Case study: Sri Lanka

Sri Lanka National Water Development Report

Prepared for the
2nd UN World Water Development Report

'Water: A shared responsibility'
(2006)

UN-Water/WWAP/2006/11




Sri Lanka
National Water Development Report




World Water Assessment Programme

UNESCO

UN-Water/WWAP/2006/11

Sri Lanka National Water Development Report

April 2006

Editors

K. A. U. S. Imbulana
N. T. S. Wijesekera
B. R. Neupane

The Ministry of Agriculture, Irrigation and Mahaweli Development of the Government of Sri Lanka seeks to manage water resources of Sri Lanka, with due regard to the requirements of water-user sectors, through appropriate programmes, projects and policies.

The World Water Assessment Programme is a UN-wide programme, which has been in existence since 2000. Through its Secretariat hosted by UNESCO, it coordinates the contributions of 24 United Nations agencies having concerns and activities related freshwater.

University of Moratuwa is a leading Technological University of Sri Lanka, having three faculties namely, Architecture, Engineering and Information Technology. The water division at civil engineering department of the faculty of engineering is a strong contributor to the water sector both in the country and the region by conducting water resources related postgraduate and undergraduate programs, projects, and with active contributions to water research.

The editors: K.A.U.S. Imbulana, N.T.S. WIjesekara and B.R. Neupane

Wijesuriya, L.T, Dias, P.P.G., Panabokke, C.R., Jayatillake, H.M., George, R.S.C., Nimal Rohana, K.W., Shanmugarajah, C.K., Weerasena, S.L., Weerasinghe, K.D.N., Seneviratne, B.K.C.C., Senaratne, S., Ratnayake, U.R., Ariyabandu, M.M., Batagoda, B.M.S., Atapattu, N.K., Ratnayake, R.W.F., Wijesekara, N.T.S., Perera, A.P.G.R.L., Chandrapala, L., Basnayake, B.R.S.B., Dharmaratne, G.H.P., Mahrouf, A.R.M., Senanayake, N., Emitiyagoda, G.A.M.S., de Silva, M.P., Wickramasinghe, U., Karunaratne, R.N., Handagama, T.D., Herath, G. contributed to the study as authors of research papers contributed to Preparatory Workshop on SLNWDR held on 29-30 October 2004, as reported in the Proceedings of the Preparatory Workshop on SLNWDR, WWAP, Paris, France

Suggested citation: Imbulana, K.A.U.S., Wijesekara, N.T.S. and Neupane B.R. (eds.), Sri Lanka National Water Development Report. MAI&MD, UN-WWAP, UNESCO and University of Moratuwa, Sri Lanka, Paris and New Delhi

KEY WORDS - Sri Lanka/ hydraulic civilization/ Integrated Water Resources Management/ World Water Assessment Programme/ United Nations/ World Water Development Report/ irrigation/ agriculture/ rainfall/ river basin/ monsoon/ drought/ flood/ reservoirs/ dams/ hydrometric network/ groundwater/ aquifer/ climate change/ policy/ temperature/ humidity/ evaporation/ poverty/ demography/ health/ Millennium Development Goals/ stakeholders/ pollution/ water quality/ basic needs/ diseases/ environment/ ecosystems/ wetland/ coastal zone/ bio-diversity/ forestry/ settlements/ rural/ urban/ industry/ energy/ hydropower/ landslides/ tsunamis/ disasters/ water sharing/ traditional/ value of water/ knowledge base/ governance

ISBN 955 - 8395 - 01 - 3

Contents

List of Figures ..... (xi)

List of Tables ..... (xii)

List of Frequently Used Abbreviations ..... (xiv)

Hon. Minister's Message ..... (xv)

Secretary's Message ..... (xvi)

Foreword ..... (xvii)

Editors Note ..... (xviii)

Executive Summary ..... (xix)

Contents

01. General Context ..... 01 - 12

General hydrological characteristics 01

Hydrology 01
Topography 02
Geology 02
Soils 03
Land use 03

Major socio-economic characteristics 04

General description 04
Population 05
Economic activities 05
Cultural background 06
Education 07
Health 07
Life expectancy, nutrition and mortality rate 07

Historical background to water resources management 08

Early history of water use 08
Ancient settlements and sanitation 08
Environmental and ecosystems management 08
Water management techniques 09
Water resources development in ancient times -the vision 09
Evolution of irrigation reservoirs 09
Technological advances 10
Since european colonization 10

02. Water Resources of Sri Lanka ..... 13 - 30

Climate 13

Temperature 13
Humidity 14
Evaporation 15
Climatic variation and long term projections 15
Temperature changes 15
Rainfall fluctuations 15
Global climactic phenomena:Impacts on Sri Lanka 17
Atmospheric brown cloud 17

Rainfall 18

Variability of rainfall 18
Seasonal distribution of rainfall 18
Spatial distribution of rainfall 19

Agro-ecology 20

Surface water 20

Main tributaries, lakes, reservoirs 20

Contents

Groundwater 21
Main types of aquifers 21
Shallow karstic aquifer of Jaffna Peninsula 21
Deep confined aquifer 22
Coastal sand aquifers 23
Alluvial aquifers 23
Shallow regolith aquifer of the hard rock region 23
South-western lateritic (cabook) aquifer 23
Threats to groundwater 24
Water quality 25
Surface water quality 25
Groundwater quality 25
Impacts 26
Data and information on water resources 26
Hydrological and meteorological observation stations 26
Surface water data 26
Operational data 26
Water quality data 27
Ground water data 27
Water usage data 27
System performance 28
Human impacts on water resources - dams and diversions 29
Sizes and storage capacity 29
Dams and effects on environment 29
Main problems 30
Indicators 30
03. Water for Basic Needs and Health ..... 31 - 38
Average water consumption 31
Quantity 31
Quality 31
Biological hazards 32
Chemical hazards 32
Standards and monitoring mechanisms 32
Standards 32
Monitoring mechanisms 33
Basic services 33
Drinking water and sewage system coverage 33
Sanitation 34
Affordability of water services 34
Water related diseases 34
Water borne 34

Contents

Vector borne 35
Fluoride and fluorosis 36
Water and health issues 36
Safe drinking water during droughts 36
Environmental health information system 36
Lab services 36
Water quality surveillance system 36
Water pollution from industrial waste 37
Pesticide and fertilizer use 37
Environmental management for vector control 37
Disaster management and emergency response 37
Community awareness 37
Sanitation and water 37
Indicators 37
04. Water and Ecosystems ..... 39 - 48
Major ecosystems 39
Forest ecosystems 39
Grasslands 40
Inland aquatic ecosystems 40
Marine and maritime ecosystems 41
Agricultural ecosystems 42
Biodiversity : Threats and protection 42
Wetlands 42
Forest ecosystems 43
Animal species 43
Threats and driving forces 44
Climate and ecosystems 44
Protection of biodiversity 44
Environmental Impact Assessment 45
Policies, programmes and implementation 45
The setting 45
Policies 46
Forestry and wildlife 46
Watershed and coastal zone management 46
Implementation arrangements 46
Legislation and institutions 47
Indicators 48
05. Water and Human Settlements ..... 49 - 56
Urban and rural settlements in the context of Sri Lanka 49
Urban and rural population 49

Contents

Poverty 50
Urban poverty characteristics 50
Access to improved water supply in urban and rural settlements 51
Vision, policies and strategies 51
Rural water 51
Urban water supply 52
Water supply for urban poor 52
Institutional arrangements 52
Programmes 52
Water loss due to leakages 53
Sanitation services in urban and rural settlements 53
Contamination from wastewater discharges 54
Discharging sewage water to surface water bodies 54
Agricultural practices 54
Discharge load by sector 54
Effect of water-related natural disasters 55
Urbanization and natural disasters 55
Contingency Plans 55
Cities' impact on ecology 55
Urban development and water management 55
Water demand management 55
Pricing Policies 56
Other problems in urban and rural settlements 56
Indicators 56
6. Water and Food ..... 57 - 70
Cultivated area 57
Major & minor irrigation systems and role of irrigation 57
Water use 58
Water requirements 58
Paddy yields 60
Cropping intensity 60
Other food crops 62
Livestock, fisheries and aquaculture 62
Livestock 62
Fishery 62
Food trade and virtual water 64
Food imports 64
Goals and programmes 64
Per capita food consumption 64
Major programmes 65

Contents

Agricultural policy directions 66
Marketing and trade 67
Participatory management 68
Research and extension policies 68
Role of irrigation in poverty alleviation & food security 68
Roles of men and women in agriculture 69
Issues and constraints 70
Indicators 70

07. Water and Industry ..... 71 - 74
Industrial water demand 71
Industries and degradation of water quality 72
Policy guidelines, regulations and incentives 72
Indicators 74

08. Water and Energy ..... 75 - 80
Energy production and future projections 75
Energy need 75
Households with access to electricity 76
Hydropower 77
Number and capacity of dams 77
Proportion of hydropower in overall energy production 77
Village hydropower 77
Alternative forms of energy 78
Energy production, environment and climate change 78
Goals and strategies for future energy demand 78
Indicators 79

09. Managing Risks ..... 81 - 88
Type of water-related natural disasters 81
Droughts 82
Floods 82
Landslides 82
Tsunamis 83
Other forms of natural disasters 83
Climatic variations and long-term projections 83
Change of the rainfall pattern during different rainfall seasons 83
Wet and dry spells and amount of rainfall 84
Change of rainfall patterns and natural disasters 84

Contents

Water related disasters 85
Frequency and amplitude 85
Economic and social consequences 85
Management tools against extreme events 86
Data management 86
Structural measures against disasters 86
Non-structural measures against disasters 86
Present Status of warning systems 87
Constraints for effective disaster management 87
Land-use planning 87
Responding to disasters 87
Disaster response and recovery 88
Contingency plans and legal framework 88
Indicators 88

10. Sharing Water between Uses and Users ..... 89 - 92
Hydropower and other sectors 89
Irrigation and other uses 90
Traditional water sharing 91
Water sharing mechanisms 91
National level 91
Regional level 92
Decision support systems for sharing water 92
Indicators 92

