National Reserves and Sanctuaries were established for protection of wildlife. There are five types of national reserves: Strict Natural Reserves, National Parks, Nature Reserves, Jungle Corridors, and Intermediate Zones (the last mentioned not to be confused with the climatic zone of the same name). These areas, categorized according to degree of protection or location, all come within the jurisdiction of the Department of Wild Life Conservation.

The Forest Department must protect forest reserves and proposed reserves under provisions of the Forest Ordinance. As clearing of forests continued, illicitly and under state land settlement and agricultural schemes, however, the Forest Department has given up large areas. Deforestation from 1956 to 1983 averaged 41,500 hectares per year, largely due to shifting cultivation.

Since 1970 the Forest Department has established 40 biosphere reserves within the reserve forests or proposed reserves. They vary from 10 to 55,000 hectares and total 120,000 hectares. This program began as an activity under IUCN's International Biological Programme and later continued under UNESCO's Man and Biosphere Programme. Biosphere reserves have only administrative status, but the Forest Department accepted the proposal to designate selected areas within the forest reserves as biosphere reserves to help protect some natural forests from forest exploitation and clearing.

In the natural forests of the Dry Zone, under the Forestry Master Plan deforestation and exploitation for timber supply will continue everywhere except in the "protected areas" under the Department of Wild Life Conservation and the biosphere reserves under the Forest Department. These areas total around 600,000 hectares. However, even within these areas encroachment and illicit felling continue.

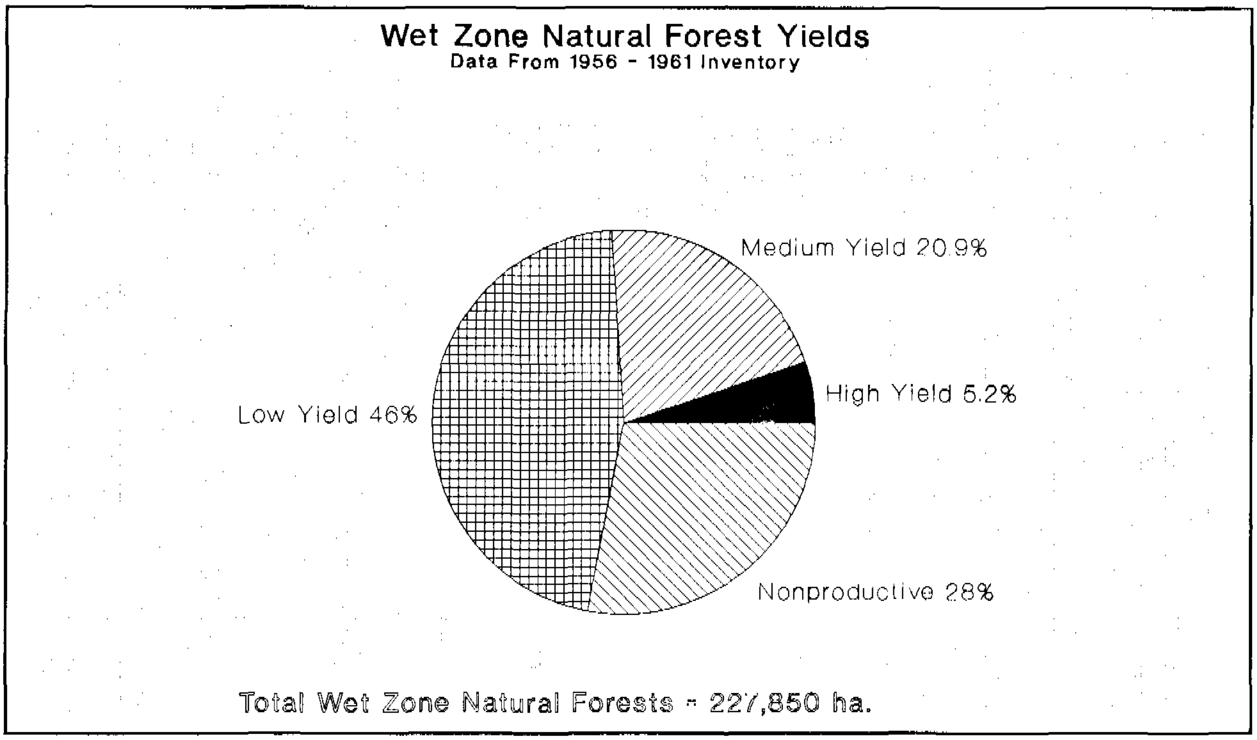


Figure 9.5a

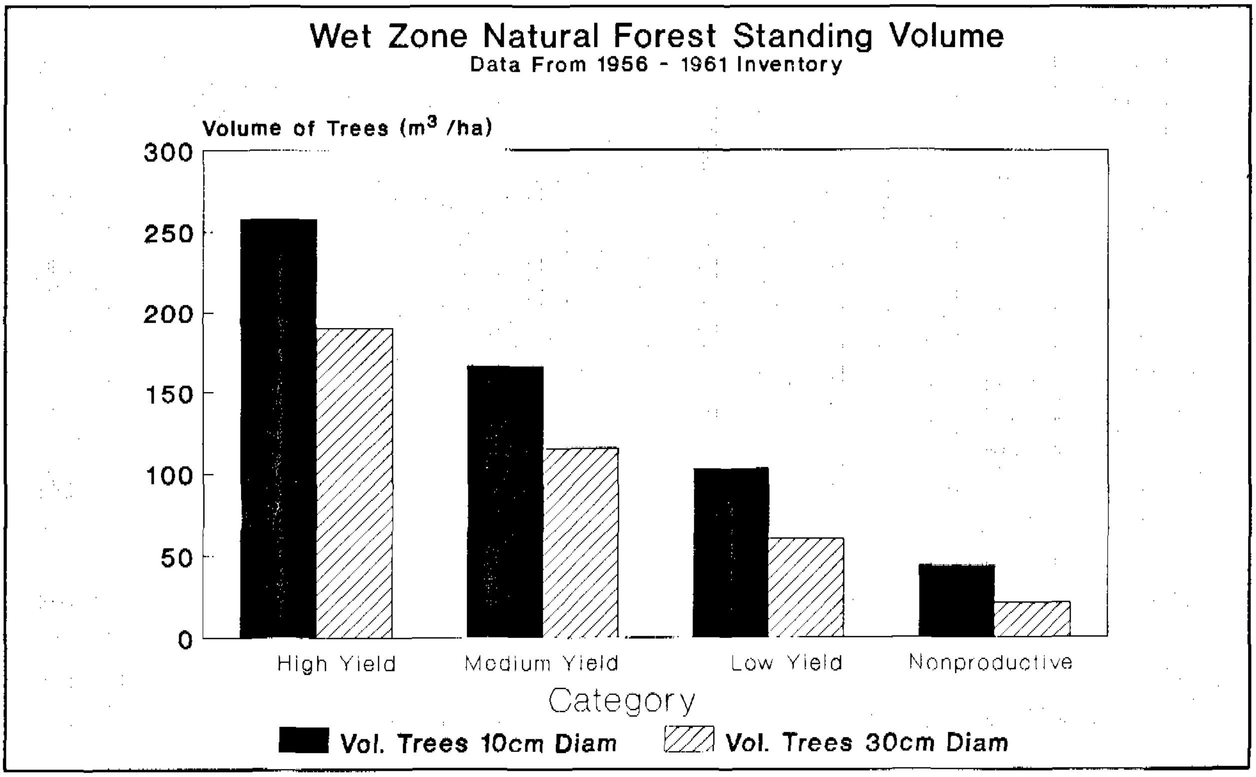


Figure 9.5b

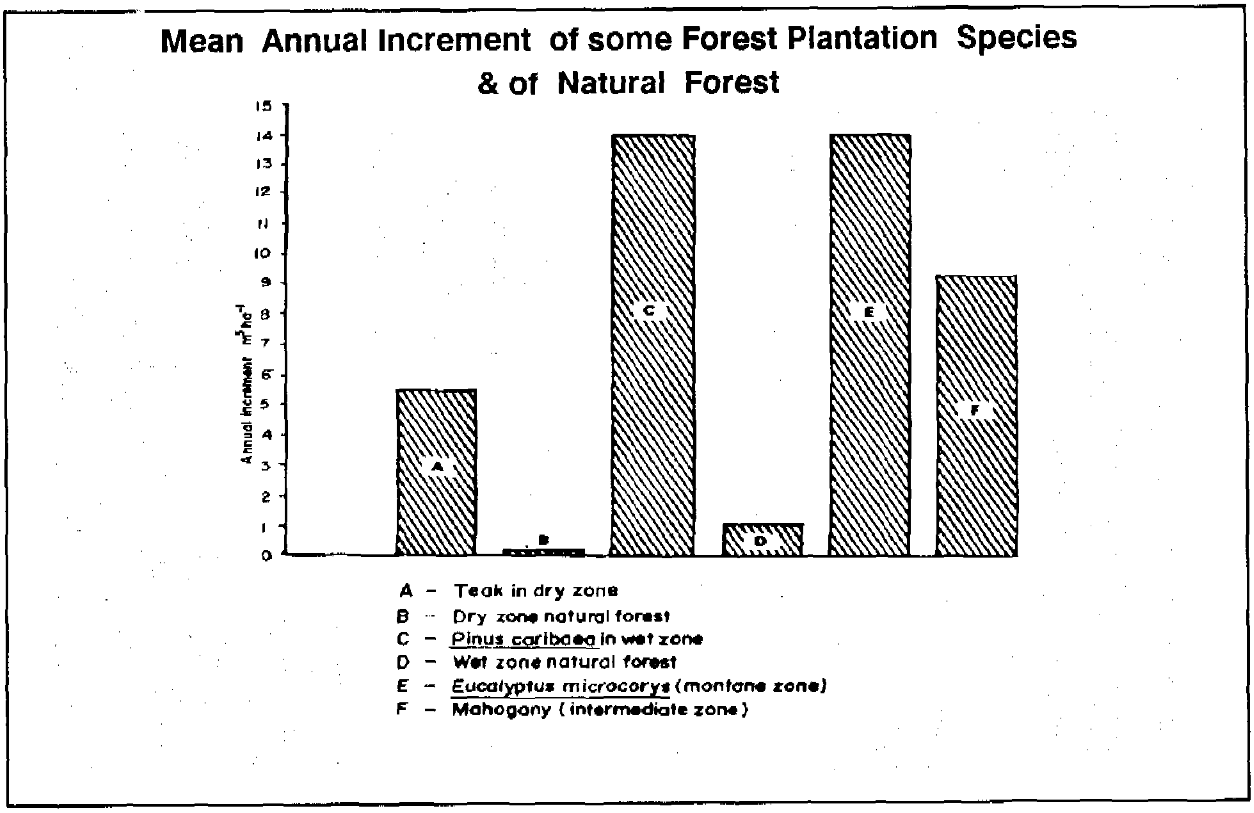


Figure 9.6

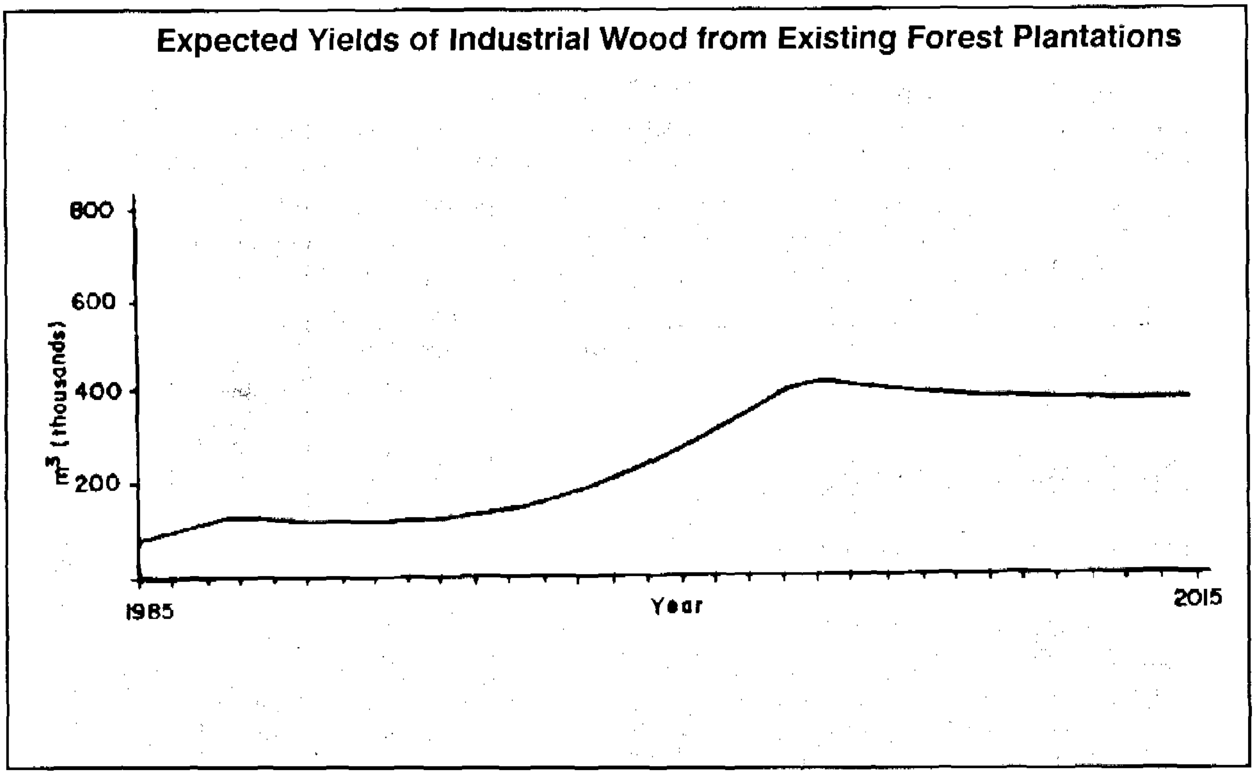


Figure 9.7

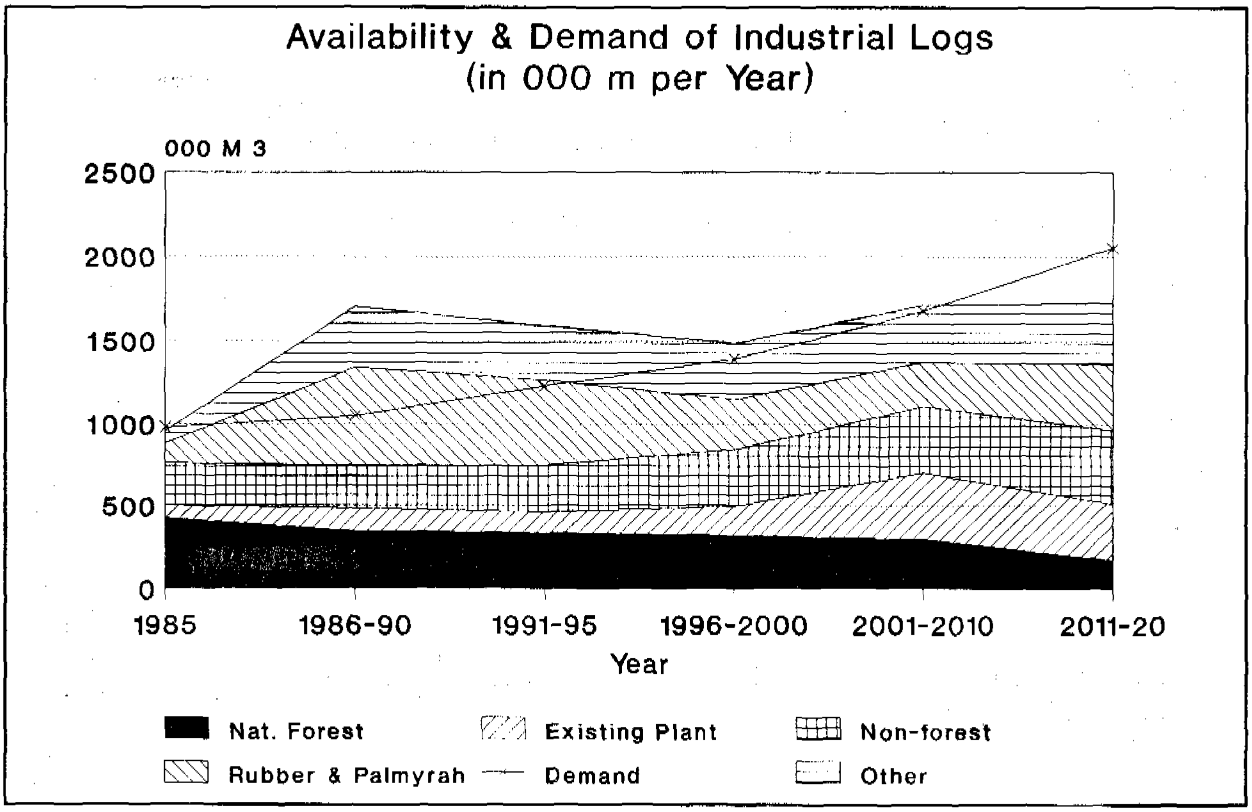


Figure 9.8

In the Wet Zone (low country, mid-country and montane region) the forest is estimated at 278,000 hectares. In the low and mid-country and in the Mahaweli catchment the area of forest is now down to approximately 8 percent of the land area. Because of the unfavorable forest-to-land ratio in the Wet Zone, no forest alienation would be permitted under the Forestry Master Plan. However, selective felling is planned in the high yield forests at middle and low elevations.

Timber Yields from Natural Forests

In terms of potential industrial wood yield Sri Lanka has two main types of natural forest. Most extensive is the Dry Zone mixed evergreen forest, or Monsoon Forest. The second, far less large, is the Wet Zone evergreen forest, or Tropical Rainforest.

'Dry Zone' - Historical Trends

The dry mixed evergreen forest is the typical natural vegetation of the Dry Zone which accounts for three-fifths of the land area of the country. Among the trees in this forest are several species of hardwoods which produce timber of the highest quality. These include *Chloroxylon swietenia*_(E: satin; S: burutha), *Berrya cordifolia* (E: Trincomalee wood; S: halmilla), *Manilkara hexandra* (S: palu) and *Diospyros ebenum* (E: ebony). As a result of highly selective exploitation over the years these prime species, which were once plentiful, are now very rare.

Large scale timber harvesting has gone on in the Dry Zone since the early 1800s. At first it consisted of selective felling of large trees of the prime species, and some of this timber was exported to Britain. Government officers were responsible for the control of timber cuts, but historical records indicate widespread illicit timbering even then.

Timber export continued until it gradually tailed off after the 1960s but exploitation for local demands increased. With rapidly rising demand many previously untouched species became exploited, along with trees well below the silviculturally desirable size. Illicit felling continued unabated through the 1970s along with selective exploitation of natural forests by contractors engaged by the Forest Department and later by the State Timber Corporation. So did widespread clearing of Dry Zone forests for shifting cultivation (*chena*). In the early 1980s large areas of Dry Zone forests were opened up under land development, particularly for the Mahaweli program. Yet deforestation trends were such that these forests were likely to have rapidly disappeared even without that program.

The forest inventory carried out in 1956-1961 identified 2.5 million hectares of natural forests in the Dry Zone (including the arid regions). They fell into one of three recognized timber yield classes: medium, low, and non-productive. No high yield natural forests existed in the Dry Zone. Figure 9.3 gives data from this inventory.

Two important points are not reflected in Figure 9.3. First, at the time of the inventory, only 35-40 per cent of the standing volume was in species normally suitable for industrial wood. *Drypetes sepiaria* (S: Wira), the most widespread tree species in the Dry Zone, has a poorly formed trunk only suitable as fuel and accounted for 25 percent of the standing volume. Second, nearly all the Dry Zone species used for industrial wood are slow to grow. As a result the annual increment of utilizable wood was found to be very low. The 1956-1961 inventory states that the Forest Department estimated the annual increment to be as low as 0.2 cubic meters per hectare.

The next major forest inventory was carried out by the FAO in 1982-1985. (Five complete districts and parts of two others in the north of the country were unable to be covered by field sampling, so data from the rest of the Dry Zone were extrapolated to these areas.) Significant highlights of this inventory:

- The loss of forest cover in the Dry Zone since 1956 averaged 38,100 hectares per year.
- No medium yield-forests were identified in the Dry Zone (see Figure 9.3). Medium-yield forests existing in 1956 had been so exploited as to move them to the low-yield or nonproductive category. Some medium-yield forests may have been cleared altogether.
- Average standing volume per hectare of trees of all species over 30 cm diameter at breast height (dbh) increased nearly 50 percent (from 26.1 to 38.8 cubic meters) in the low-yield forests, and by nearly 140 percent (from 7.9 to 19.1 cubic meters) in the non-productive forests.

The yield data represent the average for all the forests in each yield class. It is not possible to draw precise conclusions regarding the increase in standing volume because in the interim period many forests, owing to exploitation and clearing, moved from their original yield class to a lower category, and some forests were cleared altogether. Nevertheless, because increases also occurred in Wet Zone forests, there was apparently a net accretion of wood in some of the forests. Hence, even in lowest quality forests, recovery is apparently possible under the right conditions and where soils are conserved, even after heavy exploitation.

Dry Zone' - Future Trends

The Forestry Master Plan (FMP) deals with the Dry Zone natural forests on the basis of likely deforestation rates in the next few decades. Leaving out the areas under the Department of Wild Life Conservation designated as protection forests, it presents two alternative scenarios:

(a) deforestation continuing at 30,000 hectares per year until 2020, when all Dry Zone forests outside the protection areas would be cleared, and (b) deforestation curtailed to 10,000 hectares per year.

The Plan estimates the volume of wood that would become available in the two cases. It proposes that forests should be cleared for timber at either one rate or the other in order to pre-empt clearing by illicit fellers. Supplies are also expected to come from what is called "selective felling" in the areas still remaining in forest. Surprisingly, in each scenario the yield forecast of industrial wood from 1986-2020 is identical. Under either rate, in two to three decades all Dry Zone natural forests outside the protection areas, comprising nearly all Dry Zone forests now under the Forest Department (900,000 hectares), will be totally exploited and degraded to scrubland (see Figure 9.4).

A more efficient, environmentally sustainable policy alternative exists for managing Dry Zone forests, however. The FAO inventory of 1982-1985, from which the Master Plan draws its data, states that deforestation is likely to decrease after completion of clearings under the Mahaweli development scheme. It provides evidence of significant increases in standing volume in the low yield and nonproductive forests in the period following the earlier inventory. It recommends that adequate areas of over-cut natural Dry Zone forests be set apart for recovery. As a result, if these forests are adequately protected -- a critical management problem -- they can enhance ecological stability in the Dry Zone, and, several decades from now, provide indigenous Dry Zone timbers on a sustained yield basis.

'Wet Zone' - Historical Trends

Natural forests of the Wet Zone typically have a much higher standing volume than Dry Zone forests. Until the 1940s many species remained unharvested, but thereafter, with *Dipterocarpus zeylanicus* (S:hora) accepted for production of railway sleepers (or ties), and with light hardwoods required for veneer, many new Wet Zone species entered the market.

Figure 9.5 gives some data on the natural forests of the Wet Zone according to the 1956-1961 inventory.

For several reasons, data on natural forests of the Wet Zone (including the wet montane zone) in the FAO inventory of 1982-1985 are difficult to collate with those of the earlier inventory. For example, the "montane forests" of the earlier inventory comprise a relatively small area of stunted forests found at the highest elevations, while the upcountry region of the later inventory appears to have a much lower elevation limit. Again, the intermediate zone forests are separated from the Wet Zone forests in the earlier inventory, but combined in the subsequent inventory. However, taking the Wet Zone, montane zone and the intermediate zone together, the later inventory indicates a loss of forest cover of 3,400 hectares per year since 1956.

Wet Zone' - Future Trends

The 1982-1985 inventory concludes that total forest area in the wet and intermediate zones (including the wet montane region) comprises 278,000 hectares of which 120,000 hectares lies in the low and midcountry and 158,000 hectares in the upcountry. Of the total area, the Forestry Master Plan apportioned 159,000 hectares for protection and 119,000 hectares for timber supply. The 119,000 hectares are further divided into 47,500 hectares with adequate stocking for sustained yield management, 37,500 hectares with poor stocking where no selective cutting is recommended in the near term, and 34,000 hectares where the stocking is so low that no cuttings should occur until the year 2020.

The Wet Zone low and mid-country natural forests (120,000 hectares) represent ecosystems with high levels of biodiversity and endemism. These forests have been subjected to heavy overcutting and consequent degradation, and there are now strong appeals from scientists, NGOs and the informed public to set aside for conservation a good part of the 47,500 hectares earmarked for selective felling. "Selective felling" has itself often meant heavy overcutting in accessible forests.

The total area of well-stocked and sparsely-stocked Wet Zone forests taken together, may, according to some experts, total only 35,000 hectares -- just over 40 percent of the Master Plan estimates (85,000 hectares). If further analysis supports this conclusion, the Plan's proposals for felling will need revision.

Well-stocked forests are estimated to yield 28 cubic meters per hectare of industrial wood and 55-117 cubic meters fuelwood. Each year the Plan proposes to harvest 1,580 hectares or a thirtieth of the well-stocked area -- that is, a 30-year felling cycle. Intermediate felling, halfway through the felling cycle, is also proposed. The question remains: Can these levels of exploitation sustain good quality Wet Zone natural forest, or will the remaining forest be lost to future generations?