11. Valuing Water ..... 93 - 96
Economic, social and cultural 93
Multiple values and costs of irrigation water 94
Water and gender 94
Role of water in poverty eradication 95
Financing of water related MDGs 95
Cost recovery and pricing policies 95
Indicators 96

12. Governing Water ..... 97 - 108
National policies 97
Strategies 98
Action plans 99
National goals and programmes currently in progress 99

Contents

Towards millennium development goals (MDGs) 100
Water rights and customs 100
Institutions 100
International 101
National 101
Local 102
Legislation 102
National legislation 102
Provincial 102
Provincial / Local administration 103
International conventions and treaties 104
Human resources 104
Financial resources 104
Budget for water related investments 105
Management approaches 105
Demand management 105
Stakeholder participation 106
Recent programmes and policy implications 106
Indicators 107

13. Ensuring the Knowledge Base ..... 109 - 116
Traditional knowledge 109
Developments after the ancient hydraulic civilization 110
Education 110
Enrolment in schools 110
Water sciences in school curriculum 111
Water in university education 111
Research institutions 113
Public access to databases 113
Data and information dissemination mechanisms 113
Modes and organizations 113
Media 114
Internet and telephone 115
Indicators 116

14. Conclusions ..... 117 - 120

List of References ..... 121 - 127

Annexes ..... 128 - 148

Acknowledgments ..... 149 - 150

List of Figures

	Page	
Chapter 01	**01 - 12**	**General Context**
Fig. 1	1A	Location map of Sri Lanka
Fig. 2	2A	River basins of Sri Lanka
Fig. 3	2B	Topography of Sri Lanka
Fig. 4	2C	Geology of Sri Lanka
Fig. 5	4A	Soils of Sri Lanka
Fig. 6	4B	Land use map
Chapter 02	**13 - 30**	**Water Resources of Sri Lanka**
Fig. 7	14A	Monthly average maximum temperature
Fig. 8	14B	Monthly average minimum temperature
Fig. 9	14C	Monthly average night time relative humidity
Fig. 10	14D	Monthly average day time relative humidity
Fig. 11	14E	Average monthly pan evaporation (mm/day)
Fig. 12	16	Deviation of Sri Lanka's mean annual air temperature from mean of 1961- 90
Fig. 13	16	Deviation of Sri Lanka's Average Annual Rainfall from Mean of 1961-90
Fig. 14	18A	Rainfall Stations referred in the text
Fig. 15	20A	Distribution of mean annual rainfall (1961-90) (mm)
Fig. 16	20B	Distribution of seasonal rainfall (mm)
Fig. 17	20C	Agro ecological regions of Sri Lanka
	20D	Cont. Agro ecological map
Fig. 18	20E	Major reservoirs and hydropower plants
Fig. 19	24A	Different types of groundwater aquifers in Sri Lanka
Fig. 20	28A	Stream gauging stations
Chapter 03	**31 - 38**	**Water for Basic Needs & Health**
Fig. 21	33	Diagrammatic representation of the Divisional Level health system
Chapter 04	**39 - 48**	**Water and Ecosystems**
Fig. 22	40A	Natural Vegetation of Sri Lanka
Fig. 23	42A	The location of 41 wetland sites of national importance
Fig. 24	43	Decline of closed canopy forest cover
Fig. 25	46A	National Parks and ecosystems of international importance
Chapter 05	**49 - 56**	**Water and Human Settlements**
Fig. 26	50	Trends of population increase in Sri Lanka
Chapter 06	**57 - 70**	**Water and Food**
Fig. 27	59	Irrigation duty in selected major irrigation schemes
Fig. 28	59	Water productivity in selected irrigation schemes
Fig. 29	61	Variation of paddy yield
Fig. 30	61	Variation of cropping intensity under paddy cultivation
Fig. 31	63	Milk and egg production in Sri Lanka (1993-2003)
Fig. 32	63	Fish Supply in Sri Lanka (1993 2003)
Fig. 33	64	Production and availability of selected agricultural commodities
Fig. 34	66A	Food insecurity in Sri Lanka
Fig. 35	69	Area planted and production of rice (1993-2003)
Chapter 08	**75 - 80**	**Water and Energy**
Fig. 36	79	Energy demand variation in a week day and contribution from different plants
Chapter 09	**81 - 88**	**Managing Risk**
Fig. 37	82A	Temporal clustering of landslides
Fig. 38	84A	Changes in the characteristics of wet and dry spells before and after 1978
Fig. 39	84B	Rainfall intensity changes and occurrence of the land slides
Fig. 40	86A	A comparison of average rainfall 1911-1940 and 1961-1990
Chapter 10	**89 - 92**	**Sharing Water Between Uses and Users**
Fig. 41	92A	Mahaweli water distribution system

List of Tables

List of Tables

	Page	
Chapter 01	**01 - 12**	**General Context**
Table 1	03	Summary of different land use types in Sri Lanka
Table 2	04	Major agricultural crops and land use area (hectare)
Table 3	04	District-wise and sectoral distribution of population
Table 4	05	Key economic indicators
Table 5	06	Estimated poverty lines for Sri Lanka
Table 6	07	Educational attainment (30 years and over)
Table 7	08	Prevalence of under nutrition by sectors based on DHS survey, 2000
Chapter 02	**13 - 30**	**Water Resources of Sri Lanka**
Table 8	14	Monthly average air temperature (^{o}C) and diurnal range of selected locations
Table 9	14	Humidity in selected stations
Table 10	15	Reference to crop evapotranspiration at selected stations
Table 11	17	Rainfall intensity study stations and data durations
Table 12	18	Average annual rainfall and equivalent water volumes for each district
Table 13	19	Average rainfall during different rainfall seasons for 1961- 90
Table 14	19	Rainfall in the two zones of Sri Lanka
Table 15	15	Lengths of some major rivers
Table 16	22	Rainfall-runoff characteristics
Table 17	23	Characteristics of main deep confined aquifers
Table 18	26	Hydrometric station details
Table 19	27	Status of water usage data (based on Wijesekera *et. al* 2000)
Table 20	28	Station densities compared with WMO standards (Wijesekera *et. al* 2000)
Table 21	29	Fifteen largest reservoirs in Sri Lanka
Chapter 03	**31 - 38**	**Water for Basic Needs & Health**
Table 22	32	Indicators used to measure quality of water
Table 23	34	Sources of safe drinking water and service coverage
Table 24	35	Prevalence of diarrhoeal diseases among children according to the sector
Chapter 04	**39 - 48**	**Water and Ecosystems**
Table 26	40	Major forest groupings in Sri Lanka
Table 27	40	Some inland aquatic ecosystems and their extents
Table 28	41	Some marine and maritime ecosystems and their extents
Table 29	41	Examples of coastal ecosystems
Table 30	42	Diversity of floral species of Sri Lanka among selected taxonomic groups
Table 31	44	Species diversity of Sri Lanka among selected taxonomic groups- fauna
Table 32	45	Important bio-diversity reserves in Sri Lanka
Chapter 05	**49 - 56**	**Water and Human Settlements**
Table 33	50	Poverty indicators for different sectors
Table 34	51	Availability of Safe Water Across Sectors
Table 35	52	Sources of drinking water for the urban sector
Table 36	53	A water audit for Colombo Municipal Council (CMC) system (1985)
Table 37	53	Access of sanitation according to type of access
Table 38	53	Access of sanitation according to type of latrine
Table 39	54	Provision of pipe borne sewerage facilities to high density urban areas
Table 40	54	Per capita waste generation in grams/capita/day

List of Tables

	Page	
Chapter 06	**57 - 70**	**Water and Food**
Table 41	- 58	Asweddumized Rice Extent in Sri Lanka - (1979 and 2003)
Table 42	- 60	Crop water requirements of selected food crops
Table 43	- 65	Per capita availability of food commodities 2002
Table 44	- 66	Millennium development goal 1 - eradicate extreme poverty and hunger
Table 45	- 66	Nutrition related indicators: 1950-2000
Chapter 07	**71 - 74**	**Water and Industry**
Table 46	- 72	Distribution of Industries
Table 47	- 73	Industries Obtaining Water from NWSDB Schemes
Table 48	- 73	Industrial consumption of water from NWSDB schemes
Chapter 08	**75 - 80**	**Water and Energy**
Table 49	- 76	Installed Capacity of Power Plants
Table 50	- 77	Major Hydropower Facilities and their Characteristics
Table 51	- 77	Generation Summary (1989-2003)
Table 52	- 79	Expansion Proposals for Existing Hydropower Systems
Chapter 09	**81 - 88**	**Managing Risk**
Table 53	- 81	Natural Disasters in Sri Lanka from 1957 to 2003
Table 54	- 84	Change & Variability of Mean Rainfall during Different Rainfall Seasons Periods 1931-60 & 1961-90
Chapter 10	**89 - 92**	**Sharing Water Between Uses and Users**
Table 55	- 90	The demand for domestic water supply from sources linked to irrigation
Chapter 11	**93 - 96**	**Valuing Water**
Table 56	- 96	Average capital investment needed for different water supply facilities
Chapter 12	**97 - 108**	**Governing Water**
Table 57	- 100	Millennium Development Goals - Health Indicators for Sri Lanka
Table 58	- 100	Projections for water supply coverage
Table 59	- 102	Co-ordinating arrangements of the water sector
Table 60	- 103	Identified Legislation Directly Related to Water
Table 61	- 105	Public investment in irrigation
Table 62	- 105	Investment in Water Resources
Chapter 13	**109 - 116**	**Ensuring the Knowledge Base**
Table 63	- 111	Literacy Rate by Sector and Sex
Table 64	- 112	Identified Postgraduate level programs with contents related to water
Table 65	- 115	Availability of Public Communication Media

List of Frequently Used Abbreviations

ENSO	**- El Nino Southern Oscillation**
NWSDB	**- National Water Supply and Drainage Board**
WRB	**- Water Resources Board**
ID	**- Irrigation Department**
CEB	**- Ceylon Electricity Board**
MASL	**- Mahaweli Authority of Sri Lanka**
CEA	**- Central Environmental Authority**
BCAP	**- Biological Conservation Action Plan**
EIA	**- Environmental Impact Assessment**
NEA	**- National Environmental Act**
EPL	**- Environment Protection License**
CEPOM	**- Committees on Environment Policy Management**
OFC	**- Other Field Crops**
MW	**- Mega Watt**
GWh	**- Giga Watt hours**
MCM	**- Million Cubic Meters**
MAIMD	**- Ministry of Agriculture, Irrigation and Mahaweli Development**
DAD	**- Department of Agrarian Development**
DCS	**- Department of Census & Statistics**
CBSL	**- Central Bank of Sri Lanka**
UNESCO	**- United Nations Educational Scientific & Cultural Organization**

Hon. Minister's Message

The Sri Lanka National Water Development Report is a comprehensive analysis of the current status of water and other associated resources of this country.