Given widespread concern about exploitation of Wet Zone natural forests in the low and mid elevations, the Government has decided to re-examine the management plans as related to the preservation of biological diversity, conservation of soil and water, and the environmental impact of proposed felling rates and intensity.

Forest Plantations for Shelter

Afforestation in the Uva Basin shows how forestry can improve environmental and social conditions. The Uva Basin lies in the central highlands at an average elevation of about 1,200 meters bounded on the south and west by the mountainous central massif that rises to 2,400 meters. In the north and east the Basin slopes down to the lowland plains of the Dry Zone. Near the center of the Basin is the town of Welimada.

The Uva Basin comprises undulating country devoid of natural forests except in small, sheltered pockets. Dry montane grasslands, dry *patanas*, cover much of the area where no tea has been planted. When the island comes under the influence of the southwest monsoon, from May to August, rain falls on the western slopes of the central hills, leaving the now-rainless monsoon winds, to sweep across the Uva Basin. These desiccating winds frequently reach gale force, and the harsh conditions have made much of the area desolate and uninhabited.

Afforestation of the *patanas* began in the late 1930s. *Eucalyptus* grandis, *E. microcorys* and *E. robusta* were raised in compact blocks on the crests of ridges and hilltops. When successful the plantations served as windbreaks and greatly improved living conditions. Hamlets soon sprang up nearby.

Encouraged by these results, in 1954 the Forest Department selected two severely windswept, desolate areas, Palugama and Harasbadde, to raise shelter belts. Palugama produced spectacular results. Its gently undulating land was hospitable to shelter belts planted in a lattice pattern -- primary belts (20 meters wide) at right angles to the wind direction, and secondary belts (10 meters) at right angles to the primary belts. Distance between the shelter belts in both directions was 115 meters. Belts consisted of an outer row of *Acacia mollissima*, followed by alternate rows of *Eucalyptus grandis* and *Cupressus macrocarpa*. Although the *Cupressus* remained stunted, the other two species grew well, and the belts acquired a pyramidal shape in profile.

Within five years the shelter belts began to ameliorate windy conditions. Within ten years, after more growth and continued improvement in the environment, population of the area began to grow. The name of the village, Palugama, meaning 'desolate village' was no longer considered apt and it was changed to Keppetipola, after a famous Sinhala Chief!

FOREST PLANTATIONS

Historical Development

Reforestation in Sri Lanka has a long, important history. The government of Ceylon perceived that the exploitation of natural forests could frustrate sustained production of timber a century ago. 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 broadleaf mahogany, was also planted towards the end of the last 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 demand of households, the tea industry and the railway. Eucalyptus species received the greatest attention. Although originally raised to produce fuelwood, the wood of some eucalyptus species was later found suitable for industrial use. In the 1950s eucalyptus species were introduced to the lowlands of the Wet and Dry Zones.

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 annually in the Dry Zone. Forestation in the Dry Zone was carried out under the Co-operative Reforestation Scheme, the counterpart to the Burmese Taungya system. It came to an end in the late 1970s (See Box).

Recently, in the Wet and Dry Zone lowlands, planting trials with several hitherto untested species have been carried out, and two species of *Acacia* that yielded good results are now included in the forestation program.imber and Fuelwood Production

Timber and Fuelwood Production

Dry Zone natural forests are poorly stocked and most of the valuable species grow slowly. Until recently, forestation favored teak. Although the teak plantations fall into the lower classes of the Indian yield tables, its growth has been outstanding in relative terms; the average Mean Annual Increment (MAI) exceeded that of the industrial wood species in Dry Zone natural forests by 30 times (see Figure 9.6).

The natural forest of the Wet Zone has a MAI higher than its Dry Zone counterpart. Notwithstanding this, and despite the fact that the species is raised only in impoverished sites of the Wet Zone, *Pinus caribaea* has an average MAI almost 15 times that of the usable species in the natural forest.

The Forestry Master Plan concludes that the total area of productive plantation forests (1982-1985 inventory) is 97,650 hectares. Of this, 77,000 hectares consists of industrial wood plantations, comprising teak (54.4 percent), *Pinus* (24.1 percent), industrial wood species of eucalyptus (11.4 percent), and others (10.1 percent). Expected yields from these plantations up to the year 2015 are shown in Figure 9.7.

Although the Forest Department regularly conducts forestation it often neglects silvicultural operations needed to reach maximum levels of productivity. Thinnings, especially early non-commercial thinnings, rarely occur. As a result the expected increment rates (Figure 9.6) will not be realized. The proposed investment program in the forestry sector has been designed to correct the understaffing and lack of adequate financial resources that largely cause this situation.

The Forestry Master Plan recommends forestation (with industrial wood species) at 2,130 hectares per year to 1995, and 4,260 hectares per year thereafter. Because plantations will be the main source of industrial wood in the future, this rate of forestation may not build adequate wood reserves for the next century. More important than increasing the area under forestation, however, are regular, dependable silvicultural operations.

To meet future fuelwood deficits, the Forestry Master Plan recommends raising block fuelwood plantations (2,700 hectares per year) and farmers' woodlots (progressively increased from 700 hectares to 4,500 hectares per year). Block fuelwood plantations are to be raised by the industries requiring the fuel. In addition, the Forest Department could also raise fuelwood plantations in areas where deficits are likely. This will be necessary, for example, where farmers' woodlot schemes fall behind schedule.

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 rate 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 reduced hundreds of thousands of hectares of natural forests to scrub through deforestation and overexploitation. Objections to forest plantations of exotics must recognize how plantations can help conserve natural forests.

Pinus caribaea, a cause of much controversy, is planted in 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 broad leaf species when the pine is thinned.

Yet there is an urgent need to strengthen research on the biology and silviculture of indigenous species in order to identify the endemics, as well as exotics, that are ecologically preferable to species now used in forestation. The volume of research now conducted is far from adequate but until more ecologically acceptable species are found, forestation programs must continue with the species now in use.

TIMBER AND FUELWOOD DEMAND AND SUPPLY

Industrial Wood - Past Trends

Industrial wood is used in Sri Lanka primarily for building construction, packaging, railway sleepers, telegraph and electricity poles, furniture, and matches. Newsprint and wood pulp for writing paper are largely imported.

Although nearly all the forests are state owned, industrial wood from state forests provides only a fraction of what is supplied and consumed within the country. The 1956-1961 forest inventory estimated that the country consumed 855,000 cubic meters of timber and fuelwood. In 1985, consumption of industrial wood was estimated at 980,000 cubic meters, with 960,000 cubic meters supplied locally and the balance imported. Of the local total, natural forests supplied about 44 percent and forest plantations about 8 percent with the balance from rubber wood, coconut, palmyrah wood, and miscellaneous other non-forest species (see Figure 9.8).

Industrial Wood - Future Trends

Forecasts of industrial wood demand and availability for the next 20 years (Figure 9.4) suggest an annual surplus if timber from rubber, coconut, and palmyrah are included. Small quantities of these species are now used for timber but further research and development is required to improve the quality of the wood and the technology of use. In the light of declines in coconut and rubber plantations over the past four decades, pricing and other policies will be necessary to promote use of these species.

If harvests in the natural forests of the Dry and Wet Zones are reduced by conservation programs seeking sustained yields, what can be done to ensure adequate supply of timber? One option for compensation is to

The Forestry Development Program

When the Forestry Master Plan was released in 1986 ecologists and non-governmental scientific and environmental organizations soon criticized its proposal for continued exploitation of remaining natural forests. Over-exploitation had been so severe, they argued, that of the remaining 1.2 million hectares of natural forests managed by the Forest Department, only 47,500 hectares existed in the Wet Zone. The Dry Zone had no areas where stocking was sufficiently high to allow sustained timber production.

In response the Forest Department created an Environmental Division, invited forestry consultants to re-examine the felling proposals, and commissioned studies on the biodiversity of the Wet Zone natural forests. Pending the outcome of these studies (still in progress as of October 1990), the Department suspended all forest felling. Similar studies are proposed for natural forests in the Dry Zone, where natural areas may be set apart as permanent reserves under long-term management.

Under the forestry development program for the next five years (mid-1990 to 1995) the Forest Department plans systematic thinning of 60,000 hectares of plantations and to raise new plantations of industrial wood and fuelwood species. A special reforestation program will address the erodible upland areas in the Mahaweli catchment, where the forest cover is down to 8 percent of the land area, funded by British ODA. The development program will emphasize tree planting through a Participatory Forestry Project to develop silvi-pastoral and agroforestry systems mainly for the large areas of deforested, unused land in the Dry Zone.

To remedy the serious lack of skilled manpower the Forest Department will substantially increase recruitment of forest officers and accelerate training. It will also strengthen research units in the Forest Department and the State Timber Corporation. Support for the forestry development program is expected through aid grants and loans from the World Bank, British ODA, FINNIDA, UNDP, and ADB.

Assuming sustained political will, generous inputs from the government, and supplement financial support from foreign agencies, by the end of the five-year period the forestry sector should be able to carry out sustainable forest management that conserves Sri Lanka's natural forests for future generations.

increase the use of non-forest species. Other measures include greater economy in the use of timber and substitution of other materials wherever possible. Recently, for example, the government decided to use concrete instead of wood for railway sleepers; once implemented this will significantly reduce industrial wood demand. Likewise, wood could be totally replaced by concrete for electricity and telegraph poles. The National Engineering Research and Development Centre has demonstrated that a low-cost house can be constructed without the use of timber. Technological improvements in sawmilling could reduce the huge waste that now occurs when converting logs into sawn timber. To make a difference, these and other measures will need to be adopted quickly. Greater emphasis will also be necessary on raising forest plantations of industrial wood species and silvicultural operations in the plantations that increase yields.

Fuelwood - Past Trends

Biomass fuel is the source of heat for most household cooking in Sri Lanka, and the vast majority of rural households gather this fuel themselves. From surveys we know that only about 25 percent comes from the high forest. We also know that the slow, steady trend in the 1950s and 1960s from fuelwood to commercial energy (mainly kerosene) for domestic cooking was reversed in the late 1970s in response to the fuel crisis. (For details of consumption, sources, etc, see Chapter 5.)

Fuelwood - Future Trends

The proportion of biomass fuel coming from high forest is, in future, likely to increase. Fuelwood will continue to be available over much of the Dry Zone area for several years to come, owing to the presence of large areas of degraded forest. However, in the large settlement areas of the Dry Zone, shortages have already occurred. Transport of fuelwood over long distances will make costs prohibitive. The proposal to raise farmers' wood lots for fuelwood, poles, utility timber and so forth, as recommended in the Forestry Master Plan, would help solve this problem. So would action of the Forest Department to raise fuelwood plantations in strategic areas to provide supplies to sales outlets in the towns.

Biomass fuel supplies could also drop in the Wet Zone. If, as expected, more rubber wood is diverted for use as sawlogs, supplies of fuelwood from this source will drop, and scarcity will develop in Colombo and the other southwest coastal towns. In addition, any reduction in the cutting area, or cutting rates, in Wet Zone natural forests will also produce lower fuelwood yields than forecast in the Master Plan. Increased planting of fuelwood species, use of improved fuelwood cookers, transport of fuelwood from surplus areas, and use of alternative fuels are possible responses. (For further information on biomass fuel, refer to Chapter 5.)

KEY ISSUES

Severe deforestation and degradation of natural forests have afflicted Sri Lanka for decades. Because natural forests originally covered most of the island, virtually any development invariably causes some forest clearing, but deforestation has been far more extensive than development has required, and much of the clearing has been illicit. Over the past four decades, deforestation has slashed natural forests by 50 percent.

Forest degradation, while often less obvious, has relentlessly followed exploitation to meet growing demands for industrial wood. Nearly all the natural forest that remains is non-productive or low in yield. And as with clearing, forest degradation has often been illegal.

Why have these trends developed?

Public concern about deforestation and environmental degradation has never been higher in Sri Lanka, as elsewhere in the world. Sri Lanka has laws to protect forests, most importantly the Forest Ordinance, the Fauna and Flora Protection Ordinance, and the recently enacted National Wilderness Act. Yet the absence of firm and clear forest policy to mobilize public support and enforce forest laws has contributed to forest management failures.

Articulation of sustainable forest management policies requires difficult economic choices in the short term. To achieve effective policy reform the economic and social values of natural forests, and the pending threats to national welfare, need far deeper and broader understanding.

For example, the forest sector has been said to contribute only 1.7 percent of the GDP, but these figures grossly undervalue the multitude of direct and indirect services that forests provide to people and the economy. Forests regulate stream flows, stabilize steep land, control soil erosion, reduce flood intensities, prevent land desiccation, and protect agricultural land and human settlement. These economic values can be measured in Sri Lanka, as they have been elsewhere.

Natural forest products -- berries, fruit, nuts, game, and other products -- serve local economic needs even if they never reach urban or foreign markets. Medicinal substances, horticultural plants, and flowers have accounted for over 100 million US dollars in annual exports from Indonesia, and substantial, if so far uncalculated, economic value to Sri Lankans. (See box on Sinharaja.)

About 90 percent of the endemic flowering plants of Sri Lanka, and most of its endemic fauna, can only be found in the severely depleted natural forests of the southwest Wet Zone. Aside from ethical considerations, the pharmaceutical and other long-term direct economic values of these resources have barely begun to be recognized.

Minimum Area Under Forest

What is the minimum area that Sri Lanka should retain under natural forest? To attempt an answer we may assume that, following current trends, within a few decades, forest plantations and non-forest sources will meet, and need to meet, most industrial wood requirements. Arguments for retaining natural forests, therefore, largely depend on other values. Because of differences in climate, topography, population densities, land-use practices, and genetic diversity, minimum areas retained under forest must be determined separately for the dry, and wet, intermediate, and montane zones.

The Dry Zone. This region supports rigorous agricultural development. Rice fields scattered over the vast Dry Zone plains produce most of Sri Lanka's rice. Yet the natural forests protect farmers and the farmlands by reducing reservoir siltation; improving and regulating streamflow; reducing the harsh effects of strong, desiccating winds, and serving as barriers to the spread of pests and diseases of crops.

The Forestry Master Plan has designated 900,000 hectares of Dry Zone natural forests for total exploitation, leaving only the protection areas (wildlife parks, sanctuaries, biosphere reserves, and so forth) intact. The rationale: deforestation will inevitably continue, so state exploitation is better than illicit felling.

Past trends need not shape the future, however, and rational policy for Dry Zone natural forests can more beneficially derive from a number of interacting facts:

- Forest clearing for agriculture will drop sharply as the Mahaweli program nears completion, creating new needs and opportunities for planned management of natural forests.

- Unplanned and illicit felling of Dry Zone forests has converted hundreds of thousands of hectares into unproductive scrub and wasteland. Cost-effective rehabilitation can make this land valuable again.

- Protected areas in the Dry Zone occur mostly as large blocks in the driest part of the zone. They do not represent all the ecologically important natural areas within the 900,000 hectares now under Forest Department jurisdiction.

- All the remaining Dry Zone natural forests are low yield or nonproductive. They do not now provide Sri Lanka with valuable timber products.

- Unexplored opportunities exist for true multiple use of forests for timber, wildlife, and village use.

Under these circumstances, a reasonable long-term economic and environmental policy would designate at least 500,000 hectares of the Forest Department's 900,000 hectares as permanent reserve forests. These reserves can be kept free of timber felling for several decades. Eventually, however, through protection and enrichment planting, they can be managed economically to provide a modest indigenous timber supply on a sustained basis. The proposed area of permanent reserves, together with areas under the Department of Wild Life Conservation, will account for 25 percent of the Dry Zone.

The Wet Zone. In the wet southwest region of the island, the forest-to-land ratio is widely recognized as critically low. Policy debate centers around two questions: are forest areas recommended for complete protection adequate to preserve the rich genetic diversity of this region, and are selective felling proposals appropriate for the high quality natural forest that remains. The Forest Department has commissioned studies to address these questions with new facts and analyses.

Timber and Fuelwood Supplies

Reduced felling in the natural forests will also reduce annual output of industrial wood. How then can the demand for timber be met?

No single action will suffice, but a combination of policies can balance supply and demand. Much can be done to rationalize utilization practices and manage the growth in demand by reducing waste and developing timber substitutes, as discussed above. Suitable pricing policies and other regulatory measures should contribute to a reduction in the wood demand from natural forests. Proposals in the Master Plan for raising industrial wood plantations and ensuring proper silvicultural maintenance of the plantations should be implemented. Increased forestation can also build up adequate reserves of industrial wood for the future.

Curtailing the Master Plan's felling regime is unlikely to reduce overall biomass fuel supply in the next few years because adequate resources are available outside the high forests. However, new fuelwood plantations located in strategic areas may be necessary to meet long-term requirements.

Forest Plantations

Because forest plantations yield far more per unit area than natural forests, plantations will provide most industrial wood supplies. Silvicultural maintenance of the existing plantations will be essential to reach optimum productivity. New forest plantations as recommended by the Master Plan will also be required. Continuing silvicultural trials should address potential problems by developing management practices and finding suitable species mixes that mitigate any ecological imbalances.

Social Forestry

The Forest Department has recently included social forestry in its management and research program. Interaction between villagers and natural and plantation forests has become recognized worldwide as an essential part of forest management. Increasingly, planners will need to understand how forest systems meet social needs, and how these long-term economic values can be identified and translated into development decisions.Traditional knowledge of people on tree growth in specific locations must be obtained and used. Forest programs that give local populations a stake in the forest produce will make them more effective custodians of the forests.

Research

Forest research can no longer be narrowly confined to the dimensions of traditional forestry. To meet the requirements of Sri Lanka's increasing population multi-disciplinary research must include ecological studies of plantation species, alternative agro-forestry systems for the vast and unirrigable dry regions, methods to reduce wastage of timber and biomass, and practical measures to improve silvicultural practices. Public education and professional training will be necessary to ensure that research findings translate into practical, on-the-ground results.

A major research need centers around the question of how to improve the productivity of forest lands through far more cost-effective measures than have been used heretofore.

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Wild elephants, estimated at about 3,000, are the greatest living symbol of Sri Lanka's diverse biological resources.

10 Biological Diversity

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 fuelwood, timber, fish medicinal herbs, crop plants and animals for domestication. They have helped regulate the climate, recycle nutrients, protect soil and water, control pests and diseases and provided habitats and breeding grounds essential for fish and wildlife that enable human survival.

Biological diversity refers to the immeasurable variety of what life contains. Each species has its different races and breeds and differences among individuals. Species join to form diverse communities and ecosystems. A country's biological wealth is collectively the product of millions of years of evolution and the result of thousands of years of cultivation and domestication. Biological diversity is therefore of great value and it is more important than the material or cultural wealth of a country.

Contributions of 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	Habitat 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)
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 & breeds for enhancement of breeding programs, 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 Center

Figure 10.1

Sri Lanka, like countries around the globe, is depleting many of these resources at rates that have made many of them essentially non-renewable. Unlike truly non-renewable resources such as minerals that can be so exploited as to become scarce and uneconomic, we have, at accelerating rates, caused species to vanish altogether, or become dangerously vulnerable to that fate. Among the most significant causes of this growing problem: forest clearing and burning, shifting cultivation, wetland damming and filling, timber logging, coral reef destruction, cultivation of monocultures in crops, plantations, and forests, over harvesting of plants and animals, careless introduction of exotic species, indiscriminate use of pesticides, and pollution of our aquatic ecosystems. These and other activities diminish Sri Lanka's biological resources.

Importance of Biological Diversity

Why should we care? Sri Lanka's economy largely depends on agriculture, plantation crops, fisheries and other activities whose productivity closely connects with healthy biological systems. Natural forests support agriculture by influencing local climate, regulating water supplies, and protecting soils. They supply fuelwood and timber. Ecosystems of wetlands and coral reefs provide the habitats for fish, crustaceans and molluscs harvested by the fishery industry, they protect coasts from erosion.

At the micro level, genetic material in domesticated crop plants, trees, livestock, aquatic animals and small organisms constitutes essential biological diversity that we also use. It is the basis of breeding programs for continued improvement in yields, nutritional quality, flavor, durability, pest and disease resistance and other tangible benefits.

Other plant and animal products gathered from the wild or in cultivation or domestication, such as medicinal plants, fruits and nuts, vegetables, fibre, leather, spices, rattan and bamboo, meet daily needs of millions of Sri Lankans, and support thousands of small, village-based industries. By maintaining diverse wild varieties of crop plants we establish insurance against disease and disasters and provide the genetic material for science-based efforts to improve crops and agricultural productivity.

Yet only a fraction of the country's plants and animals have been mobilized to support human survival. The majority of wild species now unused or barely used are potential sources of food, fiber or medicines, and sources of future genetic material needed to sustain, diversify and improve agriculture, forestry, and fisheries.

Around the world, natural areas, zoological gardens, botanic gardens and other monuments to biological diversity have become increasingly important for recreation and relaxation as urban areas expand and grow. The variety of species and ecosystems provides rich scenic and recreational experiences that have become increasingly appreciated as the world becomes ever more crowded.

Figure 10.1 gives examples of the 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

Wild Resources

Despite its importance, we know remarkably little about Sri Lanka's biological diversity. Ecosystem types and variations have been relatively well studied, but the total diversity of living organisms and interrelationships among them at a community or ecosystem level are poorly recognized or understood.

The diverse terrain and climatic variation within the small land area has resulted in an interesting array of ecosystems. The country has two basic eco-zones divided by a central mountainous region which intercepts the monsoonal winds, thereby creating an ever-wet southwestern quarter and a rain shadow in the remaining area. The far northwest and southeast, which escapes the monsoons, has a climate bordering

Ecosystem types and variations in Sri Lanka

Forests	- Tropical wet evergreen forests (lowland rain forests)
	- Tropical moist semi-evergreen forests
	- Tropical dry mixed evergreen forests
	- Tropical thorn forests
	- Riverine forests (gallery forests)
	- Tropical lower montane forests
	- Tropical upper montane forests
Grasslands	- Villus
	- Savannahs (Damana, Talawa)
	- Wet patanas (wet montane grasslands)
	- Dry patanas (dry montane grasslands)
Coastal and Marine	- Mangroves
	- Salt marshes
	- Sand dunes and beach
	- Mudflats
	- Seagrass beds
	- Coral reefs
Inland Wetlands	- Flood plains
	- Swamp forests
	- Streams and rivers
	- Ponds

Figure 10.2

on 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 evergreen and thorn forest. Grasslands and a complex network of wetlands, freshwater, coastal and marine ecosystems are interspersed with the forests. Ecosystem types are listed in Figure 10. 2.

The most conspicuous groups, such as the flowering plants, ferns and vertebrate animals, are the only ones relatively well studied. Collectively they probably account for only a very small percentage of the island's total species. The lower forms of flora and fauna such as the algae, mosses, liverworts, lichens and invertebrates are very poorly known. Even less known are microorganisms such as viruses and bacteria (Figure 10.3).

Yet even among the flowering plants and vertebrate fauna it appears likely that many species remain undiscovered. Biologically rich places like Knuckles, Peak Wilderness and Horton Plains have yet to be subjected to intensive study. Systematic inventories in recent years in Sinharaja, Hiniduma and Ritigala haveled to the discovery of many new species which

Composition of Flora and Fauna

Group	Number of described Species	Percentage Endemism
Flora		
Algae	896*	NA
Fungi	1,920*	NA
Lichens (Thelotremataceae)	110	35
Mosses	575	NA
Liverworts	190	NA
Ferns & Fern Allies	314	18
Gymnosperms	1	00
Angiosperms	3,100	27
Fauna		
Land snails	266	NA
Spiders	400	NA
Mosquitoes	131	13
Blister Beetles (Terrestrial)	15	20
Fish	59	27
Amphibians	37	51
Reptiles	139	50
Birds (Residents)	237	08
Mammals	86	14

Compiled from multiple sources

* inadequate studies

Figure 10.3

Biological Diversity Of Asian Countries
(Ranked According To Average Number Of Species / 10,000 Sq Kms)

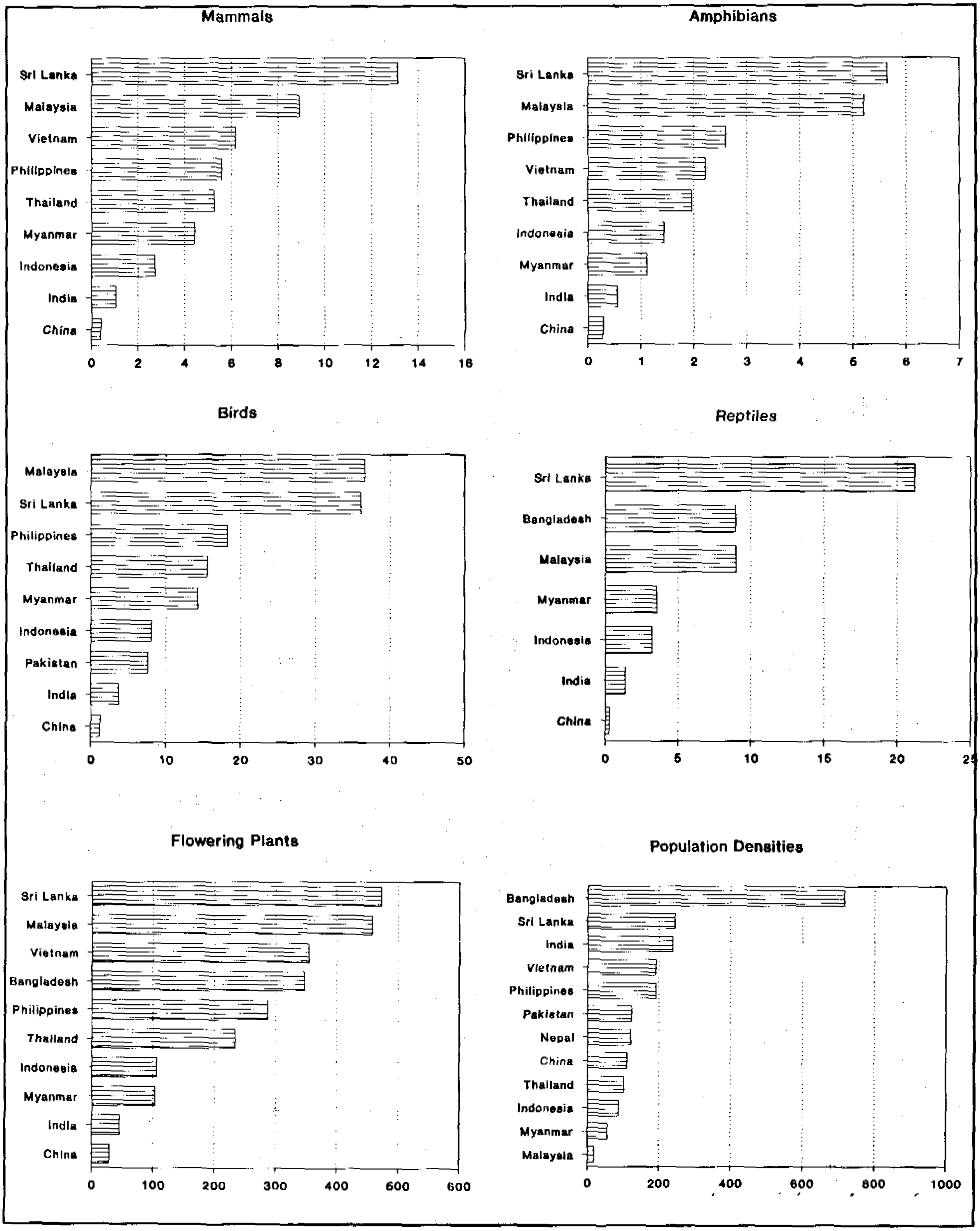
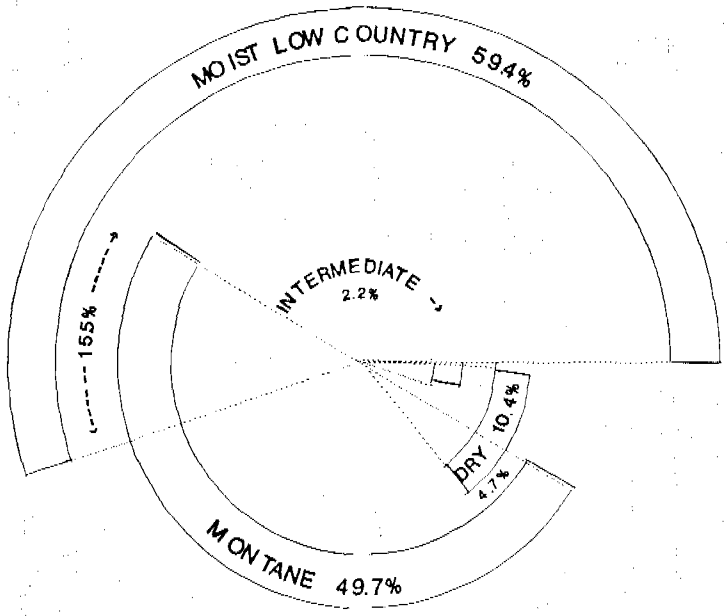


Figure 10.4

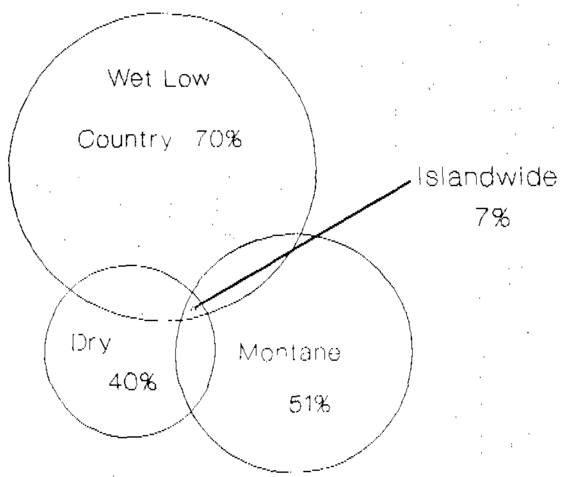
Distribution of Endemic Flowering Plants of Sri Lanka



Source: Peeris 1975

Figure 10.5

Distribution of Endemic Vertebrates of Sri Lanka (Diagrammatic Sketch)

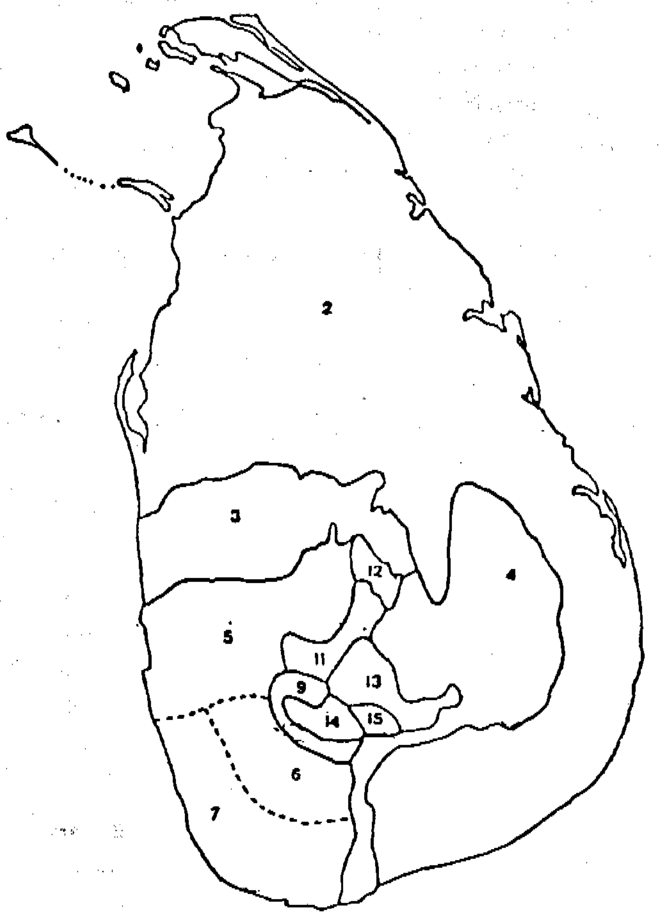


Source: Kotagama 1989

Figure 10.6

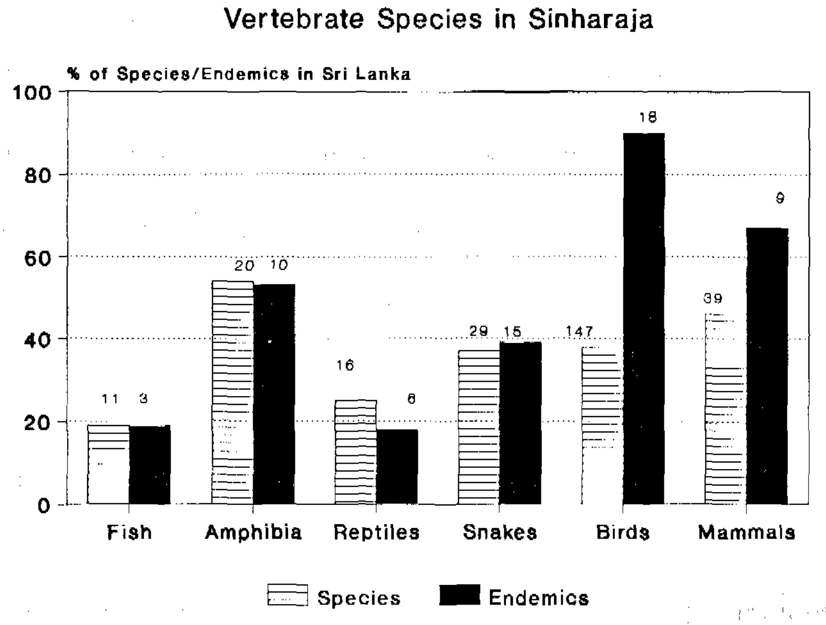
Floristic Regions of Sri Lanka

(Ashton and Gunatilleke, 1987)



1. coastal and marine belt	2. dry and arid lowlands	3. northern and intermediate lowlands
4. eastern intermediate lowlands	5. northern wet lowlands	6. Sinharaja and Ratnapura
7. southern lowlands hills	8. wet zone freshwater bodies	9. foothills of Adam's Peak and Ambagamuwa
10. Midmountains	11. Kandy and upper Mahaweli	12. Knuckles
13. Central mountains, Ramboda-Nuwara Eliya	14. Adam's Peak	15. Horton Plains

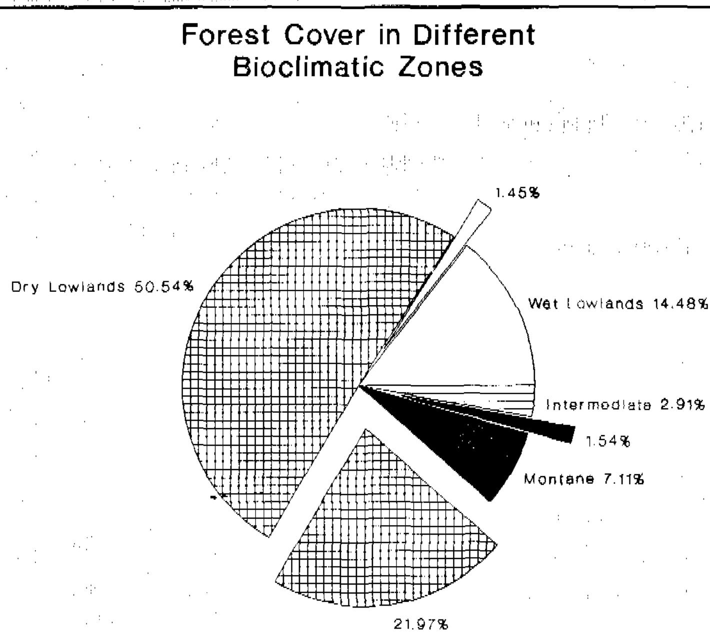
Figure 10.7



Source: March for Conservation, 1990

- Bars indicate percentage of Sri Lankan species and endemics in Sinharaja
- Figures above bars indicate numbers of species counted

Figure 10.10

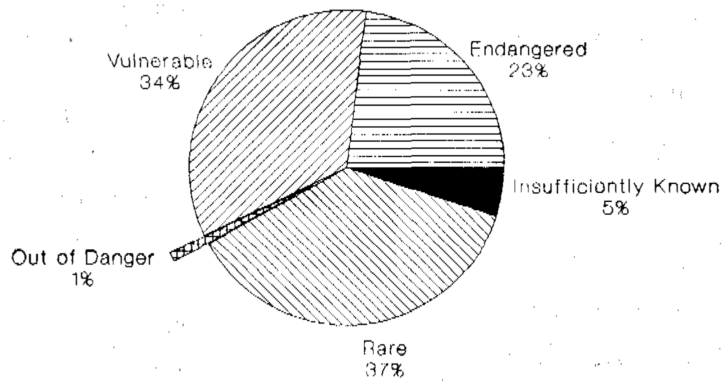


- Separate segments indicate natural forest areas

Source : Gunatilleke & Gunatilleke 1983

Figure 10.11

Status of Woody Endemics in Selected Wet Lowland Sites



Source: Gunatilleke & Gunatilleke 1990

Figure 10.12

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 ritual.

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* show much variability in seed color, pod size, and flower color.

Among the horticultural crops, several varieties of banana *Musa spp.* are under cultivation in the different agro-ecological 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 curcubits, tomatoes and eggplants exhibit much genetic diversity.

Sri Lanka has an estimated 170 species of plants of ornamental value, of which 74 species are endemic. *Dendrobium* and *Vanda* species and foliage plants thrive in natural forest habitats. Among the root and tuber crops, much variability exists among cassava, *Dioscorea,* aroids and innala *Solenostemos rotundifolius.*

Spices have made Sri Lanka famous. Considerable genetic diversity occurs among pepper, cardamom, betel and chilli. About 500 known local 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.

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 250,000 hectares. The germplasm originally introduced from Assam has undergone selection through breeding programs, and the selected genotypes are being clonally conserved in

Satinwood *Chloroxylon swietenia, ebony Diospyros ebenum* and other valuable timber species like nadun *Pericopsis mooniana* are now rare, although abundant in the last century. *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 overexploited. Some of the species endangered as a result are the orchids *Dendrobium maccarthiae, Dendrobium heterocarpum, Ipsea speciosa* and *Rhynchostylis retusa.* Sumithraarachchi (1986), has identified that of 170 species of orchids found in the island, 99 can be considered rare, 7 vulnerable, and 13 species likely to be extinct. Medicinal plants such as ekaweriya *Rauvolfia serpentina, Saraca asoca,* godakadura *Strychnos nux-vomica,* rodanti *Capparis moonii,* malitha *Woodfordia fruticosa* and a host of others have become rare in the wild. Numerous plant species recorded on 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 and disturbance of their habitats.

Nearly 16 percent of the flowering plants and 28 percent of the ferns and fern allies are considered threatened (Abeywickrama, 1987). So are twelve of the endemic genera. About 480 species of flowering plants and 90 species of ferns and fern allies belong to this threatened category. Included are 228 endemic and 252 non-endemic species amongst the flowering plants, and 30 endemic and 60 non-endemic species amongst the fern and fern allies.

Some specific information is also available on the status of threatened species in the wet lowland sites (Figure 10. 12). Over 94 percent of the woody endemics in these sites are threatened. Only 1-2 percent of the lowland woody endemics are believed to be found in large enough numbers to be considered out of danger. Another group of plants -- the commercially important rattan species -- are severely threatened. Of the 10 species, 7 have restricted distribution, 3 are endangered and 3 more vulnerable. If trends affecting these species continue, most of those considered threatened will become extinct within a decade so. Some species may already be extinct; about 50 or more plant species have not been collected for over a century, including the endemics *Cyathula ceylanica, Elliphanthus unifoliatus, Ceropegia elegans, Blumea angustifolia, Anaphalis fruticosa* and *Calamus pachystemonus.* Many more species, formerly common and widely distributed, have over the last few decades become rare or restricted to a few locations. One such species *Vatica obscura*, the only member of the Dipterocarpaceae family found outside the Wet Zone, occurred until very recently in gregarious masses in riverine forests of the eastern province. It has not been collected in the last ten years.

As an oceanic island Sri Lanka has a high percentage of endemic species that have evolved because of isolation, but they are particularly vulnerable. When their natural habitats are destroyed they are unable to recolonize the degraded soils. Over 200 naturalized aliens (Abeywickrama, 1955) include some of the most troublesome weeds. They have successfully established themselves, most often at the expense of the natural flora. Amongst fauna, the endemics represent a highly vulnerable group. Figure 10. 13 lists the status of faunal species studied so far (Kotagama, 1990).

Among the major impacts on biological diversity the single most important in recent years was the Accelerated Mahaweli Development project, which replaced about 200,000 hectares of natural wildlife habitat with agriculture, settlement and related developments. Elephants were most affected; about half the elephant population in this region (500 animals) were expected to be displaced. Other significant causes not quantified as yet: chemical pollution of air, land and water by various agricultural and industrial activities. Some mosses and liverworts, earlier common as epiphytes have disappeared or become less common in and around Colombo. Similarly *Schizaea digitata* has disappeared in most areas.

Genetic depredation occurs from more purposeful human action intended to increase food production. Modern agriculture in Sri Lanka, particularly rice, relies increasingly on a few imported seed varieties with a narrow genetic base, displacing the traditional crop varieties. Present indigenous rice varieties under cultivation have dwindled to about five percent of total paddy acreage. The spread of genetically uniform varieties, while helping to achieve high yields, also makes crops more vulnerable to pests and diseases. As the gene stock becomes less diverse we also reduce options for new crop breeding programs. Further, current efforts to develop new agricultural lands through irrigation schemes threaten the natural habitat of wild crop genetic resources, as is happening to valuable wild rice species found mainly in abandoned tank beds. Ironically, this development is occurring while innovative genetic engineering techniques are being pursued to transfer the rice traits of wild crop species to cultivated species.

TRENDS IN PROTECTED AREA MANAGEMENT

One of the world's first wildlife sanctuaries dates back to the reign of King Devanampiyatissa, when Buddhism was first introduced in the third century B.C. Later, in the twelfth century A.D. King Kirti-Nissanka-Malla prohibited the killing of animals within a radius of 35 kilometers of his kingdom of Anuradhapura. Subsequent Sri Lankan rulers protected large tracts of forests as reserves, for example Udawattekelle Reserve and Sinharaja Forest.

In modern times, however, with the enactment of the Forest Ordinance in 1907, wildlife was given legal provision through the establishment of sanctuaries -- first at Yala, and then at Wilpattu. In 1938 Sri Lanka established five categories of protected areas, under the Fauna and Flora Protection Ordinance: Strict Natural Reserves, National Parks, Nature Reserves, Jungle Corridors and Intermediate Zones. All are administered by the Department of Wildlife Conservation. Simultaneously, the Forest Ordinance established two categories of reserves: Forest Reserves and Proposed Reserves. Most recently, in 1987, Parliament's National Wilderness Act added National Wilderness Areas to the protected list. The total extent of land area under some sort of protection currently is a over 15,000 square kilometers, of which around 10 percent is in the Wet Zone and the balance in the Dry and Intermediate Zones (Figure 10.14). (See Forestry Chapter.)

Designation of protected areas does not necessarily mean that protection is effective. Anecdotal evidence indicates that illegal and unmanaged logging, hunting, gathering, farming and livestock grazing are common in most of the protected areas. In the Wet Zone alone, for example, approximately 20 percent of the forest reserves have either disappeared completely or have been reduced to small isolated patches.

Although about 23 percent of the country is under some sort of protection, only 12 percent is devoted to complete protection (National Reserves and Sanctuaries under the Fauna and Flora Ordinance and National Wilderness Areas under the National Wilderness Act). Yet, this represents a significant commitment to the preservation of biological diversity. Sri Lanka is one of only five countries in the world that has over 10 percent of land area allocated for strict conservation.

Since the first national parks were established in 1938, some 60 or more protected areas have been set aside exclusively for conservation, covering some 7,500 square kilometers. Numbers and size of the protected areas have steadily increased, particularly in the last two decades (Figure 10.15). Although there are over 60 protected areas in the country, about 40 percent are less than 1,000 hectares -- nearly all "biological islands" amongst agriculture and other developments.

Can they maintain their biological diversity? Limited research to date suggests that in the tropics the minimum viable breeding population of 500 trees of low-density species require between 6-1,000 hectares for their conservation (Whitmore, 1984). The minimum critical size required to conserve the elephants is at least 100,000 hectares of contiguous forest. Only two reserves in Sri Lanka meet this requirement.

Despite overall statistics, most protected areas exist in the Dry Zone. In the biologically rich Wet Zone only 2.6 percent of the land area (400 square kilometers) is under complete protection. Of the 18 reserves in this zone, only five are over 1,000 hectares, and only one is over 10,000 hectares. Almost all forest reserves in the floristically rich lowland Wet Zone are further subject to selective logging. (See Forestry chapter.)

In addition to these in-situ programs that have played the 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 gar-

SINHARAJA

Sinharaja, a vast legendary forest of impenetrable mystery, is becoming something very different, and very tangible: a model for optimal and sustainable use of a species-rich tropical rain forest. The Sinharaja forest is now the sole lowland rain forest in Sri Lanka big enough to have a reasonable chance to conserve the uniquely diverse wildlife of the lowland and midland Wet Zone. As a group of forests, including the Sinharaja Reserve and the forest reserves surrounding it -- Morapitiya, Runakanda, Panagala, and Delgoda -- it covers 47,370 hectares.

The fauna and flora of the Wet Zone forests of Sri Lanka, now reduced to less than 10 percent of their original extent, are the richest, by far, in all South Asia. The nearest true aseasonal rain forests are in Madagascar and Sumatra . More than 70 percent of the species are found nowhere else. Sinharaja is of outstanding value for the conservation of these plants and animals.

Very little of it is truly in the lowlands, and that part has either been selectively logged or degraded by *chena* agriculture in the past. Although the eastern end reaches almost 1,500 meters at the Handapan Ella Plains, most of Sinharaja is at middle altitudes, between 500 and 1,000 meters. Many lowland species reach up to these altitudes and mingle with the true hill species, and unlike the Far East rain forests, in the Wet Zone of Sri Lanka mid-elevation flora is intrinsically richer in species than in the lowlands.

The reason for this condition may be that Sri Lanka is geologically part of peninsular India, long known to have once been attached to a former great Antarctic continent, named Gondwanaland. An island of continental dimensions comprising India, Sri Lanka, and a sunken extension, broke off some 80 million years ago. It moved north, across what was then the eastern extension of the Pacific Ocean. The island hit landfall some 40 million years later, and it has continued moving inexorably northwards, slipping beneath the Asian plate, as the rumpled carpet of the Himalayas bears testimony. The island continent broke loose after modern land plants, many modern insects, but only the marsupials among mammals had evolved. It was large enough, and was separated for long enough, to allow the evolution of distinct forms of life, rather like a minor Australia.

What were these forms, and do any still exist? We know from the fossil record that the climate of Antarctica at the time of embarkation must have been warm and moist - similar to the mid-elevation climate of Sinharaja. But apart from an Agamid lizard, and the remarkably elegant small tree *Hortonia,* there is little obvious evidence of Sri Lanka's ancient past. The presumably primitive Gondwanan land animals were eliminated by the more advanced continental Asian fauna when the continents collided. The island continent had to pass north through the doldrums, over whose quiet waters no rain falls. Rain forests in such seasonal regions are confined to the most constantly humid zone, which is within the cloud base on the mountain slopes, usually starting at about 800 meters. The modern Lankan flora could therefore be descended from such a time.

Botanical research reveals that more of Gondwana remains in Sri Lanka than first meets the eye. The tree family *par excellence* of moist mountain forests is the Fagaceae, the oaks. Though there are more species of oak in the Himalayas than anywhere else on earth, not a single Fagaceae exists in South Asia. Acorns, which have little dormancy and are only dispersed incidentally by animals that collect them to eat, have apparently failed, even after 40 million years, to cross south of the Gangetic Plain. In the moist fastness of Sinharaja, and elsewhere in the Wet Zone of Sri Lanka particularly at mid-elevations, extraordinarily primitive members of another family, the Dipterocarpaceae, remain conserved. Currently dipterocarps are best known in the Far East, where they supply over half the hardwoods on international markets. Their ancestors survive in the hills of Sri Lanka. In Sinharaja the dipterocarps, reprecented by many species in the two endemic groups *Stemonoporus*, and *Shorea* section *Doona*, reign supreme. The serried crowns of the majestic yakahalu, *Shorea gardneri*, once mantled the hills throughout the Wet Zone. Now, thanks to tea plantations and other development, the last stands are confined to Sinharaja and the Peak Wilderness, still conveying there an eerie memory of the ancient Gondwana forest. Sinharaja therefore serves as a genetic repository for some of Asia's most important economic plant groups.

These unique Lankan *Shorea* trees, some ten species in all, serve as examples of the other crucial contemporary value of Sinharaja. Their seeds, rich in vegetable oils, have traditionally been a major food for the rural poor, particularly during times of scarcity. Their timber, however, is the leading source of plywood for tea chests. Sinharaja has therefore become the stage for urgently needed pioneer research which seeks to reconcile modern commercial priorities with the traditional uses which have served rural communities for centuries. The Wet Zone of Sri Lanka is ideal for such research. On one hand the forest is unique in its biodiversity. On the other the Lankan people, who over history have become concentrated in the wet lowlands of the southwest, still retain a sustainable system of land and forest use of extraordinary sophistication and intensity -- the historical precursor of the celebrated agriculture and home garden systems found from Indianized Asia eastwards to Bali and the Philippines.

Sri Lanka is a nation of smallholders. In the past, every family owned its own irrigable land above which, on the lower slopes, was their artificial forest in which useful forest plants were grown and in whose shade their homes were built. Further above, extended the great forest, property of the king, in which villagers by right could harvest fruit, medicinals, cord, fish and game, fuel and occasionally construction timber. Although the country is poor, its quality of life has been unusually good in large measure because of this ancient pact with the land. But forest logging has put this balance in jeopardy. Unlike traditional uses, logging is a destructive form of harvesting, and the villagers are only minor beneficiaries. Nevertheless, many of the plants valuable to villagers prosper in well managed regenerating forests following logging.

A group of Lankan researchers have seen the unique opportunities to reconcile traditional rights of the rural population with modern requirements of the state that Sinharaja and its neighboring villages present. Social and biological scientists are working together in the forest, developing a common methodology to address an interdisciplinary challenge. They are documenting the biological resources of the forest and monitoring the productivity in nature to determine how the resources can best be manipulated to yield in perpetuity, without loss of species. Social scientists are for the first time detailing traditional uses and the methods of harvesting and quantities used; economists are beginning to calculate the manifold values of the forest in terms of the rural economy, the national economy including timber, water, soil, and tourist values, and also the global value of Sinharaja's irreplaceable genetic resources.