Sri Lanka takes pride in her achievements in the field of water resources development. In her message to the souvenir published to mark the 75th anniversary of the Irrigation Department, Hon. Sirimavo R.D. Bandaranayake, former Prime Minister and one of the great leaders of independent Sri Lanka, described the contribution of our ancient rulers to world civilization in the following manner:

"Whereas the kings of different Asian races belonging to ancient civilizations more or less contemporaneous with our own are known to have concentrated on building vast edifices like the pyramids, our own ancient kings not only built massive temples and dagobas to perpetuate for all time our religion and our culture, but also paid as much attention to the construction of stupendous and magnificent irrigation works, so that there was no need for the country to depend on external sources for the purpose of feeding her people"

History explains how this prosperity deteriorated since the 12th century. After independence in 1948, we made substantial gains in water resources development. However, the water related problems such as increasing water demand for urban population and industries, pollution of water bodies, water-related disasters, and insufficiency of water for agriculture are major challenges faced by the government of Sri Lanka. The World is aware that the Tsunami of 2004, which resulted in the loss of more than 35,000 lives and colossal damage to property, was the biggest misfortune in our recorded history. Although such events are beyond human control, this report has intensively analyzed and presented vital information on how to respond to such unexpected disasters, and measures to mitigate adverse effects of such calamities in the future.

The policy of the Government recognizes that water is a valuable resource and the people of Sri Lanka are its owners. Therefore, it is timely that a report of this nature takes stock of the outlook of water resources of the country. The critical issues outlined in the report will attract the attention of policy makers, and provide guidelines for the design of comprehensive and sustainable solutions to water problems of the country.

I wish to convey my gratitude to the United Nations World Water Assessment Programme for assisting my Ministry to carry out the studies that were necessary for this resourceful product. The support extended by the UNESCO office in New Delhi and the University of Moratuwa needs special mention. Finally, I wish to thank all the experts and other staff who contributed to this publication.

Maithreepala Sirisena
Minister of Agriculture, Irrigation and Mahaweli Development and Environment

Secretary's Message

I am both pleased and privileged to send a message to the Sri Lanka National Water Development Report.

Although Sri Lanka is not considered a water scarce country, the availability of water as a sustainably managed resource is emerging as a challenge for national development. The proposed expansion programme of the industrial sector in the south and eastern parts of the country has been constrained by the availability of adequate quantities of water. In addition the growing urban population has to be provided with safe drinking water and clean sanitation. Although we have approached self sufficiency in rice production, our cropping intensities remain low. In order to strengthen the irrigated agriculture sector it is also necessary to support rural livelihoods in a sustainable manner. The findings of this report indicate that climatic changes during the past few decades have had adverse consequences on the frequency and distribution of rainfall, the impacts of which are likely to be more pronounced in the dry zone of Sri Lanka.

The approach to address the challenges of water resources management should be both comprehensive and integrated. It is in this context that the Project sought to obtain the expertise of Sri Lankan nationals in the fields of irrigation, water supply, health and sanitation, agriculture and environmental management, for the preparation of this report. The study has helped to generate a dialogue among government officers, consultants and university academics. It is also pleasing to note that the state sector had played a key role in the study.

It is my conviction that the Sri Lanka National Water Development Report will provide valuable insights into the nature of water resources in Sri Lanka, and prepare the base for future water resources development and management. I wish to thank the United Nations World Water Assessment Programme (WWAP), Dr. Gordon Young, Coordinator of WWAP and his staff at the Secretariat in Paris, and the UNESCO Office in New Delhi and its staff for invaluable support provided to carry out the study. Special mention must be made of the contributions made by University of Moratuwa.

The WWAP activities in Sri Lanka were initiated in the year 2000. It is therefore my duty to acknowledge the encouragement given by former Ministers, and the guidance of the Ministry Secretaries, who were in charge of the subject of irrigation and water resources, during the study period of this Project.

I also wish to congratulate the authors, editors and others who have contributed in various ways to bring out this valuable Report.

T. M. Abayawickrama,
Secretary, Ministry of Agriculture, Irrigation and Mahaweli Development

Foreword

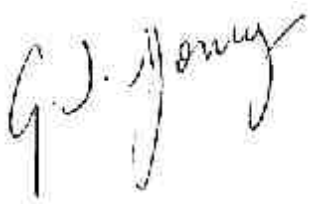
It is with great pleasure that we present the state of the art Sri Lanka National Water Development Report, the result of sixteen months of work, involving all major stakeholders in the water sector, representing Ministries, universities, research institutions and the private sector. This report clearly reflects the water related challenges facing the people of Sri Lanka. The findings of this report will help the readers, researchers and policy makers to understand the fragile nature of the water resources against a backdrop of increasing population, industrialization, growing settlements and increasing need for food.

Sri Lanka, from the early beginning of the establishment of the World Water Assessment Programme (WWAP) has been a valuable partner. The initial project that was started in 2002 with the evaluation of water resources of Ruhuna Basins now has evolved into a national level case study with an authoritative report as the end result.

Water is everybody's business and it is important to make sure that this vital resource is managed in an integrated fashion bringing together and addressing the needs of all stakeholders. The Sri Lankan authorities have been making a sincere effort to put this idea into practice. This report not only compiles the latest national information and statistics on water related issues but also provides a self evaluation of their institutional capabilities for making assessments on which rational management decisions can be made.

Struck by the tsunami disaster in December 2004, Sri Lanka suffered great social and economic losses. Although over a year has passed, this tragedy continues to overwhelm Sri Lankans in many ways. Due to this event, some of our respected Sri Lankan colleagues were lost. However, even during those difficult times, the progress of the case study development did not falter. Consequently, I would like to dedicate this report to our Sri Lankan colleagues who lost their lives in the tsunami event and to their families in grief.

We salute the enthusiasm of Sri Lankan officials to put this report together.



Gordon Young
Co-ordinator, World Water Assessment Programme

Editors Note

The Sri Lanka National Water Development Report (SLNWDR) is the culmination of the hard work by a group of water professionals affiliated to the government ministries, departments, research organisations, national universities and the private sector to study and compile valuable water and associated information of Sri Lanka. Proceedings of the Preparatory Workshop for the Sri Lanka National Water Development Report which was published under the patronage of the UNESCO New Delhi and several specific boxed case studies contributed by the individual authors could be stated as the building blocks for this report. The quick responses made by the authors to reviewer comments and the support extended to ensure the quality of the document are commendable. The editorial inputs were to review and organise the contents and to ensure the structure of the document, presentation styles, formatting of the contents.

This document which reflects the water status of Sri Lanka commencing from present scenario to management challenges that have to be incorporated for sustainable development incorporates up-to-date data and information along with illustrative maps and case studies. Therefore it is an indispensable document for water engineers, planners, administrators, managers and decision makers. This is also a very valuable document for the general public, school children, university academics and researchers as it provides the reality of the status of water in Sri Lanka incorporating a quantitative approach. Attempts were taken to identify and present the spatial distribution of information pertaining to the issues discussed in the document. The list of references in the report provides a value addition and room for further study.

The contributions made by many agencies, officials and individuals were immense in making this effort a success. Though efforts have been taken to include all the names of those who supported in numerous ways, several may still have been missed amidst the load of work that had to be attended to complete the work in time. Those efforts and names that were unintentionally excluded are humbly acknowledged. Invaluable support and encouragement was extended by the Honourable Minister and the Mnistry of Agriculture, Irrigation and Mahaweli Development, the UNESCO New Delhi, the Department of Civil Engineering of University of Moratuwa and the Secretariat of World Water Assessment Programme, Paris towards the organising of the workshops, coordinating the activities, and ensuring the funding support. Opportunity is also taken to thank the printers for their support to complete this work on time.

K. A. U. S Imbulana
N. T. Sohan Wijesekera
Bhanu Neupane

EXECUTIVE SUMMARY

Background

The Indo-Aryan settlements that are believed to have originated in the fifth century BC were initially located on the west-central coast and on the banks of major rivers. These settlements were probably the cradles of the ancient hydraulic civilization of Sri Lanka. The vision behind the ancient hydraulic civilization of Sri Lanka was based on scientific principles of integrated water resources management. Achievements in the fields of irrigation, drinking water supply, sanitation, urban development and environmental management have been considered unique.

Sri Lanka gained independence from the British in 1948. Since then there had been an intensive programme to develop irrigation infrastructure, especially during the period 1948-2000. The Senanayake Samudra built in the 1950s, remains the largest reservoir in Sri Lanka. The Mahaweli Development Project was the largest water resources development project undertaken by Sri Lanka. Apart from the impact on agriculture, these developments brought substantial benefits to many other areas that included flood control, hydropower generation and domestic water supply.

Water resources

Rainfall in Sri Lanka is of multiple origins with monsoonal, convectional and depressional rainfall types accounting for a major share of the annual rainfall. The mean annual rainfall is 1861 mm, which is approximately equivalent to a rainfall volume of 120 BCM (billion cubic meters) of rain water over the land area.

Twenty out of the 103 rivers in Sri Lanka are classified as wet zone rivers, which carry about half of the annual surface runoff. Annual runoff is estimated to be around 35% of the annual rainfall. However, there are considerable variations of the individual values across rivers. Building numerous reservoirs and diverting water to the dry zone compensated this unequal distribution. There are 80 dams which qualify under the major dams category as defined by the International Commission of Large Dams.