Rising interest in Sinharaja among scientists has been matched by the Lankan public, thanks in particular to an articulate and effective private group, the March for Conservation. With the participation of the scientific and conservation communities, and help from the World Conservation Union, a conservation master plan for Sinharaja has been prepared to reconcile the interests of all Lankans in its natural wealth, while also ensuring its protection in perpetuity.

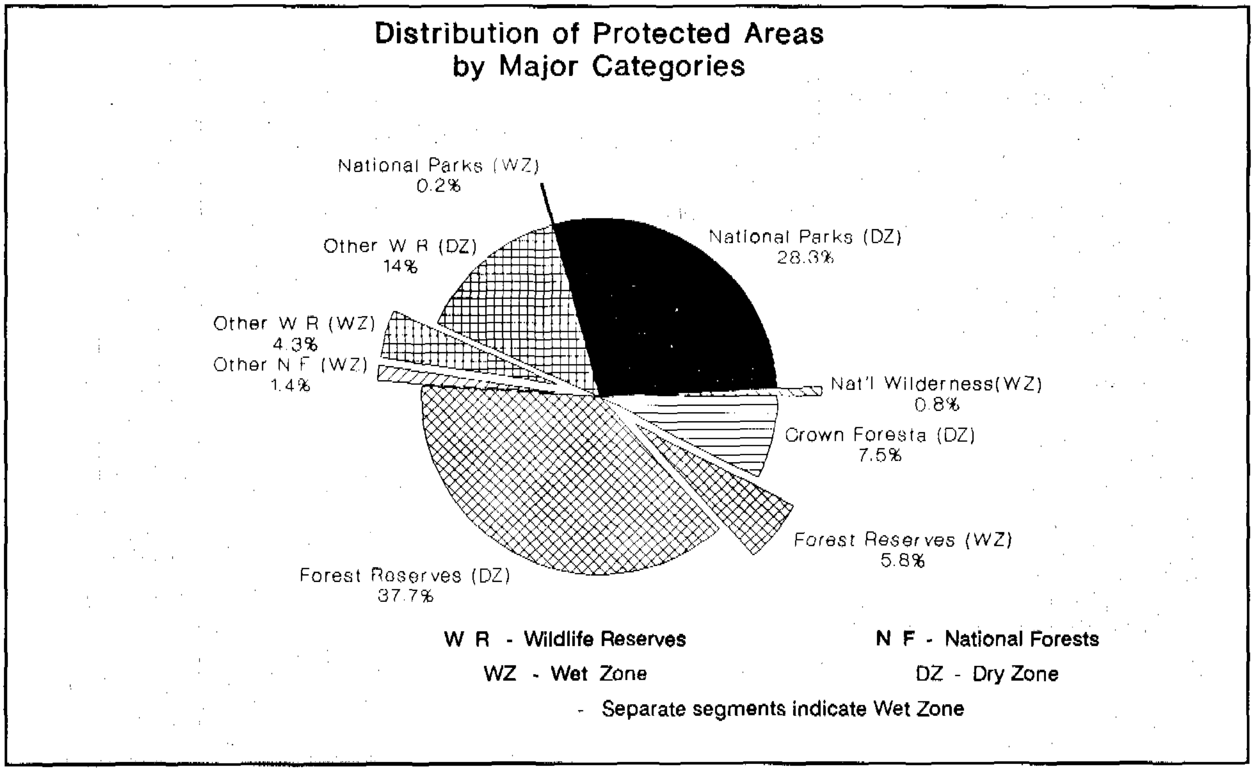


Figure 10.14

dens, 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 1,179 different species (Gunatilleke and Wijesundera, 1982), including about 14 percent of the local endemic flowering plants. The Botanic Gardens are a last refuge for at least five endemic plants that have not been found in the wild during this century.

INSTITUTIONAL CONSTRAINTS AND NEEDS

Sri Lanka's great wealth and diversity of biological resources has the support of laws and protected area coverage. Yet all the best evidence shows that here, as elsewhere in the world, biological resources are being depleted at unprecedented rates. The values of biological diversity are among the least appreciated, and, in economic terms, poorly valued natural resources. No single step will suffice to include these values in our thinking and decisions about how to proceed with economic development. A number of policy initiatives and improved institutional efforts will be necessary, as discussed below.

Knowledge Base and Analytical Capability

Lack of information and analysis constrains sustainable use of biological resources. Current data collection and monitoring neglect the needs of policy makers and resource managers to measure conditions, trends, and values of the resources. We lack information to help us measure management performance and to hold institutions accountable for their actions in protected areas and in planning and implementing environmentally significant development projects.

In response, scientific studies must document the extent, species composition, and ecological dynamics of the biological systems to determine trends in biological productivity, resilience, and current and potential economic and social values. Such data should provide bases for more realistic computation of how people benefit from conserving biological resources, and how conservation promotes economic efficiency as well as intergenerational equity.

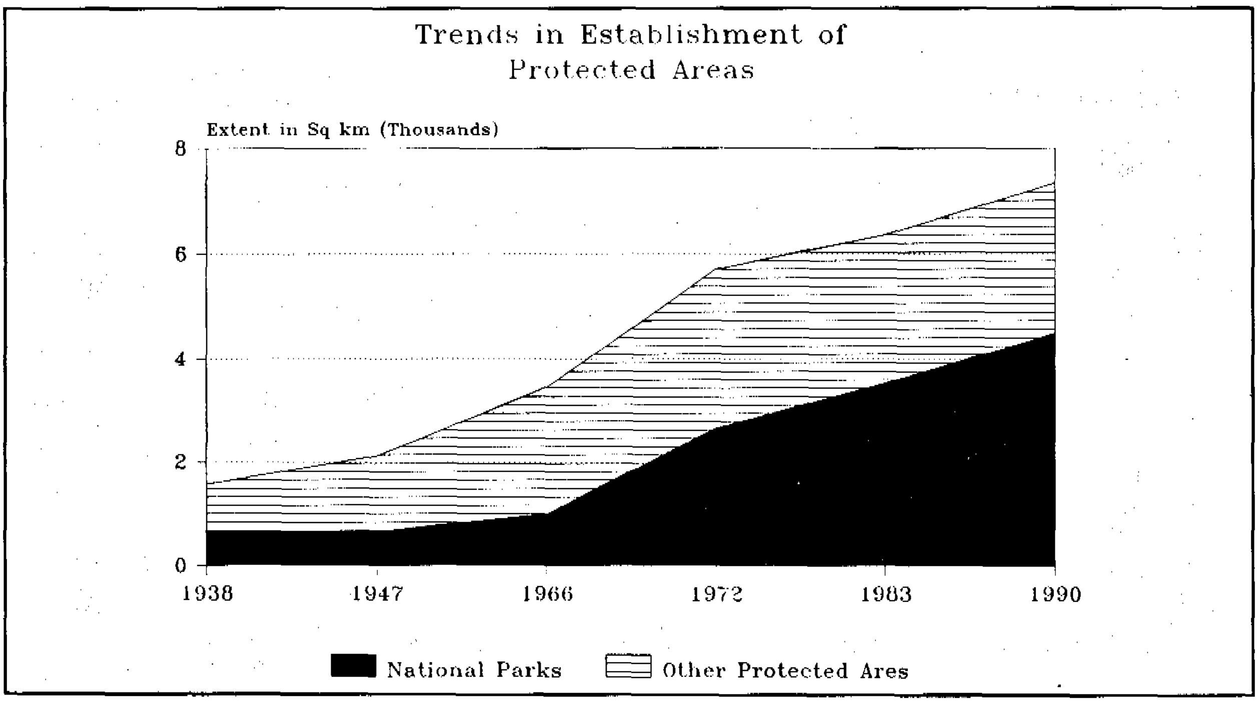


Figure 10.15

Providing Economic Incentives

Although biological resources are of immense economic value, their conservation is only possible if their economic values are appreciated by local communities. Yet local communities often lack opportunities and incentives to participate in the sustainable use of biological resources.

Local rights to collection of non-timber forest products and other natural products can provide the basis for sustainable community management and increased local incomes. The promotion of low resource impact, high revenue ecotourism can provide economic incentives for local people to protect biological diversity.

Expanding Awareness

A fundamental barrier to conservation of biological diversity is the fact that people who earn immediate benefits from exploiting these resources do not pay the social and economic costs of the resource's depletion.

Methods can be developed to quantify the direct and indirect values of biological and genetic resources. These values can be translated into meaningful terms at the local community level. At the national level the inclusion of biological resources as a capital stock in national income accounts, provides opportunity for doing so.

Promotion of Cross-sectoral Collaboration

Numerous government agencies manage biological resources in Sri Lanka, including all the agencies concerned with land and water. Wetlands fall within the jurisdiction of at least ten or more state agencies. Genetic resources of cultivated crops and livestock fall within the purview of many other agencies and ministries. Responsibilities for biological resources, although clearest for forests and wildlife preserves, remain highly fragmented.

Many of these problems can be solved if agencies share information, establish common objectives, and arrive at common definitions of problems and solutions. Program coordination and development of adequate staff, budgets and other resources can follow these critical initial actions.

Strengthening Protected Area Management

Protected areas remain the most valuable tool for preservation of species and ecosystems. Although expanding protected area coverage remains important, the immediate challenge is to improve the management of existing areas.

Additional staff training, facilities for basic monitoring, and incorporation of local people in management and low-impact tourism are among the critical needs that can be addressed through proposals to donor agencies.

Policy Shifts

Government policies are a direct cause of depletion of biological resources, here as elsewhere, often despite good intentions. Policies on land tenure, soil conservation, agricultural development, forest management, and many other less obvious subjects directly or indirectly affect sustainable biological diversity.

Opportunities can be explored to increase incentives for landowners to protect long-term biological resources. For example, removal of subsidies for pesticides and agricultural chemicals can help reduce overuse of fertilizers that pollute soil and aquatic systems. Water quality standards for streams, estuaries and other waters can be established that are backed up by combined penalties and incentives for polluters. Long-term tenure, or full ownership, may also create promising incentives. Short-term tenure rights can discourage long-term investments in natural resource management in favor of short-term payoffs.

Incorporating Values into Economic Planning

Environmental impact assessment is one of the most valuable tools for incorporating biological diversity and environmental considerations into economic development planning and implementation. Its use requires skills largely lacking within the public and private sector.

Training, both short- and long-term, can help government agency and private sector staff to analyze development proposals and alternatives. It can focus on promoting broad understanding of events and impacts causing significant environmental changes, how impacts can be measured, in economic as well as environmental and social terms, and how to grapple with data gaps concerning biological resources. Agency heads can be made more familiar with the value of natural resource analyses and the importance of effective monitoring and implementation.

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SIGNIFICANCE OF THE COASTAL REGION

- It contains 34 percent of the country's total population and represents 24 percent of the land area.
- It contains the country's principal city of Colombo, the largest six of the twelve Municipal Councils and 19 of the 39 Urban Councils.
- Its marine fishery supplied 97 percent of total fish production -- during 1987-1988 two-thirds of the animal protein consumed.
- Its exports of fish and aquatic products earned 576 million rupees in 1987 and 825 million rupees in 1988.
- Sun, sand and surf of its sea beaches are Sri Lanka's major tourist attractions that also offer recreational opportunities for her people.
- Its natural coastal habitats -- coral reefs, estuaries and lagoons, mangroves, tidal flats (salt marshes), and barrier beaches -- are immensely productive, essential for national growth and rich reservoirs of genetic resources.
- It bears significant minerals, such as ilmenite and monazite-bearing beach sands, silica sands, Miocene limestone, kaolin, china clay, copper magnetite and peat.
- It hosts over 80 percent of the industrial units located in and around Colombo alone, and several other major units elsewhere, many of which are highly polluting.

ECONOMIC AND SOCIAL SIGNIFICANCE

Over the past five centuries, following foreign occupation, the country's development has been closely linked to maritime affairs. Expanding international trade and commerce accelerated population shifts to the coasts. Since Independence (1948), coastal settlements grew in size and economic importance, particularly in the south, southwest and west. By 1981 the census recorded 5.04 million people, or 34 percent of the total population, living in coastal Assistant Government Agent (AGA) divisions, of whom 45 percent lived in urban areas. Fishing, tourism, industry, and agriculture sustain the growing economy of the coastal region, defined as the AGA Divisions with maritime boundaries (see box).

Fishing is the predominant coastal economic activity in the eastern and northeastern coasts during the southwest monsoon (from April to August) and in the southern and western coasts during the northeast monsoon (from December to March). The marine fishery industry provides full employment to about 80,000 persons, part-time employment to about 10,000 more, and indirect employment to another 5,000, contributing about 1.9 percent to the GDP in 1988. Marine fisheries contribute most (65 percent) of the animal protein and 13 percent of the total protein consumed by Sri Lankans. Export of fish and aquatic products drew an average 616 million rupees in foreign exchange in 1980-1987, or 2.8 percent of Sri Lanka's total non-traditional export earnings. Total export earnings in 1988 were 825 million rupees.

Ten Fishery harbors serve large fishing vessels with most traditional vessels and smaller fiberglass boats using beach landings close to fishing villages. Fishermen also use beaches to fish, mend nets, repair boats and build temporary dwelling units.

Coastal agriculture contributed 17 percent to total agricultural GDP in 1988. Paddy accounted for 70 percent, coconut 26 percent, and rubber 2 percent of the coastal agricultural GDP. About 55,900 hectares of coconut are currently cultivated in the coastal region defined by the coastal AGA divisions. Small areas of tea are found in the coastal divisions of Galle, Matara, Colombo and Kalutara regions, and cinnamon is grown in the coastal divisions of Galle, Matara and Kalutara districts.

Tourism in Sri Lanka has primarily focused on its scenic sandy beaches and coastal estuaries and lagoons. About 85 percent of tourist revenue comes from facilities in coastal areas, supplemented by the diversity of attractions in the interior cultural triangle. Today over 75 percent of graded hotels and over 80 percent 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 3,050 million rupees, but then came a sharp decline in arrivals and revenue until a sharp upward trend developed in 1990 (see Figure 11.2). Both high and low projections of tourism to 2000 anticipate over 1 million annual arrivals.

Pleasure travel accounts for about 92 percent of the total arrivals in Sri Lanka. Business and official travel accounts for about 6 percent, while arrivals for other purposes such as social, religious, cultural and educational account for the balance.

Wildlife resources add to coastal tourist potential. Two large National Parks, Wilpattu and Ruhuna (better known as Yala), border the coast. Wilpattu, closed in recent years, extends over about 30 kilometers along the northwest coast, and Yala borders the southern coast for over 50 kilometers. Several lagoons and coastal wetlands serve as bird sanctuaries. A marine sanctuary was declared in Hikkaduwa in 1979, although without enforcement or sanctuary management.

PRESENT CONDITIONS

The extent and variety of coastal habitats that provide such important economic and environmental values are displayed in Figure 11.3. All of these values are being diminished by various actions that have become significantly more serious over the past twenty years. Coastal erosion has threatened coastal investments, and pollution and competition for resources have degraded coastal systems in ways that jeopardize long-term tourist, fishery, and other sustainable economic and environmental values. Demographic and development trends highlight needs for increased attention to each of these problems and their cumulative effects.

Coastal Erosion. Erosion (see Chapter on Land Resources) endangers Sri Lanka's beaches and adjoining coastal land. Wind, waves and currents constantly pound the coasts, diminishing beaches and eroding bluffs. Effects vary from place to place, but they are aggravated by sand mining, coral mining, removal of vegetation and poorly sited or designed buildings, harbors and coast protection structures. Since 1981 the government has carried out major coastal erosion protection programs with foreign donor support.

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 Department. A CCD study found that some 500,000 cubes (1,415,000 cu. ft.) of sand were mined in the coastal stretch from Puttalam to Dondra Head in 1984 -- nearly all (97 percent) 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 prevent 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.

Habitat Degradation and Overexploitation of Resources. Coastal habitats are under enormous pressure because many are small and especially vulnerable to degradation. Puttalam Lagoon, for example, is Sri

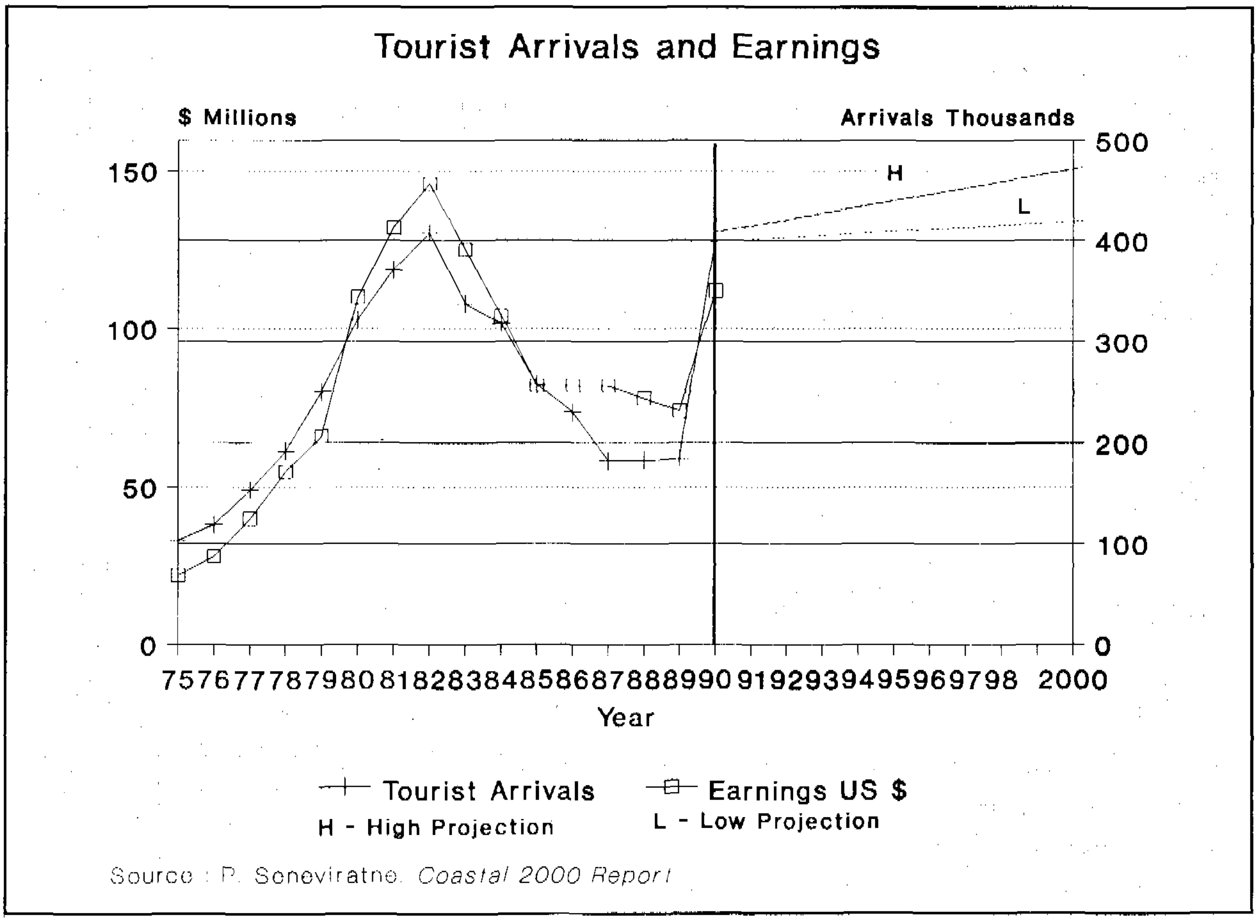


Figure 11.2

Lanka's largest estuary, but it is only about 20 kilometers long and 2 kilometers at its widest point, covering 36,426 hectares. The low tides along our coasts (about 75 centimeters) restrict most mangroves to narrow belts along the lower reaches of rivers and narrow edges of lagoons and estuaries, so there are no large mangrove forests. Those that exist have become severely reduced by overuse, abuse, and conversion to other uses. Coral reefs have similarly become badly degraded and their productive habitat diminished.

Coastal Pollution. Major sources are oil pollution from shipping and fishing craft, discharge of industrial effluents, sewage and domestic waste. Five miles off the southern and southwestern coasts a major international shipping route carries estimated annual traffic of over 5,000 tankers, posing risks of an accidental oil spill. Cleaning of fuel tanks in and around ports causes minor discharges that may account for frequent tar balls on southwest beaches.

Fecal pollution of beaches and coastal waters (for example, at Hikkaduwa) comes from temporary housing settlements near the beach or hotels that illegally discharge raw sewage. Pesticides and fertilizer from agriculture and inland industrial activities also cause coastal pollution.

Coastal and inland industries contribute chemical, heavy metal, and organic pollutants. Major sources of industrial pollution include the Valachchenai paper factory, which sends quantities of waste into the Batticaloa Lagoon, and the Embilipitiya paper factory, which similarly pollutes the Walawe Ganga estuary. The Lady Catherine Industrial Estate sends large quantities of industrial waste into the Lunawa Lagoon. The lake opens to the sea but sand bars frequently block its mouth. Once a flourishing fishing lagoon, now it is a mosquito-ridden stagnant body of water. At the Kelani Ganga estuary pollutants come from a large number of tanneries and other industrial plants. Industrial water

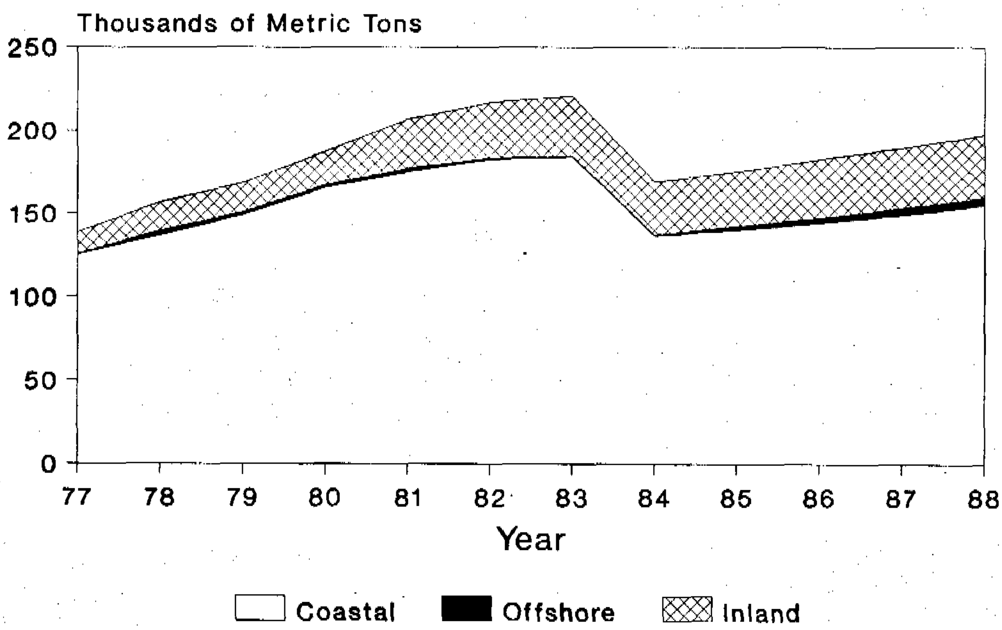
Extent of Coastal Habitats by District in Hectares

District	Mangroves	Salt Marshes	Dunes	Beaches Barriers And Spits	Lagoons And Basins Estuaries	Other Water Bodies	Marshes
Colombo	39	-	-	112	-	412	15
Gampaha	313	497	-	207	3,442	205	1,604
Puttalam	3,210	3,461	2,689	2,772	39,119	3,428	2,515
Kilinochchi	770	4,975	509	420	11,917	1,256	1,046
Jaffna	2,276	4,963	2,145	1,103	45,525	1,862	1,49
Mullaitivu	428	517	-	864	9,233	570	194
Trincomalee	2,043	1,401	-	671	18,317	2,180	1,129
Batticaloa	1,303	2,196	-	1,489	136,822	365	968
Ampara	100	127	357	1,398	7,235	1,171	894
Hambantota	576	318	444	1,099	4,488	1,526	200
Matara	7	-	-	191	-	234	80
Galle	238	185	-	485	1,144	783	561
Kalutara	12	-	4	77	87	476	91
TOTAL EXTENT	12189	23819	7606	11800	158017	18839	9754

Source: CCD Internal Report No. 13: Report on the preparation coastal habitats, 1986

Figure 11.3

Fish Production 1977 - 1988



Source: Fisheries Development Plan, Ministry of Fisheries and Aquatic Resources

Figure 11.4

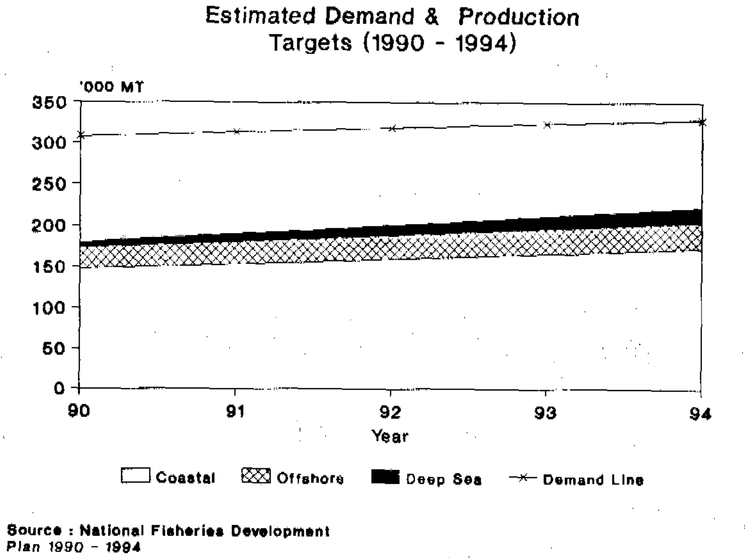


Figure 11.5

pollution occurring inland from the coastal zone is now subject to permit regulation by the Central Environmental Authority.