The groundwater resources are considered to be lesser compared to surface water resources. Seven main types of groundwater aquifers have been identified. The estimated groundwater potential is 7,800 MCM per annum. Both the quantity and quality issues limit the use of groundwater. It is widely used for domestic, small scale irrigation, industrial and other uses. The serious threats to groundwater aquifers include:

- Nitrate and bacterial contamination of groundwater.
- Severe stress on shallow groundwater that occurs under the small tank cascade systems due to over extraction.
- The rapid expansion in urban, rural and semi-urban settlements increasing stress on both the quantity and quality of water in the aquifers that supply the domestic needs.

- Although there is a relation between the chemical properties of water and health, inadequacy of geo-chemical studies and dissemination information (such as updated maps) is a setback for improving the health conditions.

Water for basic needs and health

Apart from the natural impurities derived from the environment, water pollution caused by human activity is causing concern to the health authorities in Sri Lanka. Among the common sources of pollution are the following:

- Sewage, which contains decomposable organic mater and pathogenic agents.
- Industrial wastes, which contains toxic agents resulting from metal salts to complex organic chemicals.
- Agricultural pollutants which comprise of fertilizers and pesticides.
- Physical pollutants such as radioactive substances and heat.
- Chemical pollutants of diverse nature derived from industrial and agricultural practices as well as those naturally occurring in the soil are increasingly finding their way into public water supplies.

The availability of safe drinking water varies across sectors. The estate sector, where prevalence of diarrhoeal diseases is high, does have poor access to safe drinking water compared to other sectors. As the poverty incidence in the estate sector is high, the link between poverty and access to basic water needs is evident. An important factor contributing to high morbidity from diarrhoeal diseases is the lack of access to safe drinking water. About 70-75% households, do have access to safe drinking water. However, the duration of availability varies spatially and according to the climatic factors. About 75% of the urban population and 14% of the rural population are served by pipe-borne water. The percentage of households having safe sanitation is about 85-90%. The national target seeks to provide safe drinking water for the entire population by 2025.

Out of vector borne diseases that have a greater public health importance, malaria and Japanese encephalitis are considered to be the diseases most often associated with irrigation systems. The most common vector encountered in these diseases is the mosquito. Malaria continues to be a major public health problem and socio economic burden in Sri Lanka. The diseases resulting from chemical characteristics of water include those due to the presence of heavy metals; dental fluorosis resulting from excess fluorides; dental caries resulting from fluoride deficiency; and effects of iodine deficiency.

Water and ecosystems

The rich natural ecosystem diversity of Sri Lanka consists of,

(a) marine and maritime or coastal ecosystems

(b) natural forest ecosystems,

(c) the natural grassland ecosystems and

(d) inland wetland ecosystems.

Among the terrestrial natural forest ecosystems in Sri Lanka, tropical lowland wet evergreen forests or lowland rain forests exhibit the highest biological diversity. The fragmentation of coastal ecosystems and forests, particularly the tropical wet evergreen forests or rain forests of the lowland wet zone are extremely high. The close canopy forest cover is decreasing gradually, which impacts on the biodiversity. It has reduced from about 69% in 1900 to about 22% by 2000. In recent times, the rate of deforestation appears to be slowing down. The reasons could be policy considerations, institutional arrangements and legislative enactments effected recently, as well as the slowing down of agricultural expansion.

The main driving force for deforestation is the increasing population and resulting land hunger, leading to increased pressure on forest lands for conversion to non-forest uses. The conversion of forests to plantation agricultural crops such as coffee, tea and rubber, inappropriate land use trends, unsuitable forestry practices, and the high market price of timber are some of the other causes for deforestation. Poverty too is a key social issue contributing to this situation.

Sri Lanka currently has a fairly extensive system of protected areas, covering nearly 14% of its total land area. While most habitats are represented within the existing protected areas system, most of the major conservation areas lie within the dry zone, which too is a cause for concern. After the establishment of a Ministry in charge of the Environment in 1990, policy development for environmental management improved. Two important legal instruments created recently were the "Environmental Impact Assessment" (EIA) and "Environment Protection License" (EPL). These will ensure sustainability of the projects and contribute towards environmental conservation.

Water and human settlements

About 95% of the urban population enjoys access to safe drinking water supply. The corresponding figure in the rural sector is 75%. Safe drinking water for the rural population is mainly supplied through dug wells and tube wells. The government plans to provide 100% of the urban population with piped water supply by 2010. A major rehabilitation work of the Colombo city sewerage system will be completed in the same year.

Pollution of land, water and coastal resources in urban areas, and degradation of aesthetic value due to poor waste management and unsanitary disposal of liquid and solid waste are key issues to be dealt with. Air and noise pollution and loss of biodiversity are also evident especially in several cities in Sri Lanka. Lack of institutional, technical and law enforcement capacity in local authorities in arresting degradation of

urban environment and natural resources base are identified as the main constraints for continuance of these problems. Current pricing policy is based on the recovery of operational costs of the service provider.

Sri Lanka is committed to provide infrastructure and services to urban poor living in under-served settlements for a long time. With this objective in sight, the government, with the help of NGOs, initiated several short and long term programmes to provide shelter and basic amenities for the targeted population. The main focus of the current programmes is to solve the social, economic, environmental and physical problems resulting from rapid and unplanned urbanization. Provision of safe drinking water and adequate sanitation are among the major challenges faced by the communities and those who strive to serve them.

Several major challenges face the planners who strive to provide safe drinking water and sanitation for the urban population, such as providing drinking water and sanitation to peripheral areas around urban centers while achieving the twin objectives of equitable water supply and demand management.

Water and food

The total extent of asweddumized[1] lands available for rice cultivation was 741,716 hectares in 2003 of which 45%, 24% and 31% of the total extent were under major irrigation, minor irrigation and rain-fed systems respectively. The area under irrigation had been increasing steadily throughout the last century, especially after 1950. The rate of increase had declined after the completion of Mahaweli Development Project in mid 1980s. The current trends indicate a slower growth rate of the total area under irrigation. However, the current emphasis on restoration, augmentation and rehabilitation of existing irrigation systems coupled with improved water management, will result in an increased and more stable cropping intensity. Several programmes implemented by the major irrigation agencies in the recent past to improve water use efficiency have contributed to improved water productivity.

Sri Lanka imports large quantities of maize, lentils, soybean, mung bean, black gram and potatoes to meet the domestic requirement for food, and for the animal feed industry. These crops require relatively less water compared to rice, and could be successfully cultivated in areas with limited irrigation water.

In the fisheries sector, about 80% of the production (224,000 mt) of fish has been from coastal resources. Most of the coastal resources in Sri Lanka are being exploited at the maximum sustainable level or sometimes even exceeding it. Improvement in inland and aquaculture fish supplies is possible mainly through increased production and supply of fingerlings to the inland reservoirs. There is very little information available on specific allocation of water for uses such as inland fisheries.

Since independence in 1948, the Government of Sri Lanka has initiated a series of policies and programmes to improve food security and nutritional levels in the country. Self-sufficiency in rice and generation of rural employment were considered priority considerations of successive

[1] Asweddumized land refers to total cultivable land available in the country for rice cultivation.

governments. The country has achieved near self-sufficiency in rice, producing 3.0 million mt. of paddy in 2003. Rice production increased steeply from the mid 1960s leading to a "green revolution" that was aided by intensive research into high yielding hybrid varieties of rice, integrated pest management, and facilitated by a host of policy measures that included provision of irrigation facilities, the popular fertilizer subsidy scheme, agricultural credit facilities, price support schemes, import restrictions and import substitution, and better water management.

Participatory management in irrigated agriculture was accepted as government policy, and several programs have been implemented for more than two decades to encourage and facilitate higher participation of farmers in the management process.

During the past two decades 28 improved rice varieties have been developed and released for cultivation in Sri Lanka. At present, these improved varieties cover over 98% of the total extent cultivated. Agro-ecology specific improved farming technologies have been developed.

Despite these benchmark indices for nutrition, the level of malnutrition among children during the year 2000 has been significantly high. About 36% of pregnant women were found to be anaemic. Overall sectoral analysis shows that the nutritional status of children and women in the urban sector is significantly higher compared to that in rural sectors. The Food Balance Sheet data of 2002 indicates a national level per capita availability of 2,360 calories and 59.6 grams of protein per day. The average per capita intake per day by the poor households has been estimated at only 1,778 calories.

The production level of rice, the staple food in Sri Lanka, achieved its highest in 2003. The extent cultivated, and the amount produced in 2003 were 982,610 ha. and 3,071,206 mt. respectively. Increases in agricultural productivity through new technologies will be an important contribution to reduce rural poverty, to improve food security as well as nutritional levels of the increasing population. The interaction of farming communities with the state is important in promoting adoption of recommended technology packages by farmers to enhance productivity in food sector.

Water and industry

The present distribution of industries in the country is uneven. There is a high concentration of industries in the western and northwestern regions, in districts such as Gampaha, Colombo and Kurunegala, while it is low in some other districts, especially those in the northeastern areas. According to the Department of Industries, heavy industries are mostly located in Colombo and Gampaha districts, which are in the wet zone.

Pollution of both surface water and ground water sources due to improper disposal of wastewater and solid waste by industries is a grave concern in certain areas. A study conducted by the Central Environmental Authority(CEA) in the Kelani River, which is the main source of drinking water to Colombo, reveal that there is damage due to polluting industries, with the possibility of ground water also being polluted. Other studies reveal adverse effects of polluted well-water in mixed residential and

industrial areas. It has however, to be noted that there is a higher tariff for industrial and commercial consumers than for domestic consumers, the ratio being 1:6.

Water and energy

The major primary energy sources of Sri Lanka and their respective shares are, hydropower (9%), petroleum (41%) and biomass (50%) (in 2001). The distribution of sectoral electricity consumption in Sri Lanka for 2002 shows that the main consumer is the domestic sector (49%), closely followed by the industrial and commercial sector (48%).