Marine Fishery Resources

Resources and Production. For management purposes marine fish resources are classified as coastal (within 40 kilometers of the coast), offshore (40-100 kilometers), and deep sea (beyond 100 kilometers).

Today the coastal fisheries provide nearly all (97 percent) of the marine fish production, employment (90 percent) and foreign exchange earnings (nearly 100 percent). As shown in Figure 11.4 peak production since 1977 occurred in 1983 with a harvest of 184,049 tons. Production declined thereafter, primarily because of civil unrest in the two major fisheries in the north and east.

The last data available -- the Fridtjof Nansen Fishery Survey in 1978-1980 -- indicates that areas of highest fish concentrations are found inside or close to the continental slope. Highest fish densities occur from Negombo to Galle, the banks off Hambantota and from Trincomalee to Mullaitivu. The survey estimated that annual sustainable yield of coastal fisheries is 250,000 tons -- about two-thirds of it pelagic species and the rest demersal and semidemersal species. The most available small pelagic fish are sardines, Indian mackerel, and herrings. Large pelagics include the Spanish mackerel, tuna, barracudas or pompanos. Demersal species include prawns, silverbellies, moonfish, ribbonfish and large demersals such as breams, groupers and snappers.

By 1988 traditional fishing boats still dominated the fleet of 28,000, but 46 percent were mechanized. As in many other tropical fisheries, many species are caught in a single fishery using a variety of gear. About 80 percent of total coastal production comes from the gill net fishery, using both mechanized and nonmechanized craft. The once dominant beach seine fishery that contributed three-fourths of the total production in the 1940s has declined to about 11 percent, as other methods have become more efficient.

Projected Demand and Production Targets. The government's Fisheries Development Plan seeks to improve nutrition through increased fish production. At present per capita fish consumption of 17.52 kilograms, demand for fish is projected to increase 9 percent from 1990-1994. The Ministry of Fisheries proposes to meet these demands and reduce projected imports with a 25 percent increase in fish production, primarily from coastal fisheries (Figure 11.5).

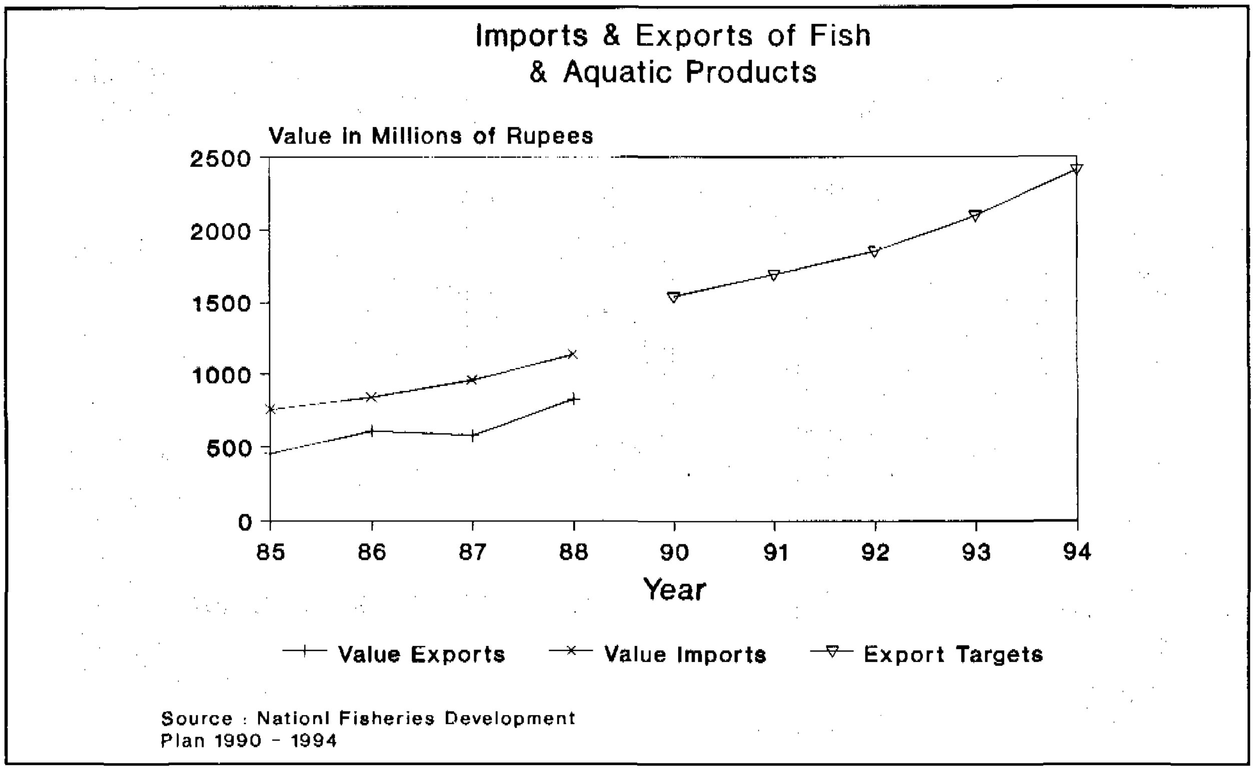


Figure 11.6

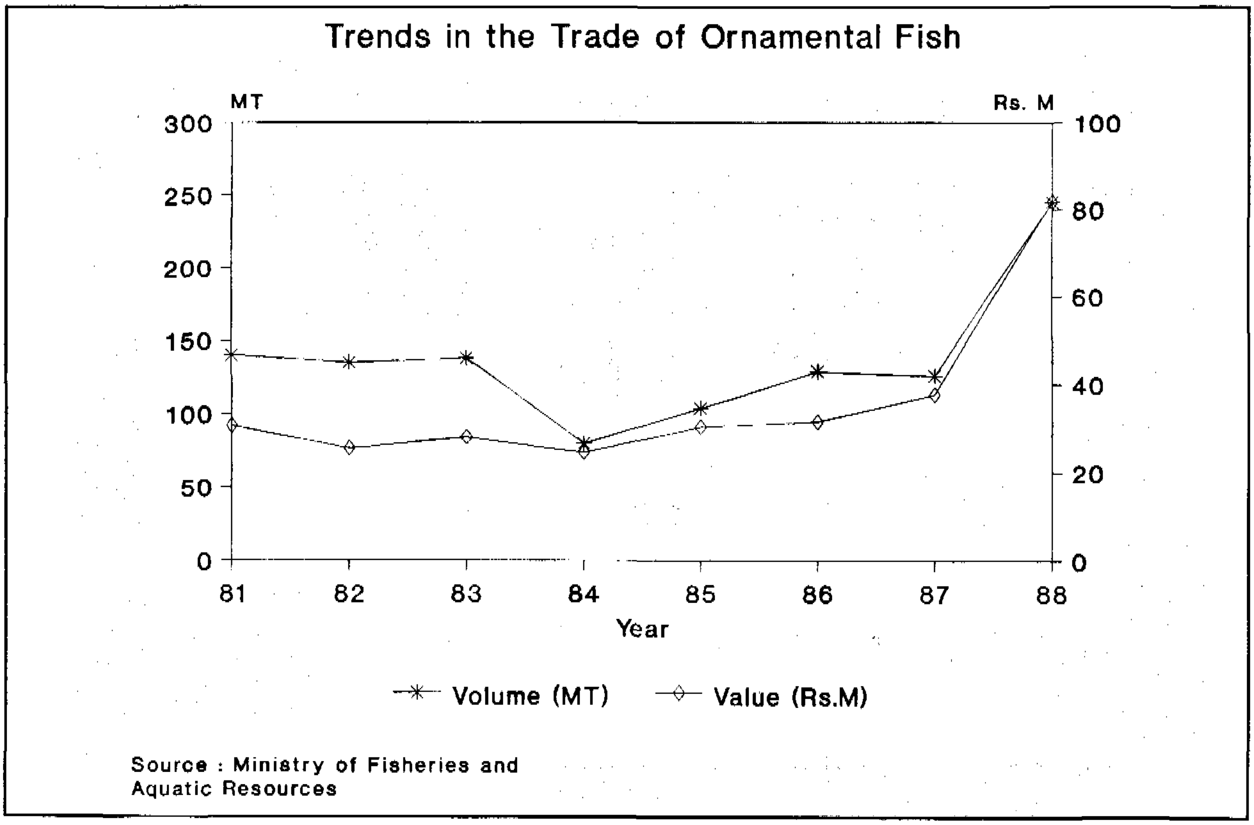
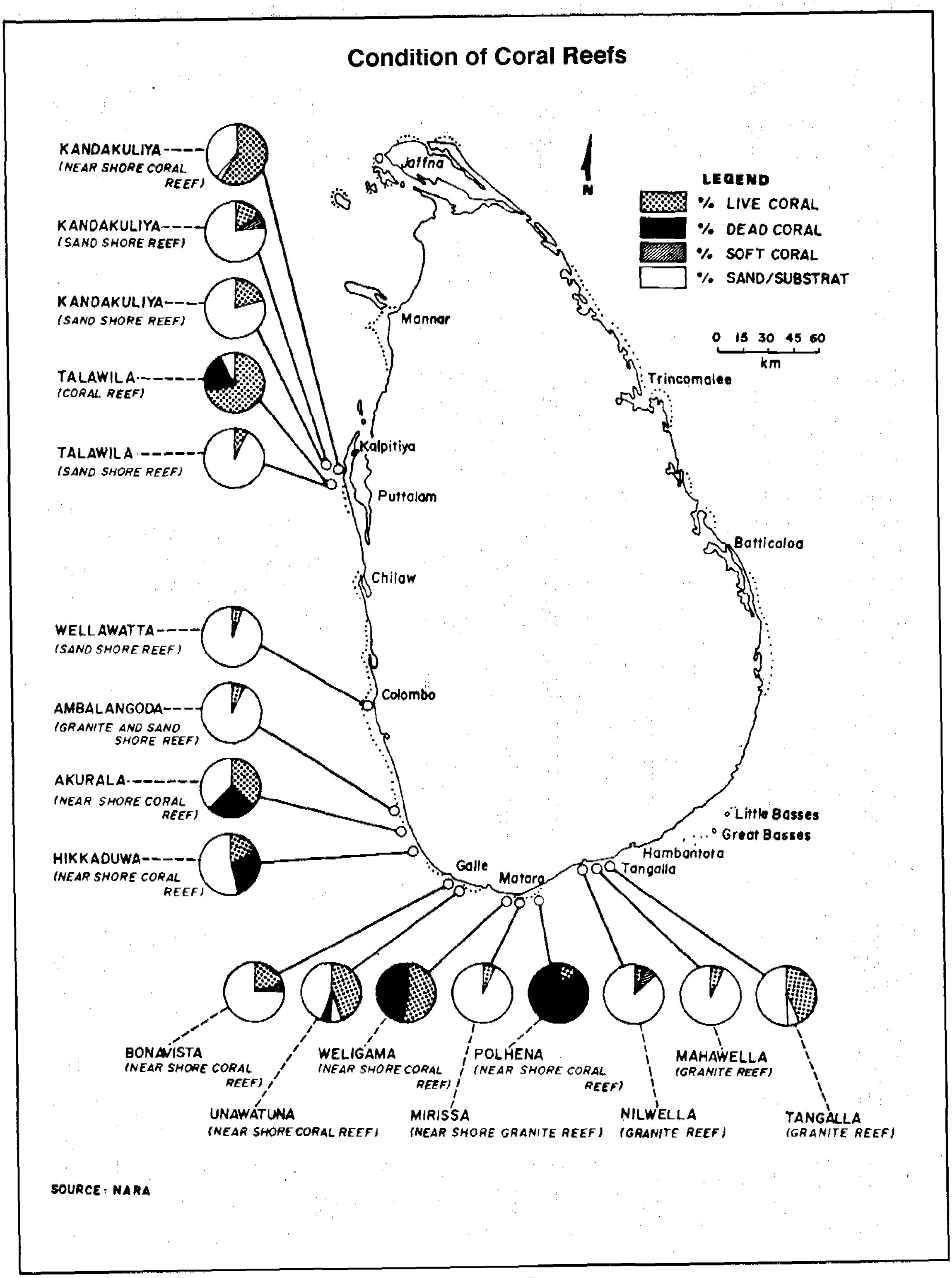


Figure 11.7



Condition of Coral Reefs
KANDAKULIYA (NEAR SHORE CORAL REEF)
KANDAKULIYA (SAND SHORE REEF)
KANDAKULIYA (SAND SHORE REEF)
TALAWILA (CORAL REEF)
TALAWILA (SAND SHORE REEF)
WELLAWATTA (SAND SHORE REEF)
AMBALANGODA (GRANITE AND SAND SHORE REEF)
AKURALA (NEAR SHORE CORAL REEF)
HIKKADUWA (NEAR SHORE CORAL REEF)
Jaffna
Mannar
Kalpitiya
Puttalam
Chilaw
Colombo
Galle
Matara
Trincomalee
Batticaloa
Little Basses
Great Basses
Hambantota
Tangalla
N
LEGEND
% LIVE CORAL
% DEAD CORAL
% SOFT CORAL
% SAND/SUBSTRAT
0 15 30 45 60
km
BONAVISTA (NEAR SHORE CORAL REEF)
UNAWATUNA (NEAR SHORE CORAL REEF)
WELIGAMA (NEAR SHORE CORAL REEF)
MIRISSA (NEAR SHORE GRANITE REEF)
POLHENA (NEAR SHORE CORAL REEF)
NILWELLA (GRANITE REEF)
MAHAWELLA (GRANITE REEF)
TANGALLA (GRANITE REEF)
SOURCE: NARA

Figure 11.8

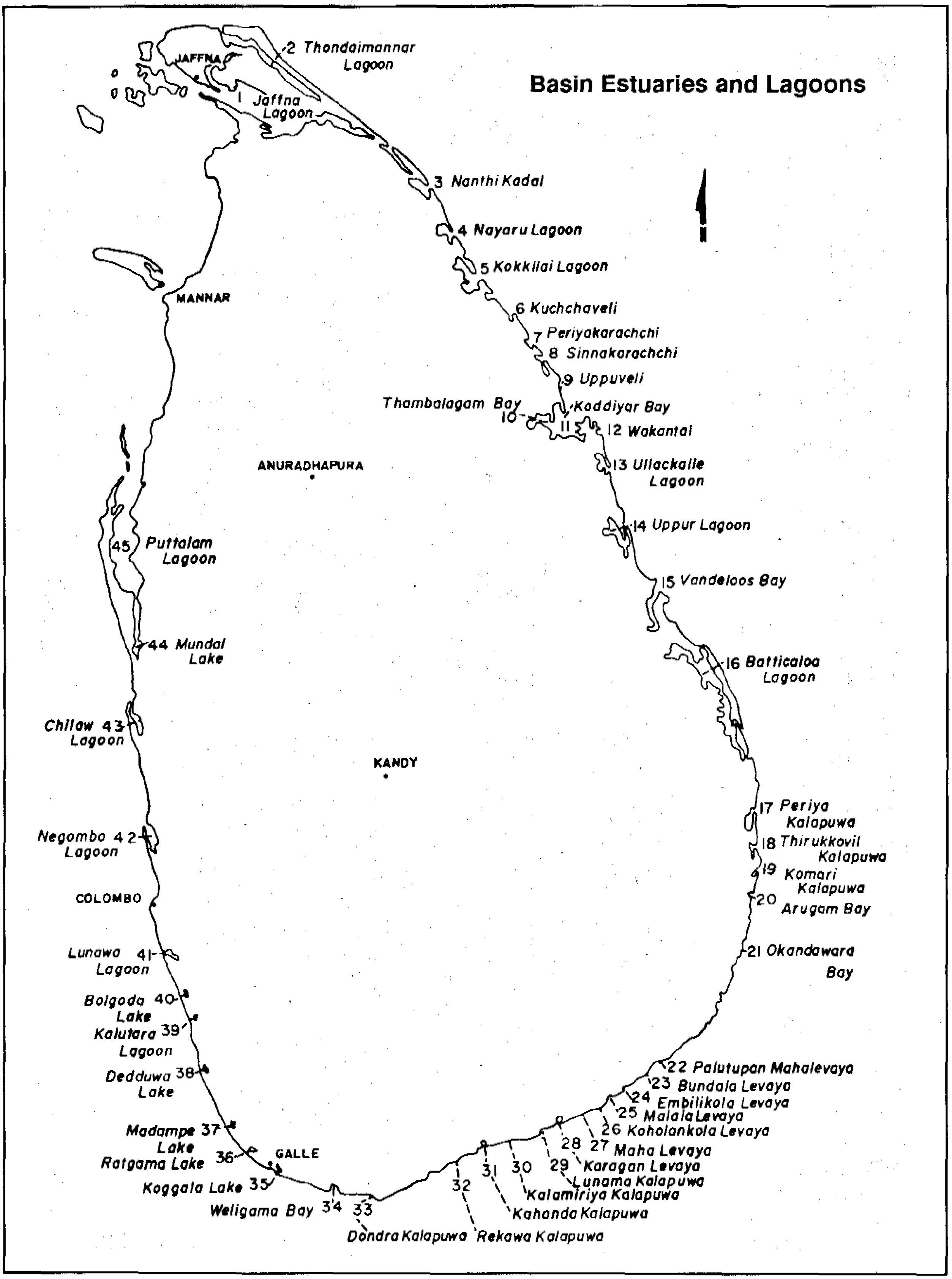

Basin Estuaries and Lagoons
JAFFNA
1 Jaffna Lagoon
2 Thondaimannar Lagoon
3 Nanthi Kadal
4 Nayaru Lagoon
5 Kokkilai Lagoon
6 Kuchchaveli
7 Periyakarachchi
8 Sinnakarachchi
9 Uppuveli
10 Thambalagam Bay
11 Koddiyar Bay
12 Wakantal
13 Ullackalle Lagoon
14 Uppur Lagoon
15 Vandeloos Bay
16 Batticaloa Lagoon
17 Periya Kalapuwa
18 Thirukkovil Kalapuwa
19 Komari Kalapuwa
20 Arugam Bay
21 Okandawara Bay
22 Palutupan Mahalevaya
23 Bundala Levaya
24 Embilikola Levaya
25 Malala Levaya
26 Koholankola Levaya
27 Maha Levaya
28 Karagan Levaya
29 Lunama Kalapuwa
30 Kalamiriya Kalapuwa
31 Kahanda Kalapuwa
32 Rekawa Kalapuwa
33 Dondra Kalapuwa
34 Weligama Bay
35 Koggala Lake
36 Ratgama Lake
37 Madampe Lake
38 Dedduwa Lake
39 Kalutara Lagoon
40 Bolgoda Lake
41 Lunawa Lagoon
42 Negombo Lagoon
43 Chilaw Lagoon
44 Mundal Lake
45 Puttalam Lagoon
MANNAR
ANURADHAPURA
KANDY
COLOMBO
GALLE

Figure 11.9

Current Status of Marine Resources. It has been over ten years since Sri Lanka has assessed its fish stock. Lack of data and inability to assess trends with accuracy seriously affect fishery planning and management. NARA's research has pointed to opportunities for expanded fisheries, particularly in the deep sea, and resource constraints, particularly closer in.

Large Pelagics

- Large pelagics (skipjack tuna, yellowfin tuna, bill fish, shark, seerfish etc.) in the coastal region are already exploited at an optimal level. However, small tunas (kawakawa and frigate tunas) that mainly inhabit the continental shelf area are not yet exploited to the maximum sustainable yield.

- The fishery for large pelagics in the offshore/deep-sea area can be expanded. The stock of these highly migratory species appears healthy, based on the increasing catch, especially from the purse seine fishery in the southwest Indian Ocean.

- From exploratory tuna fishing in offshore/deepsea areas use of multiple gear has resulted in high catch rates, particularly in the south, with the most profitable fishing zone 48-160 kilometers off shore.

Small Pelagics

- Sardine stocks (*Amblygaster sirm*) on the west coast are exploited at an optimal level and no increased effort should be permitted, meaning no more boats, in the small meshed gillnet fishery.

- In contrast, sardine stocks in the south and southwest are not exploited at the maximum level. Fishermen can be encouraged to use the small meshed gill nets for sardines in this area.

- The purse seine fishery in the southwest appears to be maintained at the correct 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.

Crustaceans

- Lobster production in the south declined by nearly 50 percent, from 200 metric tons in 1986 to 110 metric tons in 1988, indicating serious over-exploitation. About 25 percent of the lobsters landed are under-sized, and more than 50 percent of those caught during August-September are egg-bearing. Trammel nets (Disco nets) cause considerable damage to the lobster resources and NARA has recommended that they be prohibited in the lobster fishery.

- Prawns on the west coast are exploited at an optimal level. The Maximum Sustained Yield for Negombo is about 152.6 tons and the number of boat days is 21,200. The present level of prawn catch in the Kalpitiya Lagoon mouth area is also sustainable.

Foreign Trade in Fisheries and Aquatic Products. Sri Lanka's foreign trade in fisheries and fishery products is relatively insignificant. Exports consist of prawns, lobsters, crabs, ornamental fish, shark fins, all of which come from the marine sector. Imports consist of canned, dried, and maldive fish. Trends in exports and trade balance (Figure 11.6) show an increasing trend in the value of exports and imports but the trade balance has remained adverse. The Fisheries Development Plan 1990-1994 seeks a trade surplus by increasing exports of fish and fishery products (Figure 11.6).

Ornamental Fishery Resources. The international aquarium trade has boosted Sri Lanka's ornamental fishery exports (Figure 11.7). Ornamental fish exports rate third highest in terms of volume and value of fishery exports (behind prawns and lobsters). Nearly 70 percent of the aquarium fish exported are brackishwater or marine species. Of the marine species exported approximately 80 percent are fin fish while the balance are invertebrates -- corals, bi-valves, holothurians, echinoderms, and so forth. A few large traders dominate; a list completed in 1984 indicated that of the 26 exporters, 3 who dealt primarily with marine species shared nearly 80 percent of the export trade.

Approximately 139 species of marine fish are exported. Included are 29 species of butterfly fish, 13

Coral Mining

For years coral reefs along Sri Lanka's southwestern coasts have been subject to large-scale destruction from mining of coral for the lime required in the building industry. Activity is particularly intense in Akurala, Seenigama, Kahawa, Warallana and Totagamuwa, between Talpe and Ahangama, Mirissa and Madihe, and in the Rekawa village. Coral reef destruction also occurs in certain areas along the east coast. Mining reduces coral reef barriers against wave erosion, destroys habitat of a large numbers of marine fauna and flora, including economically important fish species, and can eliminate potential for sustainable tourism.

Mining for coral also occurs inland, where large deposits can be found along the southwestern coastal belt. A survey carried out in 1984 by the CCD from Ambalangoda to Dikwella revealed that 18,000 tons of coral are collected annually to supply the lime industry. Of this, 30 percent is from mining the reef, 12 percent is coral debris and 58 percent is obtained from inland deposits.Socio-economic aspects

A direct benefit from coral mining is its generation of employment in mining, collection, transportation, operation of lime kilns, and the gathering of fuel wood. A survey carried out by the CCD in 1990 from Ambalangoda to Hambantota revealed that nearly 2,000 persons were dependent on inland and offshore coral mining and related activities. Over 400 lime kilns exist in the area, of which 178 are located within the coastal zone under the Coast Conservation Act -- 300 meters inland of the coastline. The majority (90 percent) of the people are aware that coral mining is prohibited by law, but they continue because they have no other means of income or because they do not believe in or care about its adverse environment impacts.

Lime production is the main source of income of the people in the Rekawa village, where about 80 percent of the families are directly or indirectly involved. This, however, is a recent phenomenon. Since 1970, severe drought resulted in the decline of agricultural activities and farmers turned to lime production instead. Subsequently, due to declining fishery productivity of the Rekawa Lagoon, large numbers of fishermen also joined the industry.

Legal and Enforcement Aspects

The Coast Conservation Amendment Act of 1988 imposed severe restrictions on the removal, possession, storing and processing of coral and the operation of lime kilns within the Act's 'Coastal Zone.' Enforcement was immediately hindered because of the socio-economic distress caused to many families who depend on these activities for their livelihood.

Unsuccessful efforts have been made for several years to discourage coral mining. Coral miners have not yet been persuaded to take up other less lucrative employment, for the CCD lacked the mandate or the resources to provide employment alternatives. Among the agencies that can help do so the coral miners' problem has had low priority. Moreover, to enforce the reef protection provisions, the CCD has to rely on local police action. Faced with the favorable returns from reef mining, available at least in the short term, CCD has been unable to obtain the necessary cooperation for enforcement from local political and administrative leaders.