At the beginning of the year 2002, only 65% of the population had access to electricity from the national grid, which is planned to be increased to 77% by end of 2006. The electricity demand is growing at a rate of 7-8% annually. The share of hydropower in total electricity generation has fallen from nearly 100% in 1990 to about 42% in 2003. The drop of the hydropower contribution was mainly due to its inability to produce sufficient energy during frequent droughts, especially in late the 1990s and early 2000s. However, hydropower is a major indigenous source of power, has lesser impacts on environment, is relatively cheap and therefore contributes positively to the Government's plans to increase national access to electricity. The government is therefore committed to develop all the possible hydropower options. Some prospective hydro projects have been identified according to the long-term (15 years) generation expansion plan of the government. There are some possibilities of expanding the capacities of the existing hydro plants as well.

Managing risks

Landslides, floods and droughts are the most common and destructive types of natural disasters in Sri Lanka. Droughts have caused severe losses to the economy, including disruption of livelihoods and agricultural productivity. However, inadequate impact assessment arrangements make it difficult to assess the losses accurately. During 2001, the country had to face power cuts, sometimes extending to 8 hours/day. This resulted in substantial losses to the industrial and manufacturing sectors.

Kalu Ganga, Gin Ganga, Nilwala Ganga, Kelani Ganga and Mahaweli Ganga are reputed to be flood prone basins. The most recent experience in Sri Lanka was the floods that occurred in May 2003, which is described as the worst since 1947. A large proportion amounting to about 250 accidental deaths that occured in 2003, were caused by landslides. Most of the landslides that occurred in Sri Lanka were during the northeast monsoon, the southwest monsoon and the second inter-monsoon period Landslides have direct implications on flooding.

The tsunami that occurred on 26th December 2004 was the biggest natural disaster ever to strike Sri Lanka. It resulted in 38,900 deaths and displacement of about 443,000 people in the eastern and southern coasts. The damage to homes, infrastructure, ecosystems and agricultural lands

was enormous. The cost of the damage to assets is estimated as US$ 1000 million. The cost of recovery is about twice that amount, or about US$2,100 million.

Out of the disrupted livelihoods, fisheries were the most affected. It is reported that the coastal population affected was as high as 80% in some of the coastal districts on the east. However, as in other cases of disasters, the cost of human suffering remains less noticed and unaccounted for in cost estimates.

The currently ongoing research reveals that environmental damage to coastal ecosystems such as coral reefs and mangroves reduced the capacity of the natural barriers to mitigate the tsunami force and thus intensified the destruction. Therefore, the government and NGOs are planning to restore these natural barriers where possible, and preserve the ecosystems with the participation of the community.

The analysis of long-term temperature data of the island clearly indicates an increasing trend of air temperature, particularly during the recent few decades. Analysis of inter-annual as well as intra-annual rainfall trends of central Sri Lanka has shown that there is a decrease in the annual rainfall in the region. The bulk of the decrease in annual rainfall has come from the northeast monsoon with a decrease of as much as 19%. Similarly the decrease during first inter-monsoon period is 10.5%, while no significant changes have been observed during the southwest monsoon and the second inter-monsoon. Other major observation is the reduction in the numbers of rainy days giving rise to an increasing trend in intensity of rain and prolonged dry spells.

The most significant point this change has caused is the shifting of demarcation lines of current wet and dry zones, with a reduction in the area under the wet zone. The expected impacts of the observed climatic changes are as follows:

- Increasing intensity of rainfall and prolonged dry spells will result in flash floods, decreased contribution to groundwater and increase soil erosion.
- The dry zone of Sri Lanka receives most of the rainfall during northeast monsoon and first inter-monsoon. The reduction of rainfall during these periods and reduction of rainfall in the upper catchment areas of the major rivers will result in severe and more frequent drought conditions in the dry zone, within which also is a major part of the irrigated area.
- The heaviest impact of climate changes will be on irrigated agriculture, drinking water and sanitation.

Management tools against extreme events include guidelines and thumb rules based on research studies, structural measures or innovations on reservoirs and flood protection infrastructure, and non-structural measures against disasters such as advance warning systems.

The constraints to implementation of effective disaster management systems include the following:

- Inadequate arrangements for data sharing

- Inadequate resources for data collection and dissemination
- Lack of clear responsibilities and inadequate coordination among institutions
- Weaknesses and inadequacy of early warning systems

Sharing water between uses and users

The major issue related to water sharing is the allocation among different water user sectors, especially during droughts. Decisions are often taken with due consideration to social and economic factors. In general, water requirements for drinking, sanitation and livelihood purposes get higher priority during crisis situations. A formal inter-sectoral water allocation system exists in the case of Mahaweli River. The sectors that are involved in water-sharing decisions include irrigation, hydropower and domestic users.

The village tank represents a major resource base for the village community, where several traditional water-sharing methods have been practiced. One such system is the "Bethma" which determines the cultivation extents during a drought period, which is one of the traditional mechanisms to share water related benefits.

Valuing water

Sri Lanka recognizes the fact that water has social, environmental and cultural values in addition to its the economic value. Since a considerable number of people are still living below the poverty line, this is a very important consideration. The social and cultural norms established within the society have placed great emphasis on the optimum use and prevention of wastage of this vital resource.

The financing of water resource development has traditionally remained the responsibility of the state. The payment of costs for providing water services, primarily in the community water supply schemes, is a widely accepted concept today. Recent expansion of the system of community management of water services through local councils etc could result in the transfer of a part of the infrastructure development and management cost to the beneficiaries. With increasing scarcity of water resources and multiplicity of demand from different user sectors, there is a need to compromise between the traditional approach and modern principles.

The value of the crop output and livestock production from agriculture constitutes the most value added component of multiple uses of water in the country. However, water used for irrigation and crop production provides value in ways other than in producing crops. These include ground water recharge, aesthetic and recreational value, domestic and human requirements during water-scarce dry seasons. The magnitude of non-irrigation benefits from water diverted for irrigation could be significantly higher than the direct economic benefits from crop

output. Irrigation water has a social value through the creation of opportunities for development in the dry regions and a critical investment for employment generation. Irrigation investments have contributed significantly to reducing rural-urban migration due to expansion of economic activities. Such aspects also need to be recognized when valuing water.

Governing water

Different aspect of water resources management is being handled by a large number of national institutions. Some of the functions of these institutions include:

- Water resources planning and development
- Irrigation
- Flood control
- Agriculture
- Drinking water supply and sanitation
- Health

Similarly there is a very large number of legislation dealing directly or indirectly with water resources. However, the legal support and implementation strategies for controlling water pollution are inadequate. The multiplicity of the institutions and legislation, unclear responsibility and accountability, and inadequate resources are cited as reasons for this situation.

Although a large number of professionals are employed in the sector, it is noted that the opportunities for long-term training leading to post-graduate qualifications, especially at the PhD level, are inadequate. Local universities play a major role in producing the required number of professionals for water resources management. There is a need to promote water-related research and establish linkages among the academics, practitioners and international organizations in order to develop the human resource base.

The proportion of the public investment in irrigation and agriculture shows a declining trend after mid 1980s. In the irrigation sector, the heavy emphasis on new construction and restoration of irrigation infrastructure has given way to investment in better management and planning of water resources. There are investment needs in the health sector, especially with regard to laboratory facilities. Over the years, private investment and public-private partnerships have increased in the water sector, and this partially compensates the reduction in state investment

Community participation in irrigated agriculture has been practiced for a long time in Sri Lanka. This was accepted as government policy in the mid 1980s. Since then community based farmer institutions have been constituted with formal institutional structures. In the water supply sector public participation, especially by women in rural water supply schemes is substantial, and the communities contribute by sharing costs and taking over the management.

Women play a significant role in agriculture. The studies in minor irrigation systems show that 75% - 85% of women are actively involved in agricultural activities. Studies in irrigation management transfer reveal that participation of women is generally low in farmer organizations. In the rural water supply sector, higher female participation is sometimes due to agency interests.

Ensuring the knowledge base

According to the population census of Sri Lanka the average adult literacy rate in 2001 was 90.7%. This rate varies according to the particular sector i.e., urban, rural and estate, and according to sex as well. In all these sectors, males show a slightly higher literacy rate than the females.

History indicates the existence of a water related knowledgebase especially in irrigation, dating back to the pre Christian period of the 6th and 5th centuries BC. The present knowledge base of the water sector in Sri Lanka is known to have been created over the centuries mainly through tradition, evolution and experience. Subsequently this has been negatively influenced by the foreign dominance and lost to a great extent.

In the case of university education, the fields of civil engineering, agricultural science and some other science programs contain water related studies, and this varies with the nature of the degree. Civil engineering degree course includes water related subjects such as hydrology, hydraulics, irrigation engineering, sanitary and water supply engineering, coastal engineering and environmental aspects of water.

Currently scientific research on water and aspect directly related to water are carried out only by few agencies. During the last decade a reasonable number of socio-economic and policy related research studies on irrigated agriculture have been carried out by International Water Management Institute (IWMI). In the recent times, their research tends to be more focused on water resources.

The major data and information dissemination mechanisms include community-participated extension programmes, printed media including newspapers and electronic media. There are few newsletters and popular magazines published by some government agencies that contain papers of informative and educational value.

Progress towards Millennium Development Goals

The progress towards achieving Millennium Development Goals (MDGs) in food security and poverty alleviation are summarized below:

- Per-capita calorie availability has increased from 1,990 k Cal/day in 1952 to about 2,200 k Cal/day in the recent times.
- Food poverty line, defined as the amount of money spent monthly on food required for a person to achieve the basic nutritional requirement, is the lowest in irrigated-agricultural areas.
- Studies carried out in Ruhuna basins for WWDR-1 show that irrigation development has contributed to improved access to safe drinking water.

- Since the mid 1980s there has been a marked increase in farmers' participation in irrigation and water resources development decisions.

Water related investments as well as health sector investments have contributed substantially to the living conditions of the community. The infant mortality rate per 1000 live births was 13.6 in 2000 compared to 92 in 1948. Incidence of childhood infections and other communicable diseases had declined due to the expanded programme of immunization and other disease prevention programmes launched by the government. Health education programmes were successful due to the high literacy rate of the population and the long term access for education of women. As a result of all these achievements Sri Lanka has been able to reach a commendable health status compared to her moderate per capita GDP.

However, malnutrition still continues to be a major public health concern in Sri Lanka. The nutritional status indicators vary according to districts. It has been shown that poor sanitary conditions and unhygienic practices are associated with diarrhoeal diseases and vector borne diseases, which in turn have an impact on nutritional status.

Conclusions

Sri Lanka has reached several milestones in the water sector in the recent past, especially in the past 50 years. The development of about 25% of the available annual water resources, achieving near-self-sufficiency in rice production, high level of access to safe drinking water and sanitation, protection of areas with high degree of biodiversity, provision of electricity to a significant proportion of the population, and the existence of a water-related knowledge base, can be considered as major achievements.

However, there are several challenges and threats to these achievements. Lack of a consensus about key policy issues constitute one of the major concerns. Other issues include declining investments in some water-related sub-sectors, competition among water user sectors, climatic changes increasing the water-related risks, lack of water-sharing methodologies, and inadequacy of databases and early warning systems. Despite gains in certain fields, inadequate progress has been reported with respect to poverty alleviation, and controlling of water related diseases. Declining or stagnant investments in water resources and health sectors threatens the sustainability of national achievements.

Chapter 01

General Context

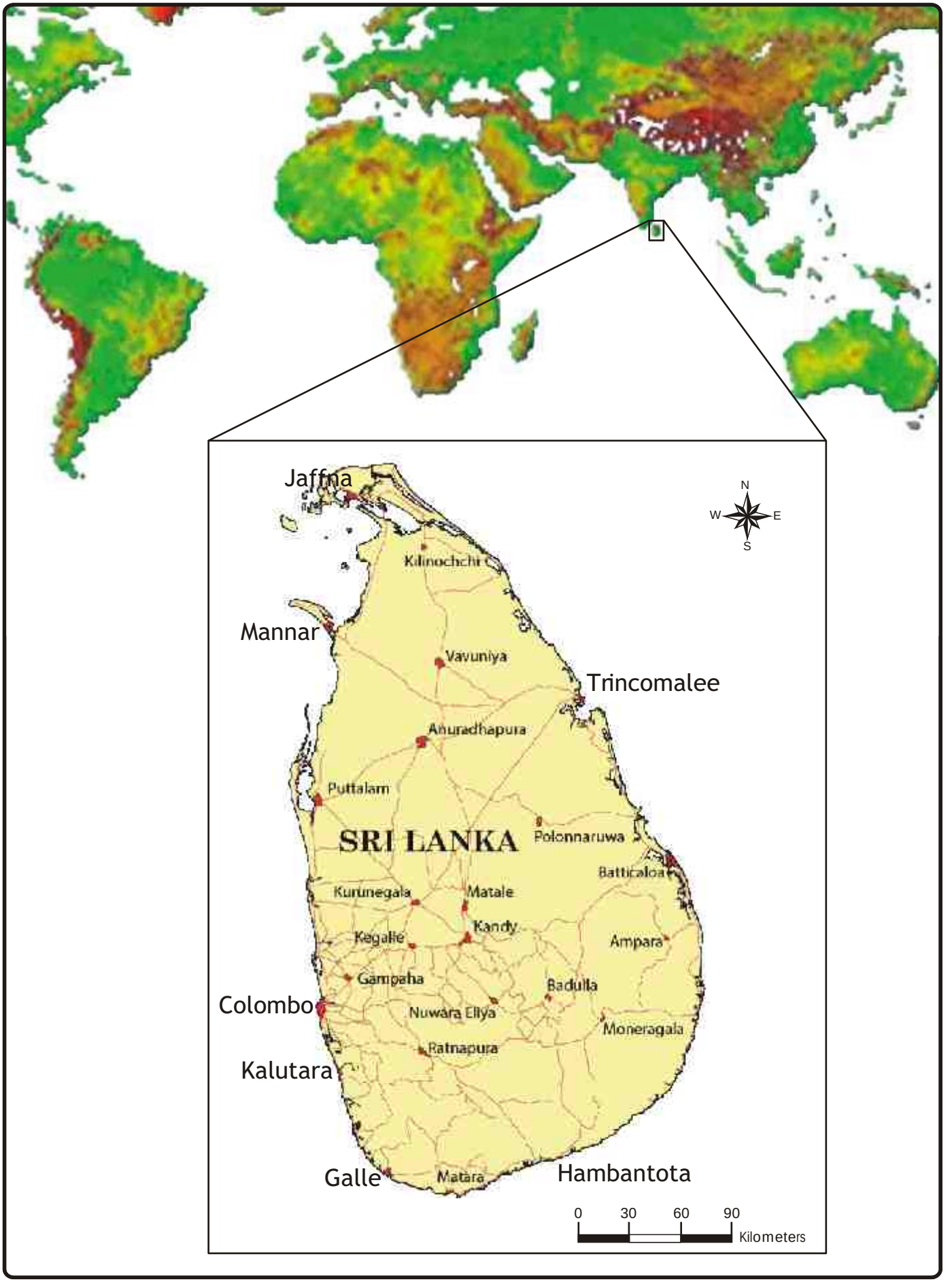


Figure 1. **Location map of Sri Lanka**
Prepared by U.R. Ratnayake (Survey Department base data)

Sri Lanka is situated in the Indian Ocean, near the southern tip of India (Figure 1), between latitudes 6°N and 10°N and longitudes 80°E and 82°E. The country is administratively divided into 25 districts. The physical features of Sri Lanka exhibit a very diverse terrain, resulting in many climatic variations within the island's small landmass of approximately 65,610 square kilometres (DCS, 2003a) with a population of around 19.5 million (CBSL, 2004). There are 103 distinct natural river basins and over 90 small coastal basins (Figure 2). Thirty-six of these watersheds have catchments areas greater than 256 sq. km (100 sq. ml) and are usually termed as major river basins (Arumugam, 1969). Water bodies cover about 2905 sq. km (DCS, 2004c) and a considerable portion of these water bodies consist of man-made reservoirs (sometimes termed as tanks).

Sri Lanka is a humid tropical island, situated in the path of two monsoons, the south-west and the north-east monsoons. Despite this, Sri Lanka has extensive areas of water deficit, and a greater part of the country experiences dry spells lasting several months. The wet zone[1] in the west of the country is the only water surplus area in the country. Acute deficits exist in the northern, north-western, north-eastern and south-eastern parts. The availability of surface water in the dry zone, which encompasses nearly 75 % of the land area, is frequently affected by the failure of the north-east monsoon. Due to poor aquifer conditions, groundwater too is limited in the dry zone (Jayatillake et al 2005).

General hydrological characteristics

Hydrology

Situated close to the equator, the tropical climate of Sri Lanka is characterized by high temperatures and monsoonal winds which give rise to a rainfall pattern with spatial and temporal variations. Rainfall is the only source of useful precipitation, its uneven distribution being governed by two monsoons along with the orographic influence of the central mountain region. Some rains occur as a result of convection effects from depressions and local thunderstorms during the transition period between the monsoons. Tropical cyclones approaching from the Bay of Bengal also cause intense rainfall during the inter-monsoonal periods, the most favourable conditions for their occurrence being October-November. They could be expected during either monsoon period as well and their contribution is significant to the total volumes of rain during those events.

1 The part of the country where the average annual rainfall is above 2500 mm is denoted as wet zone and that below 1750 mm is denoted as the dry zone. An area where the average annual rainfall is between 1750 mm and 2500 mm is known as intermediate zone.

Sri Lanka's climatic year is divided in to five seasons. The convectional-convergence period from March to mid-April, the pre-monsoonal period with a transitional weather pattern from mid April to late May, the south-west monsoon period from late May to late September, the convectional cyclonic period from late September to late November, and the north-east monsoon from November to February (NARESA, 1991). Sri Lanka with its tropical climate experiences a high relative humidity with day time values often varying between 60% and 85%. The nighttime values range from 75% to 95% approximately.

The tropical geographical location of Sri Lanka ensures uniformly high temperatures throughout the year, but the influence of the surrounding ocean makes the island free from the temperature extremes commonly experienced by continental interiors.

The mean annual temperature values in Sri Lanka show largely homogeneous temperatures in the lowlands and rapidly decreasing temperatures in the highlands. In the lowlands (up to an altitude of 100 - 150 meters), the mean annual temperature varies between 26.5 - 28.5^{O}C with an average annual temperature of 27.5^{O}C. In the highlands, the temperature falls quickly as the altitude increases, approximately at a rate of 2^{O}C every 300 meters. At Nuwara Eliya, a town situated at a high altitude in the island, the mean annual temperature ranges from 14.7^{O}C to 17.1^{O}C (Jayatillaka et al 2005).

Sri Lanka comprises of a central hill massif sloping on all sides with undulating relief and a series of mountain ranges. Three peneplains are defined in this cluster namely, a highland massif in the south-centre, an intermediate zone of upland ridges and valleys and an outer or lower zone of lowlands including a coastal fringe consisting of sandbars, lagoons and small islands (Survey Department, 1988). Well-marked scarps separating the upper two zones give rise to many waterfalls. Rivers radiate in all directions from the central hill mass. The Mahaweli River, being the longest (335 km), exhibits very complex characteristics as an integrated drainage course fed by several tributaries and watercourses. All rivers end up in the Indian Ocean, after passing through the deltaic regions.

Location, climate and topography are the main factors that influence precipitation and surface water availability. The average annual rainfall over Sri Lanka is approximately 1850 mm generating an estimated 12x10^{10} cubic meters of water, with about a third being considered as the annual surface flow to the ocean. Crystalline rock complexes covering about 90% of the island promotes heavy runoff estimated to be as high as 65% for the wet zone and 37.5 % for the dry zone (Survey Department, 1988).

As to be expected, flood situations and prolonged or seasonal droughts are not uncommon, arising from the wide variations in space and time distribution of rainfall. They have to be viewed from a local standpoint for comparison, as part of the natural system. Rivers in the wet zone are noted for their flood hazards in their densely populated and well-cultivated lower reaches. Wet zone rivers such as the Kelani, Kalu, Gin and Nilwala which frequently get flooded, show steep gradients in their upper courses and extensive flood plains in their lower courses. Flooding has been no less severe in the cases of several dry zone rivers. Flash floods resulting from high intensity, short duration rain are quite common (Survey Department, 1988).