In 1990 fresh efforts were launched to provide alternate employment, with the active involvement of the Southern Provincial Council and stringent enforcement by the police authorities. Several families in the Rathgama electorate have already been provided with alternate land and facilities for employment. At the same time police action has intensified against those breaking the reef. Court action has been initiated against several operating lime kilns. Yet the problem is far from being solved.

Certain donor agencies have indicated that urgent action is necessary to stop further destruction of coral reefs if funding is to continue for CCD programs, especially for construction of coast protection structures. Opposition to coral mining exists within the local community not involved in it, due to increased environmental awareness. These voices have helped provoke interest by the provincial administration in halting coral mining. They have become a growing factor favoring CCD's efforts to stop further reef degradation.

kilometer landwards from the mean low water tidal level. Mangroves are discontinuously distributed along the coastline and absent altogether along exposed shorelines affected by high wave energy. Mostly they occur within embayments and along estuaries and lagoons.

Of the 55 species of mangroves recorded worldwide, 23 species have been recorded in Sri Lanka. These species, only a few of which are trees, fall into two broad categories -- true mangroves and mangrove associates.

Salt marsh vegetation consists of herbaceous, salt tolerant plants growing in tidal flats or areas periodically inundated by seawater. In Sri Lanka they occur mainly in the north, northwest, northeast, and southeast where 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 growth interspersed with scrub mangroves.

Functions and Values. Each coastal wetland system functions in ways that provide tangible economic values to coastal residents.

Estuaries and lagoons, which serve as nutrient traps and highly productive water bodies, are amongst the most economically valuable habitats. They support fishing and employment of thousands of coastal residents. In 1977 for example, 1,684 fisherman depended on the fishery of the Negombo Lagoon; in 1983 the number increased to more than 2,000. Estuaries and lagoons provide seed fish and shrimp for the aquaculture industry, and ornamental fisheries that provide important employment in Negombo Lagoon, Bolgoda Lake and Trincomalee Bay.

Their other uses explain why their biological systems have become so vulnerable to degradation. On one hand estuaries and lagoons are harbors and anchorages (Negombo Lagoon, Chilaw Lagoon), disposal sites for sewage (Kelani estuary, Negombo Lagoon, Lunawa Lagoon) and industrial effluent (Negombo Lagoon, Kelani estuary, Valaichchenai estuary). On the other hand they invite recreation (Negombo Lagoon, Bentota estuary and Bolgoda Lake) that requires clean water. Estuaries supply sand that significantly helps stabilize beaches, but they also supply sand for mining (Maha Oya estuary, Kelani estuary, Kaluganga estuary) that can disrupt the beaches over time.

Seagrass beds also support highly productive fisheries. Most marine fish caught come from nearshore coastal waters along the northwestern and northeastern coasts where seagrass beds abound. Among other functions and values: seagrasses bind sediment and stabilize the bottom against erosion, provide habitats for the endangered dugong and the protected sea turtle, and provide food to several marine organisms. Some species such as parrot fish feed directly on the seagrass leaves, while peneid shrimp feed on the grass detritus. Certain juvenile fish feed upon epiphytes. One commercially important species in the estuaries and lagoon fisheries -- *Etroplus suratensis* -- is found mainly among seagrass beds.

Mangroves are widely harvested for subsistence and commercial scale operations. Some species -- *Rhizophora, Bruguiere, Avicennia* -- are commonly used as firewood. People around the Puttalam Lagoon prefer the charcoal of *Rhizophora* for its high heat and low smoke. But supplies are threatened; organized extraction of firewood for domestic use (Jaffna, Puttalam), and firing of bakeries (Puttalam), kilns (Batticaloa) and illicit distilleries (Chilaw) cannot be sustained at present levels.

Other valuable economic uses of mangrove species make a long list. Poles cut from *Rhizophora*, *Bruguiera* and *Avicennia* help in construction of temporary housing, while plaited leaves of *Nypa* are used to thatch roofs in certain areas. In the Bentota area, *Cerebra manghas is* used to make masks. Fodder for cattle and goats comes from *Rhizophora* and *Avicennia*, especially during drought periods, and leaves of *Avicennia* are sometimes used as manure. Ripe 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* branches are heavily exploited in the Negombo lagoon for the construction of brush piles (*mas-athu*). Tannin obtained from the bark of *Rhizophora mucronata* and *cerips tagal* is still widely used to tan fishing nets and sails of the traditional fishing craft. Mangrove timber is sometimes used to construct the outriggers of traditional craft.

The economic value of these mangrove uses, clearly high, has not been accurately estimated. We have not yet reckoned the future costs incurred by coastal residents if unsustainable abuses cause mangrove stocks to decline.

Salt marshes have their own distinct functions and values. In Mannar and Puttalam they are sites for collection of milkfish fry (*Chanos chanos*) for brackish water aquaculture. Like inland wetlands, they also function as bird habitat and as discharge areas that absorb storm water runoff. Livestock grazing and hunting of water fowl are carried out on a limited scale in Sri Lanka's salt marshes.

Degradation Trends and Causes. Although quantitative measures of degradation trends are spotty, we know the nature and causes of the problem.

Several estuaries and lagoons have gradually decreased in size. In Negombo Lagoon, for example, the effective water area has diminished by 791 hectares, between 1956 and 1981. The delta area at the Attanagalu Oya inlet has almost doubled during this period, indicating high rates of siltation. Apart from natural siltation and sedimentation, human activities responsible for this trend include landfilling to increase land holdings, encroachment planting of mangroves to stabilize temporary shoals, and garbage disposal. New piers, jetties, and bridges restrict the water flow and promote further siltation. The Lunawa Lagoon and the Kalametiya-Lunawa Lagoon have also decreased considerably in size from these kinds of activities.

Estuaries and lagoons seriously affected by pollution include the Negombo Lagoon, Kelani estuary, Lunawa Lagoon, Walawe estuary and the Batticaloa Lagoon. In the Walawe Ganga estuary and the Batticaloa Lagoon major contamination comes from the two state-owned paper factories. Other areas receive industrial effluent, domestic/municipal waste and sewage, and, as in Negombo Lagoon, oil from fishing craft, boat repair yards, and fuel supply stations along the banks. Certain southern lagoons are experiencing increased nutrient contents due to the rolling of coir, which leads to the release of nutrients such as nitrogen and phosphorus, causing low levels of dissolved oxygen.

Sand bars restrict water flow, nutrient exchange, and navigation. Sand bar formation can be caused by natural factors such as sediment transport patterns and rainfall patterns, but several human activities contribute to and aggravate the problem. Several recent river basin development/diversion schemes have caused restricted and altered flow patterns that have helped form sand bars. Obstructions to navigation have occurred in Chilaw Lagoon, Negombo Lagoon, and the Panadura-Bolgoda estuary.

Desalinization has adversely affected several lagoons and estuaries. The salinity of the Kalametiya-Lunawa Lagoons dropped considerably when the excess water fresh water from the Uda Walawe reservoir was diverted into the lagoon in 1950 and significantly affected the prawn fishery of the lagoon. Reduced fishery potential at Nanthikada has resulted from change in the salinity regime and inadequate recruitment from the coastal waters.

Conditions and trends in use of the limited mangrove resources have not been measured nationally, but local data highlight worrisome trends. For example, mangrove cover in the area from Thambalagam Bay (Trincomalee) to Valaichchenai (Batticaloa) has declined by 25 percent.

Conversion of mangrove areas to other uses is the greatest threat. Partial harvesting of mangroves for activities described above can be carried out at locally sustainable levels, but conversion of mangrove areas by clearing vegetation and changing topography and soil conditions causes permanent damage.

Mangrove areas are also reclaimed for housing and urban expansion, especially near populated urban centers. In Negombo, for example, about 50 hectares of mangroves were clearfelled for a national housing project in 1984.

Impoundment of mangrove areas for aquaculture ponds commenced in the early 1980s and since then the number and scale of aquaculture projects has increased. Over 600 hectares of coastal land between Chilaw and Puttalam (around the Chilaw Lagoon,

INSTITUTIONAL RESPONSES AND NEEDS

Overall responsibility for coastal resource management vests with the Coast Conservation Department (CCD) under the Coast Conservation Act No. 57 of 1981. Within the narrow coastal region defined by the Act (see **Figure 11.10**), CCD formulates and implements coast conservation projects, regulates development through permits, evaluates development project impacts through discretionary environmental impact assessments, prepares and implements a Coastal Zone Management Plan, and conducts research in cooperation with other agencies.

CCD's mandate is unusual among government institutions because it was designed to cross over and help coordinate the sectoral management authority of many other agencies. It can do so because it exercises regulatory authority over new coastal development. In practice it meets its mandate through frequent and informal interagency 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 and efforts within and outside of the coastal zone;
- The National Aquatic Resources Agency (NARA), situated within the Ministry, was established in 1981 to carry out broad research and development, monitoring, and research coordination functions concerned with Sri Lanka's marine and inland aquatic resources.
- The Urban Development Authority (UDA) exercises comprehensive management authority over development within and outside of the coastal zone, including all areas within one kilometer of the coastline, which it has designated as "urban." Detailed land use plans have been developed for some rapidly growing urban centers (Colombo, Ambalangoda, Hikkaduwa) with others in progress. All building construction within coastal areas requires a permit 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 Greater Colombo Economic Commission. Other agencies, like the Ceylon Electricity Board with its role in developing thermal electric generating plants, can exercise significant jurisdiction 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 resource and environmental policy generally.

Sri Lanka exhibits all the pressures of development and population density that threaten coastal resources in every part of the world. It is blessed, however, with unusually farsighted coastal legislation. CCD's establishment of a regulatory program, and completion of a coastal plan have made rational management of coastal resources possible, and possibly easier than management of many inland resources. On the other hand, CCD's task is made difficult not only by the usual limitations of staff and resources, but more so by its legally limited jurisdiction -- 2 kilometers out to sea, 300 meters inland, and 2 kilometers inland for rivers and estuaries. Given the ecological and hydrological systems and adverse development impacts that respect no such artificial boundaries, coastal management requires complex interagency coordination and agreement.

Looking beyond the bureaucratic challenge, however, CCD sees its success increasingly tied to its ability to work through local communities and interests whose economic and social self-interest requires sustainable coastal development. Efforts to conduct coastal management through smaller units and at grass-roots levels will require substantial public education and new opportunities for employment and income generation that will maintain coastal resources and productivity for future generations.

flood plains. An attempt is made here to develop a framework for appropriate classification that, once refined, can facilitate the gathering of scientific data necessary to support wise use of our water resources.

Unlike coastal ecosystems, inland aquatic resources are not subject to influence of ocean tides. Yet they are essential breeding, rearing and feeding grounds for

kilometers. These river systems can be classified into three types, based on gradient of the river bed, and velocity and permanence of the water:

- *slow-flowing perennial,* usually confined to the lowlands where the gradient is flat and the flow of water is sluggish, such as the Maha Oya and Deduru Oya;

Classification of Inland Aquatic Systems of Sri Lanka

SYSTEM — **SUB-SYSTEM**

- INLAND AQUATIC RESOURCES
  - RIVERS & STREAMS (Riverine)
    Habitats contained within a channel.
    - SLOW FLOWING (Lower Perennial)
      Gradient low and water velocity low; water flows throughout year; substrate consists mainly of sand and mud; floodplain fairly developed.
      eg. slow flowing perennial rivers and streams
    - FAST FLOWING (Upper Perennial)
      Gradient high, velocity of water fast; water flows throughout the year; substrate of rock, cobbles or gravel; little floodplain developed.
      eg. fast flowing perennial rivers and streams
    - SEASONAL (Intermittent)
      Water flows for part of the year;when water is not flowing, it may remain in isolated pools, or surface water may be absent.
      eg. seasonal streams
  - WETLANDS (Palustrine)
    Floodplains and shallow-water habitats dominated by vegetation or those < 2 m depth at low water levels or < 8 ha of surface.
    eg. riverine marshes
    non-riverine marshes
    wet montane grasslands
    swamp forests village,
    tanks ponds rice paddies
  - DEEP WATER (Lacustrine)
    dammed river channel :
    > 8 ha area
    - DEEPWATER (Limnectic)
      Deep water habitats within lacustrine system; 2m depth at low water level
      eg. perennial reservoirs/tanks
    - SHALLOW FRINGE (Littoral)
      Wetland habitats within lacustrine system: extends from shoreward boundary of deepwater habitat to depth of 2m.
      eg. reservoir/tank fringe wetlands

Figure 12.1

- *fast-flowing perennial,* mainly confined to the hill country where the gradient is steep and flow of water fast, such as the Kotmale Oya and Behihul Oya;
- *seasonal,* where water is confined to small isolated pools in the river bed or completely absent during the dry season, such as the Wasgomuwa Oya and Bodigoda Aru.

Wetlands (Palustrine system)

Wetland systems consist of extensive marshes connected to rivers or seasonally flooded and isolated from rivers, and many small permanent or seasonal ponds, swamps and other water-dominant and water-influenced habitats. About 95 percent of Sri Lanka's inland freshwater wetlands are man-made, comprising mainly rice paddies and village reservoirs.

The depth, duration, chemistry and temperature of the water, and cultural practices determine the nature and productivity of wetlands -- the amounts and types of vegetation and fish, molluscs, birds, crustaceans, insects, worms and micro-organisms which find food and shelter in the substrata and within the vegetation. Floods, droughts, frost and high winds are among the important events that shape the natural ecosystems.

Because of their steep gradients, most of Sri Lanka's rivers and streams, particularly in the southwest, have not developed extensive floodplains. They are usually characterized instead by narrow, restricted floodplains along most of their length and notably near the river mouths.

Floodplains associated with rivers

Floodplains associated with rivers are best represented along the Mahaweli Ganga, Kala Oya and Modaragam Aru (Fernando, 1971). The most extensive, the Mahaweli Ganga floodplain, occupies around 50,000 hectares of the eastern lowlands. Much of this floodplain has a natural or semi-natural vegetation cover consisting of a complex array of diverse habitats. Inland freshwater habitats include small streams, riverine marshes, seasonally flooded swamp forests and seasonal tanks. The coastal saline habitats include estuaries and deltas, mangrove swamps and intertidal mud flats.

These habitat types have intricate interrelationships between biological and hydrological characteristics. The riverine marshes or 'villus' occupy natural depressions between the levee ridges of the channels of the Mahaweli and its various active or former distributaries, or between these levee ridges and the adjacent upland areas. They directly connect to the river by narrow channels. During the dry season, when the river is low, much, but not usually all of 'villu' water may flow out to the river through these channels.

Coastal habitats near the river mouth, including mangroves and mudflats, coastal waters and productive estuaries, depend on the upland wetlands of the floodplain for their nutrients, hydrological regime, and water quality. The river, floodplain and associated coastal ecosystem form interdependent parts of a complex hydrologic system.

Not far inland along the western coast, the 60-hectare Bellanwilla-Attidiya marsh is one of the few remaining freshwater wetlands near Colombo and is another example of a wetland system associated with a river. Located in the floodplain of the Bolgoda Lake, which is connected to the Bolgoda Ganga, it was partly cultivated with paddy until about 1980. Now it consists of shallow freshwater ponds, marshes and seasonally flooded grassland with scattered scrub and small trees. Although Bolgoda Lake is brackish and subjected to tidal fluctuations, the Bellanwila-Attidiya complex lies away from the river mouth and has a fresh water condition with major contributions from overland drainages and seepages. The marsh supports a variety of waterbirds in small numbers, and is an important roosting site. The open water is covered with floating weeds like *Salvinia molesta* and *Eichornia crassipes,* while the fringes contain low reeds and grass.

Floodplains isolated from rivers

Marshes within the Wilpattu National Park represent seasonally contracted floodplains isolated from river systems. They are formed in shallow depressions where local runoff collects over an impermeable layer or where water percolates through a thin layer of soil from the underlying limestone. About 40 'villus,' totall-

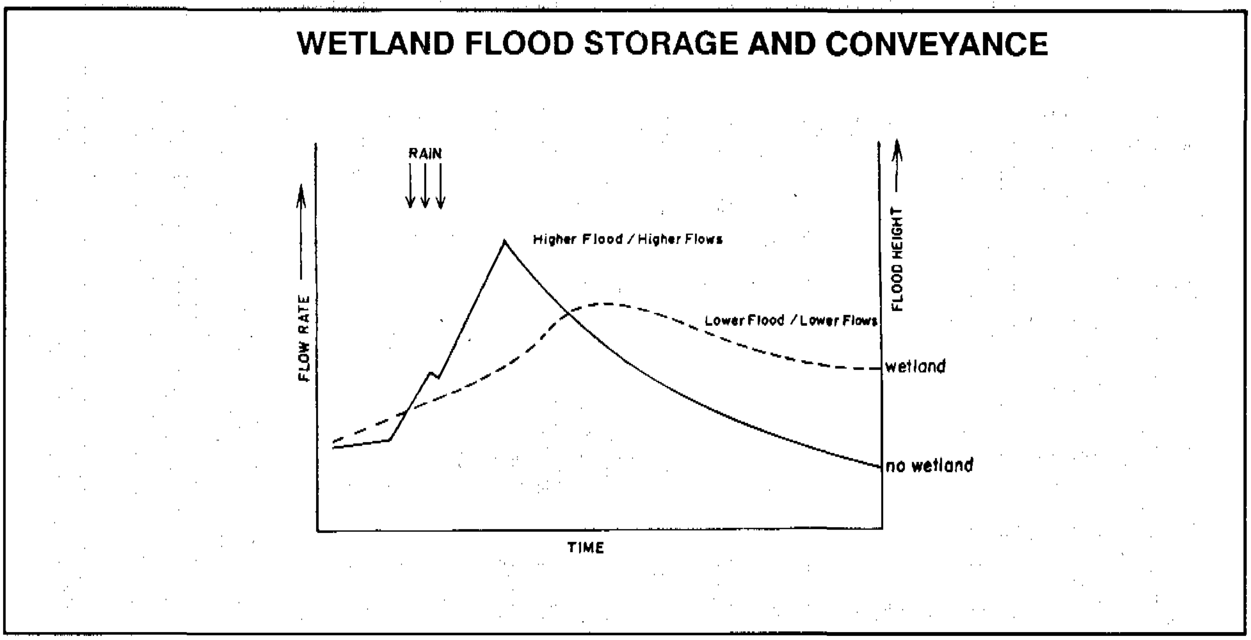


Figure 12.2

ing perhaps around 100 hectares in the park, are mostly fresh water. Several are saline even though they have no surface connection with the sea. A wide sloping beach-like fringe surrounds these 'villus' to form effective catchments. A variety of waterfowl and mammals are concentrated in and around these water bodies.

Wet Montane grasslands

These grasslands are best represented at Horton Plains, which lies at an altitude of 2,100 to 2,200 meters. The 2,000 hectares of wet montane grasslands in the valleys and lower slopes are interspersed with patches of thick montane forests on upper slopes and hill crests. These grasslands are a plagioclimax community, maintained by frequent fire and grazing (Koelmeyer, 1957). The plains receive southwest and northeast monsoons and are drained by tributaries of three major rivers, the Mahaweli, Walawe and Kelani Gangas. At the headwaters, the beds of these small tributaries are covered with peaty moss. The streams have no indigenous fish, and the rainbow trout introduced at the beginning of the century is the only fish species. Stream fauna is dominated by detritus-feeding animals.

Swamp forests

These forests occur on seasonally flooded soil in the floodplains of major rivers such as the Mahaweli, and are located between the levees of the river and the 'villus'. Extending up to two kilometers from the levees they are characterized by the presence of water or moist conditions for about three to four months of the year. Because so many have been converted to rice paddies, Sri Lanka has fewer large swamp forests than other Asian countries. Swamp forests occupy less than five percent of the floodplain area of the Mahaweli Ganga. These forests have a high density of understorey species including rattan *Calamus rotang*.

Only remnants still remain in the Wet Zone, yet even these have great scientific importance. A small patch of swamp forest in the floodplain of the Kalu Ganga near Bulathsinhala is the last refuge for two of the island's rarest endemic plant species, *Stemonoporus moonlii* and *Mesua stylosa* (Gunatilleke and Gunatilleke, 1983). This swamp forest is largely unprotected and privately owned.

Village tanks and ponds

Tanks are small, shallow flooded areas formed by rainwater collected in man-made or natural land depressions or by overspill and seepage from irrigation channels. The man-made village tanks are generally less than 12 hectares in surface area and resemble swamp marshes because they either run dry during the drought or have low water levels from July to September. About 12,000 operational village tanks now irrigate some 269,000 hectares mainly in the Dry Zone, and, to a lesser extent, in the intermediate zone. In some localities the density of tanks exceeds 0.56 tanks within a square kilometer. Sri Lanka's traditional social, economic and cultural life has been closely knit with village tanks. (See Heritage Chapter.)

Ponds are small and shallow depressions filled by rainwater and created by human developments such as excavations, road construction, gem mining, and so forth. Because so many gem pits have been created illegally they have not been filled or reclaimed after mining. Their small size and great depth makes them far more harmful than beneficial, being traps for wildlife and breeding grounds for malaria-carrying mosquitoes. An estimated 1,000 such abandoned pits lie within the Wasgomuwa National Park alone.

Rice paddies

In addition to the natural wetlands, Sri Lanka has over 850,000 hectares of rice paddies which are supported by the extensive and intricate system of man-made irrigation tanks. The paddy lands provide important habitat to waterbirds, and over 2,400 kilometers of irrigation channels connected to tanks provide additional wetland habitat.

Deepwater Habitats

The only inland deepwater habitats are irrigation tanks and reservoirs. Of the approximately 3,500 functional deepwater tanks and reservoirs in the country, only about 70 exceed 300 hectares in surface area. The total surface area of these man-made lakes exceeds 170,000 hectares. In recent years however, major reservoirs have been built in the hill country, particularly for hydropower generation, the largest being Victoria, Randenigala, Kotmale, and Castlereigh. These hill country reservoirs may reach over 40 meters in depth at full capacity. All have precipitous slopes.

In contrast, the ancient reservoirs are generally shallow, having even, small gradients and a mean depth at full capacity that rarely exceeds 15 meters. More than 80 percent of the island's inland fishery production comes from these new and ancient reservoirs (de Silva, 1988).

FUNCTIONS AND VALUES

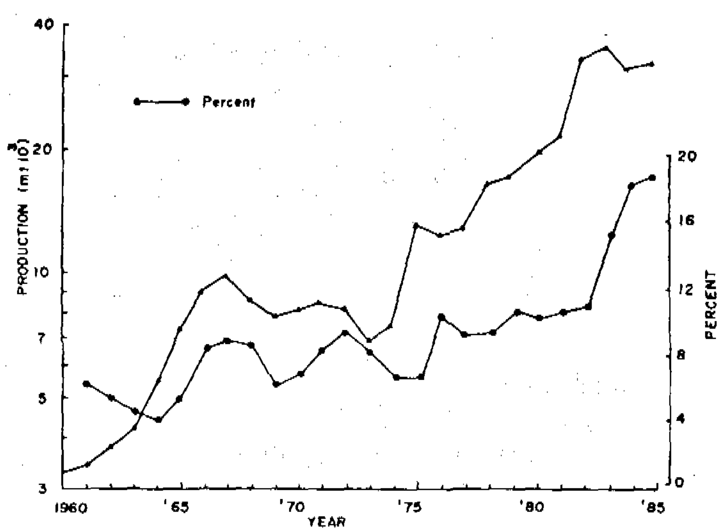
Inland aquatic habitats perform significant economic and environmental functions. What they do and how well they do it depends on their particular hydrological, biological, and physical characteristics. Hydrology drives the systems, however, and largely determines the functions and efficiency of the habitats and their processes. Based on the seminal work carried out in the United States by Adamas and Stockwell, which has gained international recognition (IUCN Bulletin, 1989), the critical functions of Sri Lanka's aquatic systems are described below.

Flood storage and conveyance

Riverine marshes and adjacent floodplains form natural waterways that convey floodwaters from upstream to downstream locations. Floodplains and wetlands, as well as deepwater habitat, store floodwater and release it slowly, thereby lowering flood peaks and protecting downstream areas (see Figure 12.2). Reservoirs and tanks are massive regulators of water, storing excessive rainfall during the monsoon periods and making it available for irrigation when and where required.

In urban areas subject to rapid storm water runoff and flooding, wetlands, particularly in the southwestern coastal zone, provide especially valuable service as "sponges" able to absorb floodwaters for later slow release. As such they serve as highly effective buffers against property damage.

Although this function is often recognized, efforts have not been made in Colombo or other urban areas of Sri Lanka to measure these wetland flood control capabilities, their economic benefits, and the costs of alternative flood control measures such as larger storm drains or flood control structures. In a well-known study of flood protection options in Boston, USA, a federal government agency determined that loss of wetlands associated with the Charles River would cause flood damage averaging 17 million US dollars a year (State of the Environment, Conservation Foundation, 1987).



Source: De Silva, 1988

Figure 12.3

Fishery production

Nearly all fish need shallow waters (wetlands or ponds) at some stage of their life cycle, to spawn, feed, or avoid predators and extreme environmental conditions. Studies have shown that two-thirds of the fish consumed in the world depend on coastal wetlands at some stage of their life, and freshwater fish depend similarly on inland wetlands and deepwater habitats.