Topography

Manchanayake and Madduma Bandara (1999) divide the country into lowlands, uplands and highlands. The lowlands are at elevations below 100 m altitude, and primarily consist of coastal areas. Uplands vary from 100 to 500 m in altitude and consist of an undulating topography with isolated hills. The highlands that rise above 500 m are divided again into three portions; the main central mass, the Sabaragamuwa ridges in the south-west and the Knuckles ranges to the north-east. There are 150 mountain peaks ranging between 1000-2000m in height. Of them, twelve peaks are higher than 2,000 m with the highest being Pidurutalagala (2,525 m). This topography influences the distribution of rivers, most of which originate from the central hills and flow in a radial pattern towards the coast, influencing rainfall pattern as well as seasons.

Geology

About 90% of the land consists of pre-Cambrian metamorphic rocks metamorphosed under granulite and amphibolite facies conditions. This is further subdivided as follows:

- Highland group, located on a broad belt running from south-west to north-east through the central part of the country.
- Vijayan complex, located on the north-west and eastern lowlands.
- The south-west group located in the south-western part of the country.
- The north-western part which comprises the rest consists of Jurassic, Miocene and Holocene sedimentary formations (Dissanayake and Weerasooriya, 1985).

The geological properties of these formations influence the occurrence of groundwater, formation

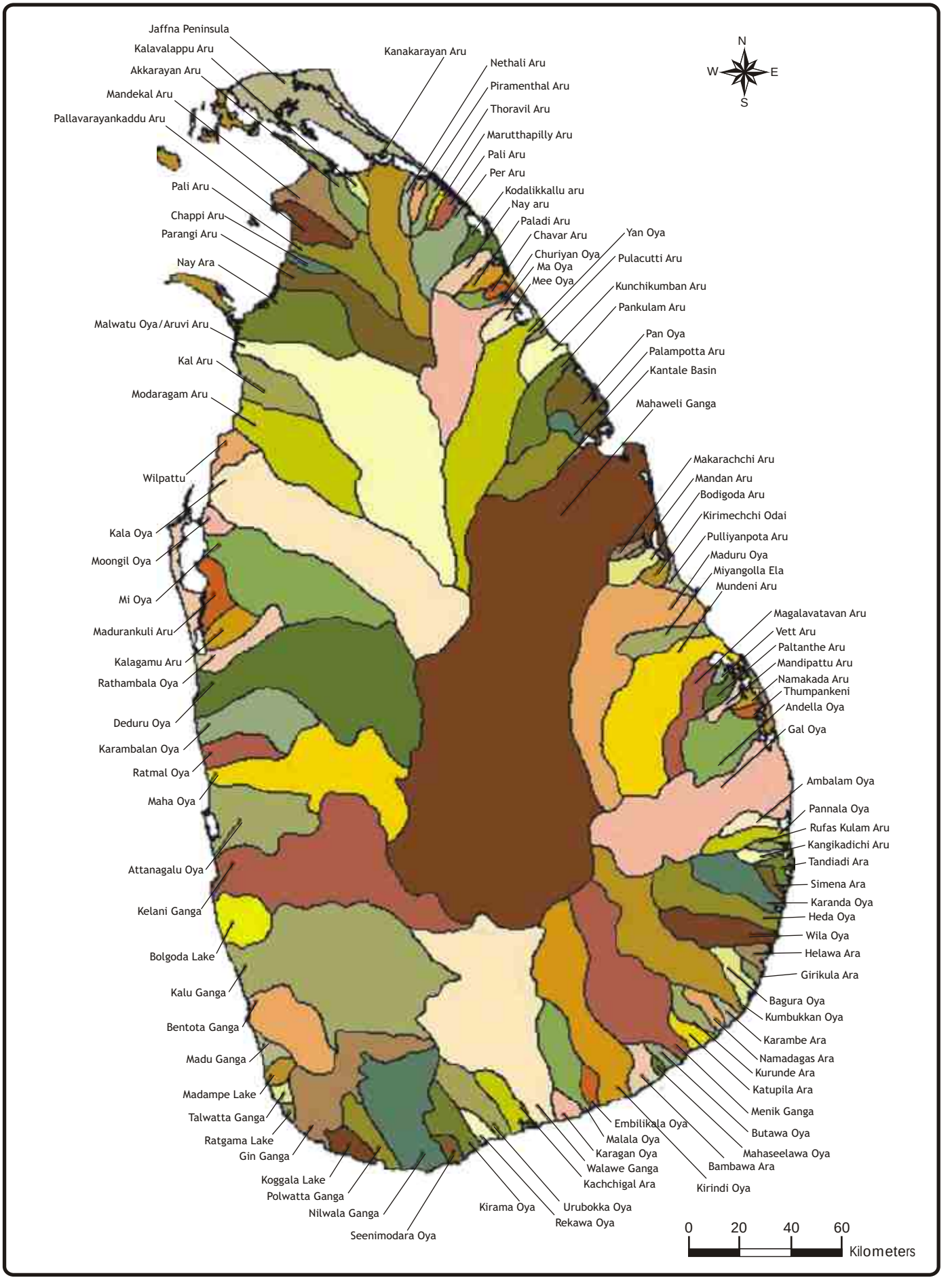


Figure 2. **River basins of Sri Lanka**

Prepared by U.R. Ratnayake (Irrigation Department and Survey Department base data)

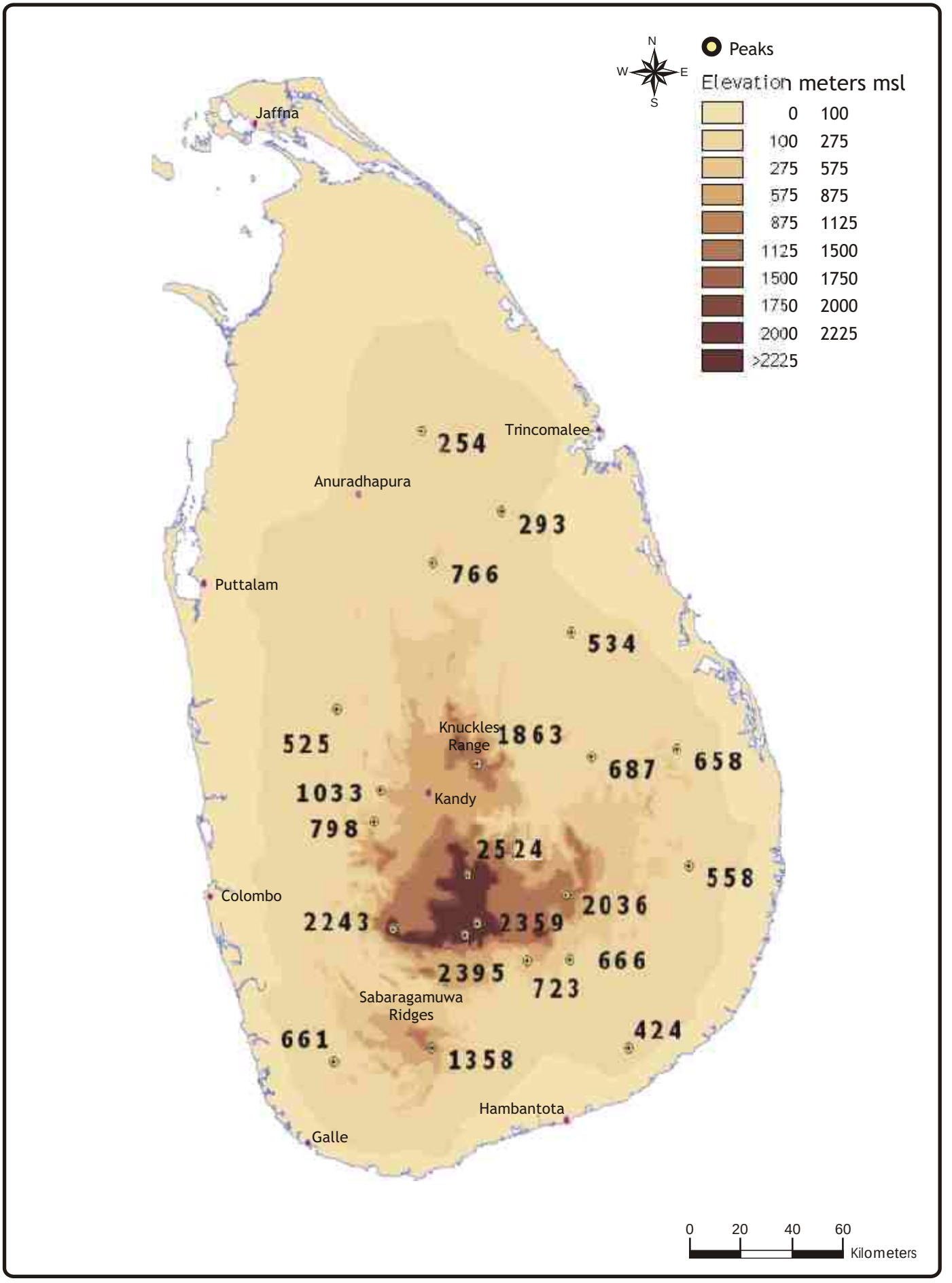


Figure **3. Topography of Sri Lanka**

Prepared by N.T.S. Wijesekera (Survey Department base data)