In ancient Sri Lanka, reservoirs, ponds, rivers, and freshwater marshes were recognized as productive habitat for inland fisheries. Records reveal that inland fisheries were economic enterprises accepted both socially and culturally (Siriweera, 1986). The earliest reference to fishing in reservoirs and canals is found in Perimiyankulam rock inscriptions (A.D. 65-109) outside Anuradhapura. The inscription refers to a tax on fish. Such a tax on inland fisheries seems to have continued throughout the first millennium, during which time the state, village assemblies, and private individuals exercised proprietorship. Fish in large reservoirs and channels constructed by the state were owned by the king, and those he allowed to fish paid a tax. Village assemblies had proprietorship of fish in the village irrigation works considered as common property. Fish harvested from these tanks were divided amongst the villagers in proportion to the paddy land held by each villager. Private individuals owned small ponds and channels that led to their own paddy fields. The ponds were constructed by individuals in their homesteads to breed fish. Inscriptions suggest that the tax on fish was abolished sometime in the twelfth century A.D.

Prior to 1960 inland fishery production in the country was negligible, but today tanks and reservoirs account for 20 percent (or 27,000-30,000 metric tons/year) of Sri Lanka's total fish production. Mean production from the reservoir fishery is presently about 307 kg/ha/yr. Production from individual reservoirs varies from 40 to over 500 kg/ha/yr (de Silva, 1988). This growing fishery largely depends on a single exotic species, the cichlid *Oreochhromis mossambicus*, which was introduced into the country in 1956 (Figure 12.3). In some reservoirs studied (Figure 12.4) production has increased fivefold or more over a six-year period. With the decline of the deep-sea and coastal fisheries its importance is expected to grow further. The increase in inland fishery production resulted largely from the concerted effort made by the government to promote Sri Lanka's inland capture and culture fishery as an integral part of rural development (Figure 12.5).

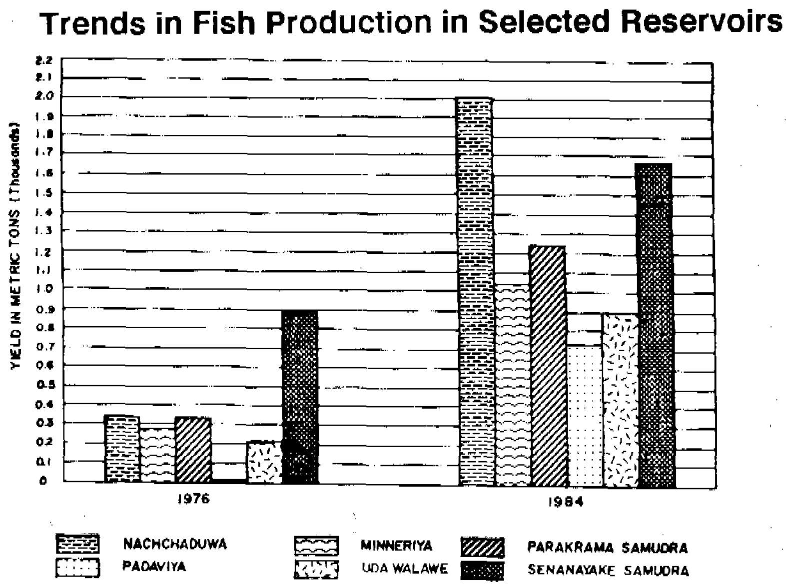
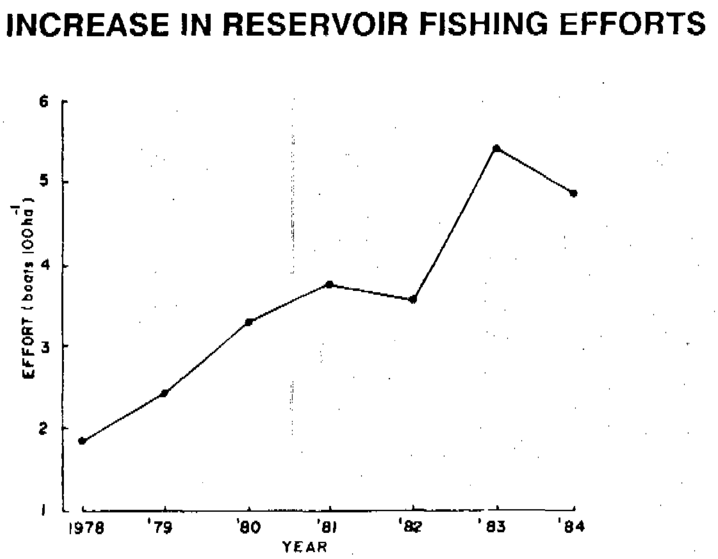


Figure 12.4



Source: De Silva, 1988

THE OVERALL MEAN EFFORT IN RESERVOIR FISHERY HAS INCREASED FROM 0.019 BOATS/HA IN1978 TO 0.050 BOATS/HA IN 1984, NEARLY A THREE-FOLD INCREASE IN SIX YEARS. HOWEVER INCREASE IN EFFORTS IN THE RESERVOIRS NOT BEEN BASED ON ANY CONSIDERATION OF THE MAXIMUM SUSTAINABLE YIELD (MSY). THIS COULD HAVE IMPLICATIONS FOR SUSTAINABLE MANAGEMENT OF RESERVOIR FISHERIES.

Figure 12.5

Although data concerning river fish fauna is limited, Sri Lanka's rivers do not, and apparently never did support a viable commercial fishery. Yet riverine 'villus' that form part of the river floodplain are highly productive, and excellent spawning and nursery habitats for many fish species, both commercial and non-commercial. Few studies have been carried out in these habitats, but Fernando and Indrasena (1969) reported that in selected 'villus' in the Mahaweli Ganga floodplain catches ranged from 35-70 kg/ha/yr. Mendis (1977) estimated that riverine marshes have a total potential annual fish production of 450 tons, about one percent of the country's total annual freshwater fish production.

Wildlife habitat

Inland aquatic habitats, particularly wetlands, are among Sri Lanka's most valuable wildlife habitats. They offer the most critical habitat components of food, water, and often cover as well. Structural diversity of vegetation, water, and open spaces maximizes the 'edges' that are so productive to wildlife. Floodplains along permanent streams and rivers provide hospitable habitat for migrating birds, deer and elephant.

The Mahaweli Ganga floodplain, including its associated riverine marshes and swamp forests, supports the greatest animal biomass density of all habitat types found in the country. Of particular importance is its value as elephant habitat because of the abundant food and water. Over 500 elephants (or one-sixth of the island's estimated wild population) use the floodplain as a corridor between the wet season feeding and dry season watering grounds. The Mahaweli Ganga floodplain occupies a relatively small part of the northeast region, however, and it is extremely vulnerable to change and external influence.

Other aquatic habitats also support major elephant populations. The environs of Senanayake Samudra support a population of 250-300 elephants, while three small tanks (Lahugala, Kitulana and Sengamuwa) within the 1,500-hectare Lahugala-Kitulana National Park are visited by over 150 animals. The reservoirs within the Maduru Oya National Park also support 150-200 elephants. These numbers underline the importance of aquatic habitats and their natural surroundings for the future survival and maintenance of elephant populations in Sri Lanka.

As developed countries have often learned too late, urban wetlands provide recreational open space and attractive habitat for birds and wildlife. Among its other important functions, the Bellanwila-Attidiya marsh in Colombo represents one of the last large parcels of open space and wildlife habitat in the district.

Livestock and grazing

Water buffalo and cattle depend on aquatic habitats for grazing, particularly the tanks and floodplain marshes of the Dry Zone. Usually 50-80 percent of the drawdown or exposed zone of the inundated floodplain and tanks after flood stage lowering is available for grazing. The large amounts of dung left by the grazing animals are an important nutrient input into these aquatic systems.

Floodplains of the Mahaweli Ganga support an estimated 50,000 buffalo and cattle. Although we lack information on trends in livestock populations in the Mahaweli Ganga floodplain, TAMS (1980) postulated that the carrying capacity for livestock in the floodplain had declined considerably over the previous two decades, due to altered river regimes or overgrazing.

Water supply

An intricate network of rivers and streams, wetlands and deepwater systems provides most of the water for irrigation, domestic uses and hydropower production. Tanks and reservoirs irrigate over 500,000 hectares of land have an aggregate installed generating capacity of 938MW (1988) and produce 27,000-30,000 metric tons of fish on an annual basis, thereby contributing substantially to the country's economic growth.

IMPACTS AND TRENDS

The functions and values of inland aquatic systems have been substantially modified in Sri Lanka since ancient times. Many of the changes are obvious -- dams have converted miles of major rivers into still reservoirs, settlements have vastly changed floodplain habitat, developments have filled wetlands, upstream land use silts up reservoirs and irrigation systems, and pesticides and fertilizers degrade tanks and harm fisheries. However, discussion of these and other impacts suffers from lack of precise data on their economic and environmental effects. Evidence is often anecdotal and oft repeated.

The crux of our problem is that we know too little about the functions and values of inland aquatic resources and cannot adequately measure their benefits. Similarly, we cannot accurately determine the costs of their degradation or destruction. Measurements become important when deciding upon new projects or needs for urban and rural planning. The discussion of impacts below points out these deficiencies.

Impoundments and diversions

Impoundments and large-scale diversions of fresh water from rivers have been buffers against extreme hydrological events such as floods and drought that can cause major socio-economic disasters. Along with these and other substantial benefits they also bring new economic and environmental risks.

Flood control bunds, like those along the Kelani Ganga, are traditional flood protectors used throughout the world. Although the bunds protect surrounding areas from flooding, they also increase flood heights and velocities within the river channels. As sediment deposits within the channels the river bed rises as well, possibly requiring higher bunds. The result is that with any breach of the flood control bunds the risks to human life and property can become increasingly severe. Risks of breaches and high losses are further aggravated by increasing settlements on the bunds. Breaching of the Kantalai dam recentiy resulted in a number of human deaths and the destruction of large amounts of cultivated land.

Net gains in deepwater habitats -- tanks and reservoirs have taken place in the last ten years. Around 25,000 hectares of deepwater bodies have been created during the last decade, around two-thirds of which are in the Mahaweli areas. The extensive network of reservoirs and irrigation channels in the Mahaweli basin now serves around 300,000 people. These systems have radically altered the hydrologic regime in ways not entirely beneficial. Flooding of the Mahaweli's riverine marshes will be reduced by 50 percent (TAMS, 1980). In the Kalawewa area the Mahaweli Program consolidated a total of 214 small seasonal tanks, covering a surface area of 3,000 hectares, into permanent water bodies for a new irrigation system. The result: a net loss of around 900 metric tons of fish production annually (Weatherly and Arnold, 1977). The fresh water flow at the mouth of the Mahaweli at Koddiyar Bay was expected to be diminished by around 50 percent (TAMS, 1980). Effects of these changes on wildlife, bird and fish populations have not been measured.

Sedimentation

The condition of wetlands and deepwater habitats usually depends on catchment systems in the upper basin. As discussed in other chapters, improper land use and agricultural practices in the upper watersheds change the amount, timing and quantity of water, and increase soil erosion. Cultivation on the edges of streams and rivers has occurred throughout the country, despite requirements of the Soil Conservation Act for stream bank buffers. More than twenty years ago the Water Resources Board estimated that along 122 miles of stream in the Kumbalwela Korale area only 17 percent of the required statutory buffer acreage was retained (Interim Report of Land Commission, 1986).

Anecdotal evidence suggests that damage to life and property caused by this land degradation has increased and occurs more frequently. The floods and landslides experienced in the southwest part of the country in 1989 affected over 225,000 people and left over 300 dead. Funds needed to rehabilitate the affected people, not the land itself, were approximately 120 million rupees. (See Land Resources chapter.)

Conversion to alternate uses

Wetlands located in the southwest and coastal regions of the country have been drained, filled and reclaimed to provide new land for agriculture, housing and commerce. These projects have, however, significantly impaired flood drainage, resulting in damage to housing, property, agricultural land and roads.

In the last two decades nearly 70,000 hectares of low-lying marshy areas have been filled or identified for reclamation. Of these, some 16,000 hectares were in the southern and southwestern sectors of the island (Second Interim Report of the Land Commission

MUTHURAJAWELA MARSHES - NEGOMBO LAGOON
PREPARING A MASTER PLAN

Just north of the Kelani Ganga estuary lies the Muthurajawela marsh -- approximately 3,000 hectares of largely undeveloped marshy land just seaward of the major industrial areas of Northern Colombo. Some 400 years ago Muthurajawela was an alluvial flood plain and fertile paddy land. The 3,000-hectare Negombo Lagoon, adjacent to the north, was then the island's foremost seaport and commercial center for the Kotte Kingdom. Subsequently Dutch and then British engineers divided Muthurajawela and radically changed its hydrology by many ill-planned canals, sluice gates, embankments, and roadways. Today Muthurajawela is a marshy water retention area largely uncultivable and heavily infiltrated by saline water, yet it still serves many uses. Negombo Lagoon is no longer the center of commerce for western Sri Lanka, but it remains a highly productive estuary and important commercial fishing center.

Like many other marshes around the world close to industrial and human settlements, pressures mount to develop Muthurajawela for housing and commercial uses. It lies within the Gampaha district whose population of nearly 1.4 million in 1981 has grown annually by 1.8 percent. Planners expect the district to reach 2.7 million by the year 2001. To many the Muthurajawela marsh has appeared ideal as a site for residential and commercial development and disposal of wastes. Proposals for substantial filling and construction were recently formulated for government approval, which prompted new concerns about the effect on the functions and values of the marsh. In response, His Excellency President of Sri Lanka, R. Premadasa, announced in mid-1989 that he would "freeze all development proposals of both the public and private sectors" until an environmentally sound master plan had been prepared. Responsibility for the plan was placed with the Greater Colombo Economic Commission. The planning process, now underway, is being supervised by a Steering Committee representing 21 government entities and two non-governmental organizations.

Development of the plan will follow the gathering and analysis of substantial new ecological data, including a survey to analyze geomorphological aspects to understand long-term natural changes that have brought about the existing condition of the marsh, and the role of the marsh as a hydrologic resource able to buffer floods, moderate salt balances and carry out drainage functions. Scientists will analyze data on climatology, flora and fauna, and the linkages between the Muthurajawela and Negombo Lagoon and the coastal and upland regions. Armed with this information the study will assess what kinds of changes can occur with extensive alteration of the marsh. Planners and ultimately policy makers will then be able to carry out sound development that avoids costly environmental and economic mistakes.

Even without new development, however, dynamic impacts already affect the marsh and Negombo Lagoon. To determine the nature and significance of these impacts scientists must analyze a complex array of information. A variety of activities affect the marsh/lagoon system. They include tourist and agricultural uses, small-scale peat extraction, dumping of waste, contamination from various urban and industrial sources, marginal paddy cultivation, and home gardening developments. Although these uses continue at present, in many cases they conflict and cannot all be sustained. What happens to the Muthurajawela marsh also significantly affects the sedimentation, water quality, and economic uses of Negombo Lagoon. Left to natural processes planners believe that Negombo Lagoon would become part of a continuous marsh cut by channels like the Muthurajawela marsh.

The process of the Master Plan preparation is now scheduled for completion by June 1991, when the two-year technical assistance provided by the Netherlands Government will come to a close.

1985). Most filling has been carried on around Colombo where development pressure is highest. Approximately 204 hectares of low-lying marshy land around Colombo has been reclaimed by the Sri Lanka Reclamation and Development Corporation alone since its inception in 1968. Another 400 hectares of such land in the Colombo and Kotte areas have been identified for future reclamation, together with another 92 hectares at Attidiya. A further 2,000 hectares situated at Muthurajawela is currently being considered for reclamation for housing and industry (see box on Muthurajawela.) Unfortunately we lack quantitative measures of the increased flooding and damage caused by lowland filling, but residents of Colombo frequently attest to the increased frequency and severity of road flooding throughout the city.

Information on wetland losses in areas outside Colombo is limited and often subjective, but because inland wetlands receive little protection under existing state laws they remain vulnerable to development. Urbanization threatens wetlands in the southwestern and southern parts of the country. Agricultural development projects pose equally serious threats to wetlands in the Dry Zone.

As in so many other countries, however, accelerated wetland destruction has enhanced public concern and debate. Recently this has led to legislation to protect the Bellanwila-Attidiya marsh (1990) and requirement of an environmental impact assessment for the Muthurajawela reclamation and development project.

Pollution

Rivers, streams, and wetlands have been common dumping ground for sewage, industrial and agricultural effluent, municipal garbage and other toxic materials. Suspended sediment loads in streams and rivers are the result of soil erosion from agriculture, construction sites and forest clearing. Because wetlands are natural sinks for pollutants as well as nutrients, pesticide runoff, toxic metals, petroleum runoff, or other hazardous waste can contaminate them. Many refuges in the United States have become seriously polluted by agricultural drainage making them unfit for fish and wildlife. Avian diseases have been one result, reported in North America, Japan, Africa, and Europe. (World Resources Institute, 1987.)

INSTITUTIONAL CONSTRAINTS AND RECOMMENDED RESPONSES

Wise use of inland aquatic resources can reduce costs of natural disasters and increase food production and long-term economic welfare of the people. These goals require a number of policy initiatives and new or better institutional efforts to overcome many long-standing constraints. The most critical needs:

- Management of upper and lower catchments for long term maintenance of dams and irrigation systems.
- Catchment and downstream land use management to reduce the number and costs of floods.
- Technical skills and management to increase productivity of small tanks and ponds for irrigation, fish and prawn cultivation.
- Containment of inland aquatic pollution from agriculture, industry and other human activities.
- Public education to enhance understanding of the functions and values of inland water resources and needs for watershed management.
- Coordinated data gathering and research on inland aquatic resources.
- Assessment of costs and benefits of new construction projects and watershed programs in terms of inland water resource sustainability.

Sri Lanka needs to address a number of serious institutional constraints in order to increase the capacity for action on these concerns.

Establish responsibility for management and research

One major issue is confused government responsibility for inland aquatic resources. A multiplicity of government ministries and departments share jurisdiction over various aspects of inland resources and watersheds. Only the Mahaweli Authority has authority to manage the Mahaweli watershed, yet even it lacks un-shared, unambiguous responsibility to do so. Approximately 25 agencies are involved in water resource research and management ranging from the Irrigation Department, to the Water Resources Board, to NARA, but their actions are poorly coordinated. The National Aquatic Resources Agency has broad research and research coordination authority over inland waters, but its responsibility for carrying out practical research linked with practical management needs remains unclear. Divided interests and overlapping functions among the agencies with limited staff capabilities and resources seriously constrain efficient water resource management.

Set priorities for improved legal enforcement

Laws and practices have failed to protect aquatic systems from unnecessary degradation. Abuses of legal requirements cited above -- lack of stream buffers, settlements on bunds, failure to reduce soil erosion or rehabilitate gem pits -- are well known and oft-discussed. On one hand these failures indicate administrative inefficiencies, carelessness, or malfeasance that can and should be corrected. On the other hand, they indicate basic difficulties in relying on regulations instead of incentives to achieve sound environmental management; people will not move off the bunds until they have somewhere else to live. In the long run, some laws and regulations may need to be changed. Nevertheless, clear law enforcement priorities can be set, based, for example, on measures of significant environmental and social harm and the practicality of compliance.

Establish incentives for conservation

Government enforcement of wetlands, floodplains, or watershed soils regulation is likely to fail unless local residents also have a stake in self-enforcement and can enjoy at least some of the benefits of their conservation efforts. Local residents need opportunity and incentives to participate sufficiently in the management of inland aquatic resources.

Mechanisms do not exist to help upstream users benefit from their actions that can protect water supplies that downstream users depend upon. The benefits of water development projects have often been delivered solely to downstream areas that are physically, culturally and politically distant from the catchment. The needs of the catchment dwellers are not often perceived as part of the development effort. This has created difficulties in achieving feasible land use in the catchments as well as optimal distribution, water quality, and runoff on which downstream suppliers depend. Catchment dwellers therefore need incentives to protect upland resources. Greater use of traditional forms of home garden plantings, ground cover, and other productive vegetation programs offer one possibly attractive incentive scheme.

Incorporate benefits into projects and markets

We undervalue environmental goods and services that aquatic systems provide. Government projects and programs often fail to assess the benefits of aquatic systems or the costs of their loss. Markets do not fully reflect the value of watersheds and inland aquatic resources, the products they produce or the environmental services they provide. Neither do they reflect the real costs of environmental degradation, whether in the form of soil loss in the catchments, or pollution and loss of aquatic habitats. Often the cost of wetland loss is passed directly to the people who depend the most on the ecological services of these resources.

Establish public dialogue over cultural barriers

Cultural beliefs can constitute barriers to sustained economic value of inland water resources. If raising and harvesting of fish from inland waters is perceived as contrary to religious teaching, the choice of not producing inland fish is appropriately left to public consideration. However, the nutritional, direct economic, and other environmental costs of the choice need broad understanding. Among these costs: if fishing is not done in inland tanks and ponds, then residents may have less incentive to protect these resources from siltation, or pollution, with the consequent diminuition of other inland water values.

Identify and redress key information gaps

Lack of information on functions and values of inland aquatic resources, adverse impacts and trends, and benefits to be enhanced, are additional barriers to sustainable use of inland water resources. We know far too little about the values of inland water habitats to fish, birds, and wildlife, the impacts of pesticides and fertilizers on water quality and human health downstream. For example, evidence exists that sedimentation can impair tanks and reservoirs, but research can show precisely how serious the problem is, how to identify and rank the causes, and evaluate interventions. Where data is available, much of this information is incomplete, imprecise, and often out of date. Data collection and monitoring on inland water systems is still poorly developed and often not directed to the needs of policy makers or resource managers seeking sustainable development.

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Environmentally sustainable development will meet the aspirations of future generations.

13 Toward Sustainable Development

This profile indicates what environmental stresses must be reduced or eliminated to make sustainable development possible in Sri Lanka. This final chapter focuses on the priorities for response, and the practical opportunities for achieving substantial economic and other benefits from environmental actions.Success depends, however, on new and far more efficient institutional approaches to natural resource management.

Trend is not destiny

Sri Lanka can avoid the accelerating land degradation, urban and industrial pollution, impoverishing desertification and deforestation, and degradation of irrigation systems that now waste the economic, social, and natural resources of so many developing countries. Like them, Sri Lanka suffers steady degradation of the environment. As demands on natural resources rise they diminish future development opportunities. But at this point in its history the island's water, land, biological diversity, climate, and levels of health and literacy are in far better condition than in most developing countries of Asia and elsewhere. By marshalling knowledge, establishing priorities, and applying practical environmental management, Sri Lanka can alter the disturbing trends and improve its future prospects.

Sustainable development initiatives

Given the failure of so many rapidly developed countries to incorporate environment into their development programs, what patterns of development will best meet the needs of present and future generations? Sri Lanka is mapping its own paths toward environmentally sustainable development. Three policy objectives have particular significance for natural resources:

- **One is to strengthen agriculture by diversifying products and improving yields.** This can be achieved on a sustainable basis through methods that conserve soil and water quality.
- **Another is to earn foreign exchange and create new jobs by developing industries based on agriculture, and imported or domestic raw materials.** To avoid costly pollution such actions must be grounded in cost-effective, environmentally protective science and technology.
- **A third is to enhance rural conditions and incomes by expanding economic and environmental opportunities at the village level.** To maximize the "free" services of the environment requires incentives for community forestry, forest gardens, and productive fisheries supplemented by other sustainable employment programs.

CAUSES OF NATURAL RESOURCE USE AND MISUSE

Significant global forces on the environment

Global trade and political forces have historically affected Sri Lanka's environment and they continue to do so. Global political and market forces directly affect the health of the plantation economy, the development of tourism, the costs and use of petroleum imports, and foreign investment in trade and industry. Global production of energy, particularly from coal and other fossil fuels, and destruction of tropical forests are apparently warming the earth and raising sea levels. Sri Lanka's climate and coastline will be affected in ways still not precisely clear.

Poverty cycle

Poverty driven by unemployment causes environmental degradation from which the poor suffer most directly. Data connecting these causes and effects are regrettably limited but several conclusions are obvious.

Poverty and certain cultural habits induce the shifting cultivation that curbs productivity of Sri Lanka's lands and waters. Poverty and organized timber poaching cause significant deforestation, with similar results. The poor suffer first and most from waterborne diseases, caused in part by unsanitary urban and rural conditions. Evidence from other countries, applicable in Sri Lanka, shows that the poor suffer first from inhalation diseases -- from smoke in their own dwellings, factories, and vehicles -- and irrevocable lead poisoning from petroleum fumes and dust.

Domestic economic policies

Sri Lanka's land and water uses have been recently and visibly affected by large projects like the Mahaweli Development Project, but economic policies have had even more pervasive and profound effects. These include tax, fiscal, and social policies that discourage or favor private investments in industry, private land ownership, and international trade. With the government owning 80 percent of the land, impacts of budgetary action govern land and water use in plantations, forests, protected areas, and elsewhere, including cities. Precise impacts of economic policies on environmental results are too often unclear and failures to be concerned about these links too common. If environmental and natural resource values are not systematically incorporated into economic as well as political decisions, significant natural resource misuse and environmental degradation can be expected to continue.

Population growth and demographic shifts

Demographic changes -- another worldwide phenomenon -- will make Sri Lanka's environmental problems increasingly difficult to correct. Present levels of unemployment, poverty, land degradation, and pollution are essentially unsustainable for the existing population of 17 million. Sri Lanka must nevertheless plan for a population of roughly half again as many people within the next fifty years. That means vast new demands for land, water, biomass, food, and services.

The push and pull to urban areas, though not so strong as in many countries, will cause environmental stress nonetheless. Best estimates indicate that urban population will rise from 22 percent to 30 percent by the year 2000, meaning an increase of over 80 percent in the current urban population. These new residents will need new investments in water supply, sewers and drainage. Approximately 800,000 new housing units will be required between 1990 and 2000. Heavy population concentrations will continue in Colombo and in the Wet Zone, which contains the greatest biological resources and fewest protected areas.

CONSTRAINTS ON SUSTAINABLE DEVELOPMENT

Five major environmental conditions and trends will most likely constrain long-term sustainable welfare and growth in Sri Lanka: land and watershed degradation, loss of biological resources, contamination of ground and surface water, and pollution of the urban environment. Within these five categories all worthy needs cannot be addressed with equal effort. Practical priorities require immediate focus on correcting environmental conditions most likely to injure, kill or impoverish Sri Lankans, and on actions most likely to bring tangible environmental benefits to the next generation. Preventive and corrective environmental actions can enhance national wealth and the human environment.

Land degradation

Shifting cultivation. *Chena* cultivation is increasingly practised on vulnerable areas with little or no rotation. Throughout the island acreage under *chena* has risen since the mid-1950s from 1 million to 1.2 million hectares, despite laws against it. In some regions it accounts for many of the costly earth slips. Considered unsustainable and undesirable by the First Land Commission more than sixty years ago, its ill effects are even more serious today.

Soil erosion and productivity. Efforts to increase yield per hectare of plantation and other diversified crops confront land degradation from soil erosion, overuse of fertilizers and pesticides, and rising costs of these inputs. Sri Lanka's soils are vulnerable to erosion, primarily from high intensity rainfall. One year's erosion can easily remove soils requiring a century to build. Now that nearly all available paddy lands are already in use, paddy yields appear to be levelling off, while costs of inputs (tractors, fertilizers, pesticides) are increasing. All tea plantations are highly prone to erosion. Average yield of Sri Lanka's tea plantations is low compared to other countries.

Land use. With the increasingly unfavorable ratio of people to land localized causes and effects of land waste and degradation assume new importance. Gem mining without regard for water pollution or reclamation is evident in all gem-bearing areas. It makes land unnecessarily unproductive and, by creating habitats favorable to malaria, it threatens human health. Most opportunities for large new land settlement are gone, although potentially important in some regions on a small scale. The 2.5 million hectares (38 percent of the island) identified throughout the island (mostly in the Dry Zone) as available for forests, farms, settlements or other development require water to be productive. But fresh water, although comparatively abundant in Sri Lanka, nevertheless is becoming increasingly scarce; half of all available surface water in the Dry Zone is used before it reaches the sea. At the same time, nearly 14 percent of the country is under wildlife conservation or other protected status. Some of this land may be more productive in other uses, yet the critical areas within the biologically rich Wet Zone are not adequately protected.

By reducing and eventually eliminating chena cultivation on steep slopes and replanting these areas with grasses or trees Sri Lanka can achieve far more sustainable use of its lands and watersheds. New opportunities can be developed for farmers through productive use of agro-forestry systems in place of chena. Incentives to reduce soil erosion on agricultural cropland as well as chena land will help preserve watersheds, maintain options for small hydropower development, extend the life of existing reservoirs, and retain or improve soil productivity. Watershed management has become a national necessity in the catchment areas of Sri Lanka's major rivers.

Watershed degradation

Water resource degradation. Poor land use steadily reduces the value and availability of Sri Lanka's abundant water resources. Agricultural practices cause high siltation rates in many Dry Zone tanks and upcountry reservoirs. Sedimentation of tanks, irrigation works, and upcountry reservoirs results directly from soil loss in catchment areas. Aerial photo comparisons of 1956 and 1982 illustrate high rates of siltation from clearing in Dry Zone catchments for agriculture and settlements. Development programs will require far better information than before on the economic and environmental relationship between soil erosion and the productivity of land and water.

Small hydro. Because Sri Lanka has already developed most of its available large-scale hydroelectric sites to produce 90 percent of its electric power, use of small hydropower plants may become increasingly important. Their development will become more attractive if oil prices rise above US $40/barrel, but long-term capabilities of small hydroelectric generating sites will be reduced without careful conservation of watersheds.

Sri Lanka's abundant water, and its high proportion of lentic water bodies to land area, are resources that can be envied around the world. Although all its watersheds are important, priorities for management are essential. Watershed classifications, based on value and vulnerability, can be a useful first step toward determining which areas need management attention or special protection first. Local initiatives and management activities are essential to achieve conservation. Results will depend on how well the local public and the government understand the links between watershed management and increased productivity -- from forest gardens and agricultural systems to hydroelectric generation.

Biological resource degradation

Biological resources. Sri Lanka's flora and fauna are the richest and most concentrated in Asia. A high level of endemic species is contained chiefly within the Wet Zone, the country's most populated region. Large numbers of species found in the 45,000-hectare group of Sinharaja forests are found nowhere else. Overall the biological resources that draw tourists to the country -- coral reefs, wild elephants, and native and migratory birds -- represent non-renewable, irreplaceable genetic and ecological resources of global importance. All these resources are under stress.

Forest resources. Sri Lanka's declining natural forests -- repositories of many of its most valuable and vulnerable biological resources -- have global as well as national significance. At an annual deforestation rate of over 40,000 hectares, the island's estimated 24 percent natural forest cover in 1989 is down from 44 percent in the 1950s. While declines have been less rapid than in Thailand or Nepal, they have been relentless. In general, every hectare deforested becomes a hectare less resilient and less productive, in even the span of a few years. Despite encouraging institutional changes and new forest programs,deforestation continues. Forest depletion is most significant in the already highly altered Wet Zone, where 100,000 hectares of natural forests have been lost since 1956. The size of the remaining forests has also diminished, significantly reducing Sri Lanka's biological resilience as increasing numbers of flora and fauna species become endangered or threatened.

Coral reefs. High losses of live coral reefs over the past 10 to 15 years continue virtually unabated. Losses over the past 20 years have reached 80 percent at some southwest coast locations and remain high at many others. Conditions on the east coast are known to be poor but they cannot be assessed accurately due to civil disorder. In the southwest most destruction results from reef mining for the manufacture of lime. Loss of live coral means loss of natural coastal erosion protection, ornamental fish habitat, and tourist attraction. Within a decade or so most coral, except the highly protected reefs near established tourist sites, will be destroyed.

Wetlands and flood plains. Over the past two decades nearly 70,000 hectares of low-lying marshy areas have been filled or identified for reclamation. Pollution has degraded other significant coastal wetlands and estuaries important to the coastal fisheries, although data on resulting economic impacts on coastal fisheries do not exist. Throughout Sri Lanka -- inland and along the coasts -- degradation and filling of wetlands have contributed to the loss of natural flood protection, productive wildlife habitat and other resources. The most significant wetland losses have been in the Mahaweli flood plains, where the Mahaweli program is estimated to reduce natural flooding areas of marshes and *villus* by 50 percent.

By arresting the loss of natural forests, particularly in the Wet Zone, and coastal habitats Sri Lanka can sustain and increase tourism, provide jobs for villagers as guards, maintenance personnel and guides, and support the growth of horticultural plants, fruits and vegetables for home use and business. By protecting flood plains and wetlands Sri Lanka can avoid or reduce costs of flood relief, resettlement, and investments in flood protection.

Contamination of ground and surface water

Nitrate pollution. Contamination of fresh waters by nitrates in fertilizers and human waste is a growing threat to human health. Intensive agriculture and human waste disposal in the Jaffna Peninsula already cause pollution of ground and surface water. Peak seasonal concentrations of pollutants in the Kalpitiya peninsula have reached four times the WHO guideline. Low levels of industrialization have kept industrial pollution of the Mahaweli below that of the Kelani, but nitrate concentrations show a definite upward trend due to heavy agrochemical usage in the catchment. Expansion of the agricultural and agro-based industrial sector will require careful monitoring and impact analysis.

Domestic and untreated pollution. Urban and rural water pollution from domestic, industrial, and agricultural waste also threatens human health. In Colombo less than a third of the greater metropolitan population is sewered, but waste water discharge is not treated. Most industry is centered in and around the Western Province, yet nearly all industrial waste is untreated. It accounts for much of the contamination of Colombo's waterways, along with the water pollution caused by the urban poor. In Kandy, Galle, Jaffna and smaller cities and towns, no sewers exist; most residents use on-site waste disposal, and a high proportion of wells are unprotected. Water pollution has direct impacts on industrial users as well. In some places, as with the Puttalam aquaculture industry, it directly harms the industry itself.

Many urban as well as rural areas, including outskirts of the Greater Colombo metropolitan area, rely on ground water for drinking supplies. In rural areas only 5 percent of homes had piped water at the last census (1981), and anecdotal evidence -- all we have to rely on -- suggests that ground water as well as surface water contamination is a growing hazard to health. Outbreaks of waterborne diseases continue to cause death and illness in the cities, most recently in Maale.

The health benefits of water pollution controls are themselves enough to justify effective action. Benefits of improved water quality for fisheries as well as recreation cannot be underestimated. Opportunities exist for low-cost responses and for economically attractive expenditures on infrastructure to serve new industrial and housing complexes. Educational programs on sanitation, drainage clearance, and many other cost-effective controls over pollution discharge from industry can all achieve significant results. Pricing and other policies that encourage water conservation can reduce demands on ground and surface water.

Degradation of the urban environment

Water pollution and drainage. Colombo and many smaller cities suffer from combined environmental stresses that have led to significant deterioration of health and living conditions. Lack of adequate infrastructure to supply water and sewer services is a growing threat to resident health, particularly of the poor. Filling of wetlands in Colombo -- estimated at over 200 hectares since 1968 -- has contributed to flooding and inadequate drainage systems. Contamination of ground as well as surface water is a growing, immediate problem affecting all urban areas. In the long term planning for water supply and drainage may need to anticipate the potentially significant and costly effects of sea level rise caused by global warming.

Low income housing. Encroachment of the poor on canals and river banks contributes to water pollution. Approximately half of Colombo's population belongs to the low income category, and many of the poor live in slums and shanties. With little or no access to sewage services, they contribute to and suffer from water contamination. Adequate housing is an integral part of the environmental solution to urban decay.

Air pollution. Added to these problems are the effects of urban air pollution, largely from vehicles, but also from some industries. Monitoring data are badly needed to identify links of air pollution to respiratory diseases and lead poisoning from urban dust. Health statistics in other Asian countries show alarming increases in respiratory illnesses and lead poisoning from vehicle emissions. Incidence of lead poisoning increased fourfold in Bangkok over a recent ten-year period.

Loss of amenities. Urban residents in developing countries, Sri Lanka included, suffer increasingly from loss of open spaces and other amenities. Colombo's experience with Beira Lake is an example to avoid. Parks, urban beachfronts, and other open spaces that serve essential needs for recreation have tangible and intangible benefits. Their loss can contribute significantly to a declining quality of urban life.

Solid waste. Rapid increase in the generation of domestic solid waste in Colombo and other cities results in new health hazards as well as an ugly environment. Solid waste management has become recognized as one of Sri Lanka's highest urban priorities. At present municipal services cannot keep up with demands for collection and sanitary disposal.

Solutions to urban degradation include effective environmental management. Managing urban pollution requires financing for infrastructure and effective land use zoning that respond to the environmental costs of water pollution, poor drainage, noise and traffic, and to the cost-effective benefits of sound environmental design. Much can be done to avoid environmental problems in new urban areas. Environmental factors are being recognized in developing an impact assessment for the Muthurajawela marsh north of Colombo.

Using scientific information on the hydrology and human uses of this marsh/lagoon system, planners seek ways to accommodate many conflicting functions and values with needs for urban development. Experience in other cities, including the Hackensack Meadowlands across the Hudson River from New York City, indicates how severely wasted urban marshlands can be productively used in harmony with the environment.

POLICY RESPONSES

Integrating biological resources into development and planning

Newly Industrialized Countries and other aspirants now realize that some patterns of economic growth create serious environmental and economic problems. In Sri Lanka, growth policies that protect and build on the economic and environmental value of biological resources can avoid many of these costs without risking the benefits of actions to increase industrial and agricultural productivity.

Natural forest conservation. The richest natural forests are found in the densely populated southwestern Wet Zone. Relatively small patches of natural forest still provide quantities of berries, fruit, nuts, game, medicinal substances, horticultural plants and flowers that can, if properly cultivated and marketed, bring substantial economic benefits to Sri Lanka, as they have in Indonesia and elsewhere. Besides their incalculable genetic and ecological significance, natural forests support village uses that are sustainable, as experience around the Sinharaja forests indicates. They also draw tourists.

Enhancement of forest garden systems. Highly developed in many parts of Sri Lanka, forest gardens can supply domestic fuel and produce fruit, vegetables and timber for multiple uses that have substantial economic value. Forest gardens can be created even on marginal land within a few years. Opportunities to expand forest gardens to enhance farmer income depend in part on commercial marketing for fruit, vegetables, and horticultural products.

Environmental tourism expansion. Tourism, on the upswing after a drop in the mid-1980s, provides significant direct and indirect employment to rural and urban Sri Lankans. Visitors who seek birds, wildlife, and underwater environments can contribute substantially to high-quality, high-revenue tourism. However, complex ecological systems must be carefully managed to guard against the well-known self-destructive impacts of tourism. Successful environmental tourism depends on effective management of wildlife reserves, well-designed visitor facilities, and adequate environmental education materials. The natural resources that draw tourists -- whether forests, wildlife reserves, or coral reefs -- must be immediately protected by strong enforcement. Alternative employment must be provided for those who, like offshore coral miners, now diminish Sri Lanka's sustainable resources.

Conservation of hydrologic resources. Wetlands and flood plains provide valuable "free" services for flood control, filtering of water pollutants, and nursing grounds for fish and wildlife. These functions might be better appreciated if they were translated into distinct economic values as has been done in the United States and elsewhere. Loss of wetlands and the degradation of important flood plains by human settlement have contributed to flooding and high costs of flood relief.

Coastal and inland fisheries management. Fisheries suffer increasingly from overuse and environmental degradation. Per capita fish consumption is increasing. Offshore fisheries can be sustainably exploited but opportunities to sustain near-shore fisheries need greater attention. Coastal habitats essential for coastal fishery production -- coral reefs, estuaries and lagoons, highly vulnerable mangroves, salt marshes and seagrass beds -- are immensely productive resources. Inland fisheries, if managed and protected from pollution and other physical impacts, offer additional and significant economic benefits to local residents.

Correcting Institutional Constraints

In general, Sri Lanka's natural resource management suffers from a variety of serious institutional inefficiencies:

- confused or poorly coordinated environmental management responsibilities of a multiplicity of government agencies, including those managing the 80 percent of the country that is owned by the government;

- failure of the state to set and achieve high standards for controlling pollution from state-owned enterprises, and lack of clear private responsibilities and incentives for environmental management;
- inefficient systems for gathering, analyzing, and applying environmental information to plans and operations of private or public sector agencies;
- failure to incorporate environmental impacts into economic development plans, programs, and projects of the public and private sector.

Underlying these institutional problems are essential needs for more and better focused environmental information, substantive training, and management skills in public cooperation, agency coordination, and organizational management followup actions.

Efficient environmental management cooperation

Overlapping and uncoordinated environmental action by government is not surprising. Environmental management affects every government sector and most private activities. But business-as-usual approaches will not suffice. When agency responsibilities are unclear, "red tape" and bureaucratic delays or inaction inevitably cost the environment and the economy dearly.

Nowhere are these problems more evident than in watershed management, where efficiency and effectiveness are paramount needs. Activities affecting land and water management involve scores of agencies and statutes. The Water Resources Chapter (Part I) describes how little has been accomplished in managing watersheds, largely because of confusing, conflicting, and ineffective authorities. The inescapable conclusion: unless the interaction of government agencies is drastically simplified, effective watershed management, even under the most scientifically advanced policies, will be exceedingly difficult, if not infeasible. Duties, responsibilities and lead agency capabilities need to be identified for particular watersheds of major rivers that have the most severe problems. Gaps in legal authority and management capabilities need to be clarified and actions prepared for their remedy.

Recent administrative experiences in Sri Lanka suggest that these constraints can be reduced. The concept of "lead agency" responsibilities for significant aspects of environmental and economic development has been successfully initiated. In the energy sector, the CEB has lead responsibilities for energy development, but it must work closely with other agencies and the Coastal Conservation Department has clear responsibility for land management in a narrowly defined coastal zone. Expansion of such lead responsibilities will come under the new environmental impact assessment procedures of the National Environmental Act Amendments of 1988. These require an active role by the CEA to clarify agency responsibilities for gathering, analyzing, and applying environmental impact information. CEA can help government agencies sort out their environmental management responsibilities for proposed development projects, and see that one agency takes the lead in impact assessment.

Private responsibilities and incentives

Establishing Incentives. Successful actions to control industrial and agricultural pollution, or to prevent *chena* cultivation, coral destruction, illicit gem mining, timber felling and natural forest encroachment require adequate incentives, penalties or appropriate combinations of the two.

On one hand, progress in reducing industrial pollution depends on Sri Lanka's strong enforcement of industrial pollution laws, backed by scientifically supportable standards. A private business will not usually invest in costly control equipment, recycling, or process changes unless its own operations will benefit or it is required to do so. A government-owned industry, while ideally expected to set a high environmental standard, may be poorly structured financially to make pollution control investments. Strong enforcement of pollution control is necessary for public as well as private industries. Because they have acceptable economic alternatives, enforcement can be particularly effective against large commercial concerns that violate timber and wildlife laws.

On the other hand, sole reliance on "command and control" management techniques has proved a failure in many cases involving large numbers of individuals or small operators. Remedies for soil erosion, for example, will increase costs to upstream users, but only downstream users will realize the immediate benefits. Programs that build on incentives can make it worthwhile for upstream farmers to control soil erosion. One company in Sri Lanka has found success in programs that will only pay farmers for their produce if they meet soil erosion criteria specified by company inspectors. Various economic and legal tools exist to develop incentives that benefit small- and large-scale operations.

Creating a stake in sound environmental management. Sri Lanka's experiences with natural resource mismanagement illustrate the need for individual landowners or communal organizations to have a stake in sustainable natural resource management. Fishing communities often recognize the value of coral reefs and protect them. So do owners of glass-bottom boats and other tourist guides and operators. Inland, land stewardship may best be sustained if tenure systems provide the necessary security and opportunity for owners to derive benefits from long-term investments in forests, farms, water systems, or other natural resources. This profile highlights the needs for considerably stepped-up research on land tenure and ownership and how it affects and might improve efficient long-term resource use.

Improving information gathering, analysis, and use

Research and information needs. This profile has highlighted gaps in natural resource and environmental information and research that have already led to misunderstanding and costly misuse of natural resources. Determination of research priorities goes beyond the profile's scope, but subjects to consider include the following:

- a comprehensive water quality monitoring program for streams, rivers, tanks, and estuaries, beginning with the most important water bodies, to establish baseline data and effective water quality standards;
- assessments of fish stock in coastal and inland waters from which to evaluate trends and develop sustainable fisheries activities;
- a program to assess ground water conditions and trends, including quantity as well as contamination;
- applied research on cost-effective pollution minimization technology that is appropriate and applicable to Sri Lanka's major polluting industries;
- ecological studies of appropriate uses to be made of the 2.5 million hectares of "developable" land identified by the Land Commission;
- studies to determine the present status of stream bank and reservoir reservations and their future conservation;
- ways to reduce wastage of timber and biomass and practical means to improve silviculture for energy and forest conservation;
- studies to determine trends in biological productivity, resilience and the actual and potential economic and social values of biological and hydrologic systems;
- land use studies in elevations above 1,500 meters to determine appropriate conservation programs in the face of frequent violations of forest laws.

Efficient analysis of information. Important environmental information, although gathered, is often unavailable. This problem was highlighted in particular by the Water Resources Chapter (Part II) concerning water pollution. Sri Lanka can make more cost-effective use of information gathered through cooperative agreements on laboratories and the publication and dissemination of information to all who need it. The need for easier access by government, private sector, professional and citizen users of information has been a striking finding of this profile. No library exists to obtain, log, and make available current studies on natural resource and environmental topics. As a result, despite the need to maximize the efficiency of available human and financial resources, substantial duplication exists in the preparation of studies and in the gathering of information.

Once obtained, information is still not readily available for application to problems. It is particularly important to maximize the use and efficiency of critical information for application in environmental impact assessments. Beyond that, policy makers need to be guided by the information, and see that it is actually applied to plans and operations.

Integrating environmental impacts

Frequent failures of planning. Planning is an institutional tool traditionally used and encouraged for natural resource management. In practice broad natural resource management plans like the National Conservation Strategy are often ineffective if implementation is not required or specifically linked to funding or project approval. Implementors need to have a stake in implementation results.

Environmental Impact Assessment. Today one of Sri Lanka's most potent planning and information tools is the environmental impact assessment requirement. The requirement for agencies and private business to obtain and analyze data on significant impacts of proposed action, and to disclose it to other agencies and the public before action can be taken, can bring about significant institutional change. Impact assessment is being applied in forestry management, and it has already shown its importance in the inter-agency and public debate over construction of a major coal-fired power plant at Trincomalee.

No single institutional measure over the past decade shows more promising possibilities. Its application to a wide range of economic development proposals with significant environmental impacts will require a new level of training and analytical abilities. The EIA mechanism aims to improve information and opportunities for public involvement, for coordinating government agencies and for close public and private cooperation. Experience in other countries, most notably the United States, shows that after an initial period of sometimes painful development, the EIA can become a routine tool for analysis and information disclosure. That promising result will depend on adequate numbers of highly-trained personnel as well as understanding of EIA functions and values by policy makers.

Economic assessments. Integration of economic and environmental analysis is essential for practical political and financial decision making. By translating what we know about natural resource capital -- forests, good farmland, water resources, and ecological functions and values -- we can better measure the effects of adverse impacts on them, and how these resources benefit society over the short and the long term. Efforts to improve national accounting systems are underway in developing and developed countries, and efforts are beginning in Sri Lanka as well.

VISION OF THE FUTURE

What path can Sri Lanka take to sustain economic development and maintain its natural resource heritage?

At the outset Sri Lanka must now anticipate and plan for sustaining the future economic, social, and environmental needs of 23 to 25 million people. This is possible; much higher population density can be managed without loss of significant natural resource and environmental assets. Prosperous newly developed countries like Singapore and older ones like the Netherlands have shown that high density can be maintained through careful planning while increasing opportunities for employment. On the other hand, Sri Lanka must avoid the costly experiences of developed countries with the adverse impacts -- resource depletion and pollution of land, air, and water -- that threaten human health and raise economic and environmental costs.

To avoid or minimize these adverse impacts, costs of pollution can be included in the prices of goods and services. A clean environment will depend on incentives for individuals and private enterprises to reduce pollution and other adverse impacts for reasons of self interest. It will also depend on efficient government standards, regulations and enforcement. Developed countries with a backlog of pollution can find environmental programs costly and difficult. Sri Lanka is blessed with conditions of pollution that can readily be solved with existing technology.

To sustain a future population of roughly half again as many people will require well planned urban areas. Sri Lanka's cities can be made productive centers of clean industry that offer employment for the growing thousands of people needing jobs. By offering well paid employment, pressures on critical resources can be relieved. With careful urban planning and sound design of homes and transportation and sanitation systems, urban areas can be pleasing as well as productive habitats. Supplies of clean water can be obtained from the ample surface water and ground water systems as long as waste disposal is carefully monitored and regulated. To compensate for increased urban density, urban parks and lakes can be designed and maintained for more intensive public use. Green space and opportunities for home gardens in low-rise garden apartments can offer opportunities for humane and pleasing urban life. It is still possible, with moderate investments, to bring Sri Lankan cities to a high position on the habitability scale.

To connect cities and villages Sri Lanka can have a well-maintained road and rail transportation system, building on a system that was far advanced after Independence. Better use of rail passenger and freight resources can substantially speed and increase transport of goods and people, including tourists, while helping to conserve energy and reduce pollution.

Not all new urban population needs to be concentrated in Colombo or other large cities. A strong agricultural base can support new agro-industries in and around smaller cities and villages. Small cities, based on agro-industrial activities can cater to the needs of surrounding villages. This concept of agropolitan centers will require dependable transportation and advanced communication systems to serve the needs of rural areas.

Higher agricultural productivity can be achieved through adoption of high value crops without costly reliance on pesticides and other inputs that damage sustainable productivity. Sri Lanka can adopt integrated pest management and improve traditional means for agricultural management that protect not only the health of consumers, agricultural and industrial workers, but also the environment.

Reforestation and rehabilitation of grasslands will depend on application of sound scientific methods and adequate incentives to property owners and private entrepreneurs. Some relatively unimportant wildlife reserves can be converted to enhance agricultural productivity. Unprotected areas important for their biological diversity and value can be acquired and managed. Other new areas, now lying fallow and degraded following *chena* cultivation in the biologically rich and critically important Wet Zone, can be acquired for forestry and agriculture. Opportunities for environmentally sensitive tourism in coastal as well as inland areas can become significant economic assets. The design of new hotels and tourist facilities can be accomplished without disrupting the visual integrity of Sri Lanka's landscape. The world-renowned architecture of Geoffrey Bawa and others has already established a standard of design excellence.

Sustainable development in Sri Lanka is a realistic prospect. Success will depend on initiatives that develop and apply the necessary skills, resources, and commitment, from the village to the national level.