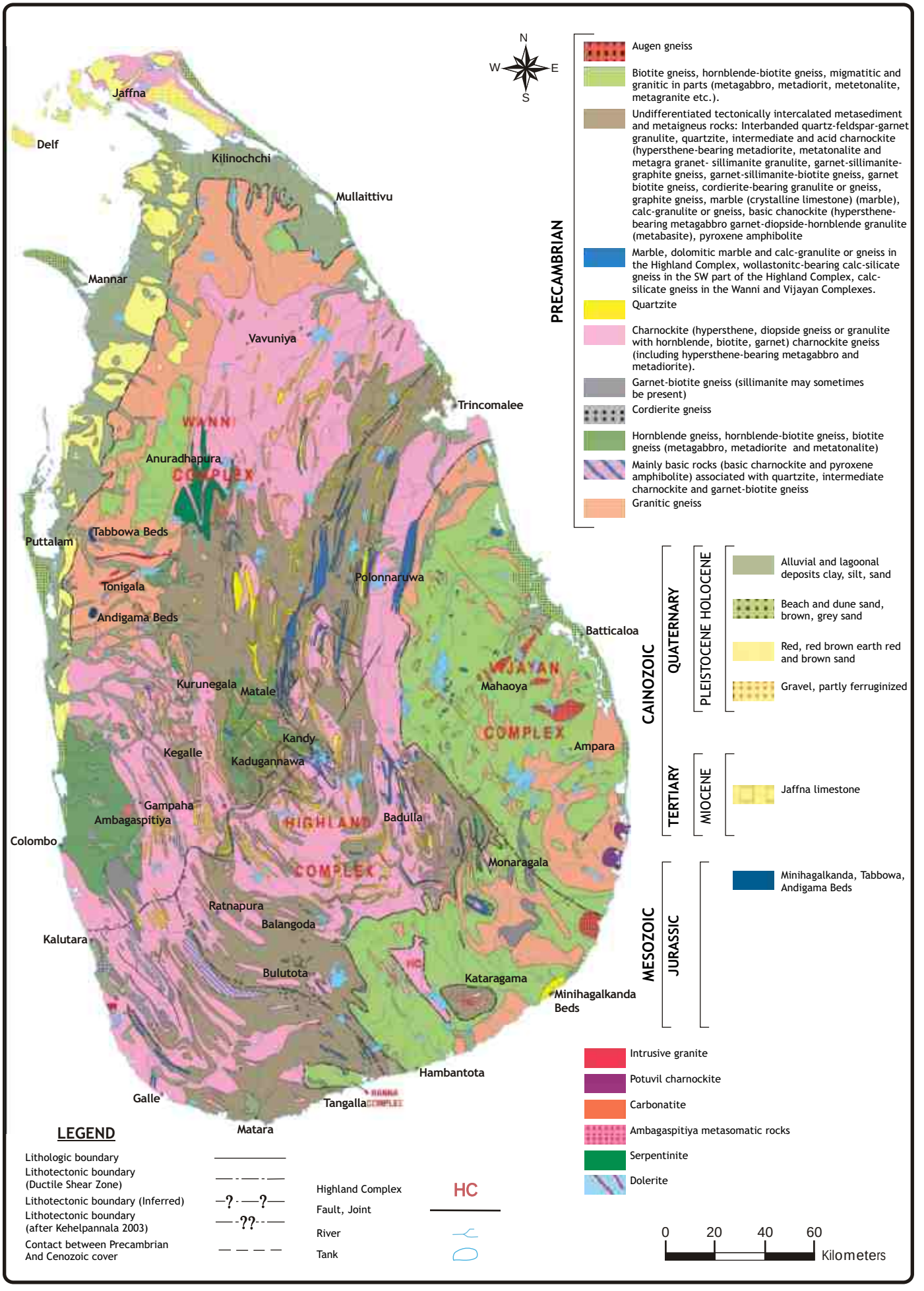


Figure 4. Geology of Sri Lanka

Prepared by N.T.S. Wijesekera (National Atlas of Sri Lanka, Survey Department base data)

of springs and soils. Quaternary sands, sandstones, clays and gravels are present in the coastal areas, providing lenses of freshwater. Groundwater is available in the zones of jointing and fracturing of rock formations (Manchanayake and Madduma Bandara, 1999). The Figure 4 shows location of geological formations and the major rock types.

Soils

The distribution of soils in Sri Lanka is influenced by the topography and climate. The major soil types include reddish brown earths, non-calcic brown earths, red yellow podozolic soils, red yellow latasols, immature brown loams and low humic gley soils. Most of the soils in the dry zone are reddish brown earths and cover a comparatively large part of the country (Manchanayake and Madduma Bandara, 1999).

The occurrence of soils influences agricultural crop selection and water use. They also impact on groundwater quality (Panabokke, 2002) and impact on environmental issues such as water logging. Figure 5 describes the major soil types and their occurrence.

Land use

Out of the total land area in the country, an estimated 5,403,899 ha or 82.3 % is owned by the state while the area owned by private owners is estimated at 1,166,235 or 17.7 % (Manchanayake and Madduma Bandara, 1999). The island had heavy natural forest cover right up to the period of British occupation in 1815. Thereafter, extensive felling of wet zone forests commenced for plantation agriculture. By 1881, the forest cover was estimated at 84% of the land area, which declined to around 75% at the turn of the century. By 1956 it had further declined to 44%. The latest estimate in 1992 places the dense natural forest cover around 20% (Nanayakkara, 1995), while the total forest cover is about 30%.

Negative impacts of past deforestation such as flooding and erosion in most of the rainfed agricultural areas cause soil losses, lower land productivity, siltation of reservoirs and reduction of the useful life of irrigation and hydroelectric infrastructure. Economic development, mainly urbanisation and industrialisation, have placed increasing pressures and generated conflict between alternate uses of water resources, which therefore needs to be harmonised through a comprehensive and multidisciplinary approach (ADB, 1998).

Different land use types can be summarized as given in the table below:

About one-third of the country's land is used for agriculture; another third comprises forests and wildlife; and the rest is used for transport, human settlements and a variety of other activities.

Table 1 Summary of different land use types in Sri Lanka

Type	Agricultural area		Land area (including agricultural)	
	Proportion(%)	Area (ha.)	Proportion(%)	Total
Paddy	39.8%	739,903		
Subsidiary crops	7.0%	131,120		
Coconut	23.9%	443,952		
Rubber	8.4%	157,100		
Tea	10.2%	188,971		
Other export crops	3.4%	62,330		
Other food crops	7.4%	137,060		
Total agricultural land	**100.0%**	**1,860,436**	**28.4%**	**1,860,436**
Forests			**23.1%**	1,516,414
Inland water			**4.4%**	290,500
Other			**44.1%**	2,893,650
Total land area			**100.0%**	**6,561,000**

Source: DCS, 2003a

Table 2 Major agricultural crops and land use (hectare)

Crop	1995	1996	1997	1998	1999	2000	2001	2002
Tea	188,970	187,563	190,473	188,971	188,971	188,971	188,971	188,971
Rubber	161,600	162,000	158,200	158,672	159,097	157,031	157,100	157,403
Coconut	443,952	443,952	443,952	443,952	443,952	443,952	443,952	443,952
Cinnamon	24,250	24,300	24,360	24,510	24,570	24,670	24,570	25,360
Coffee	16,660	16,540	16,460	16,260	16,300	15,600	15,120	14,820
Cocoa	5,730	5,810	5,840	5,760	5,640	5,430	5,030	4,850
Pepper	26,990	26,880	27,030	28,050	28,230	28,440	28,470	29,100
Cardamom	4,540	4,550	4,410	4,350	4,110	3,920	4,040	3,840
Paddy(Maha)	566,650	498,930	472,998	573,845	546,586	549,246	478,986	510,403
Total	1,439,342	1,370,525	1,343,723	1,444,370	1,417,456	1,417,260	1,346,239	1,378,699

Source: DCS, 2004c

Major socio-cconomic characteristics

General description

The government of Sri Lanka supports and implements various social welfare oriented policies and programmes. As a result, the country has made significant improvements in social development such as improvement in public health care system and education. Major health threats such as malaria have been substantially controlled and the health service has been expanded to cover the entire island, thereby resulting in a substantial reduction of the mortality rate. The introduction of free education from the kindergarten to the university level has improved the national literacy rate, particularly among women. This in turn has increased the percentage of female participation in social, economic, and political activities as well as labour force participation at all levels.

Over a long period of time Sri Lanka's economy was predominantly agricultural, and dependent on the three major perennial tree crops - tea, rubber, and coconut - for its major foreign exchange earnings. Since the introduction of open economy policies in 1977, the non-agriculture based foreign exchange earnings have increased through the export of items produced in free trade zones. This has however, resulted in a decline in the prominence of the agricultural sector whereas the trade and industries sector gained prominence. The contribution to the Gross Domestic Product by the agricultural sector too has declined to 16.3 % in 2000 while the contribution by the trade and industries sectors increased to 22.1 and 17.4 % respectively. Even so, the agricultural sector is extremely important since it continues to generate employment for about 40 % of the workers in Sri Lanka (DCS, 2003a).

It is noted that the Head Count Poverty ratio National Poverty rate (the percentage of population living below the national poverty line) excluding northern and eastern provinces for the Year 2002 had been 22.7; while for year 2000, it had been 28.8 (1995/1996). The total poverty line for Sri Lanka for the year 1995/96 has been estimated as Rs. 953.00 per person per month, with the Western, Central and Southern provinces having values of Rs. 1002.00, Rs. 973.00 and Rs. 946.00 respectively (Vidyaratna and Tilakaratna, 2003).

Table 3 District-wise and sectoral distribution of population

	District	Total Population 2001	Urban Population 2001
1	Colombo	2,234,300	1,221,900
2	Gampaha	2,066,100	301,700
3	Kalutara	1,060,800	112,700
4	Kandy	1,272,500	156,900
5	Matale	442,400	36,400
6	Nuwara- Eliya	700,100	43,100
7	Galle	990,500	110,700
8	Matara	761,200	64,500
9	Hambantota	525,400	21,700
10	Jaffna**	490,600	
11	Mannar**	151,600	
12	Vavuniya**	149,800	
13	Mullaitivu**	121,700	
14	Kilinochchi**	127,300	
15	Batticaloa**	486,400	
16	Ampara	589,300	112,400
17	Trincomalee **	340,200	
18	Kurunegala	1,452,400	34,700
19	Puttalam/Chilaw	705,300	65,100
20	Anuradhapura	746,500	56,600
21	Polonnaruwa	359,200	
22	Badulla	774,600	53,000
23	Moneragala	396,200	
24	Ratnapura	1,008,200	58,400
25	Kegalle	779,800	17,400
	Sri Lanka	18,732,400	2,467,200

*** According to the current definition, there is no urban population in these Districts.*

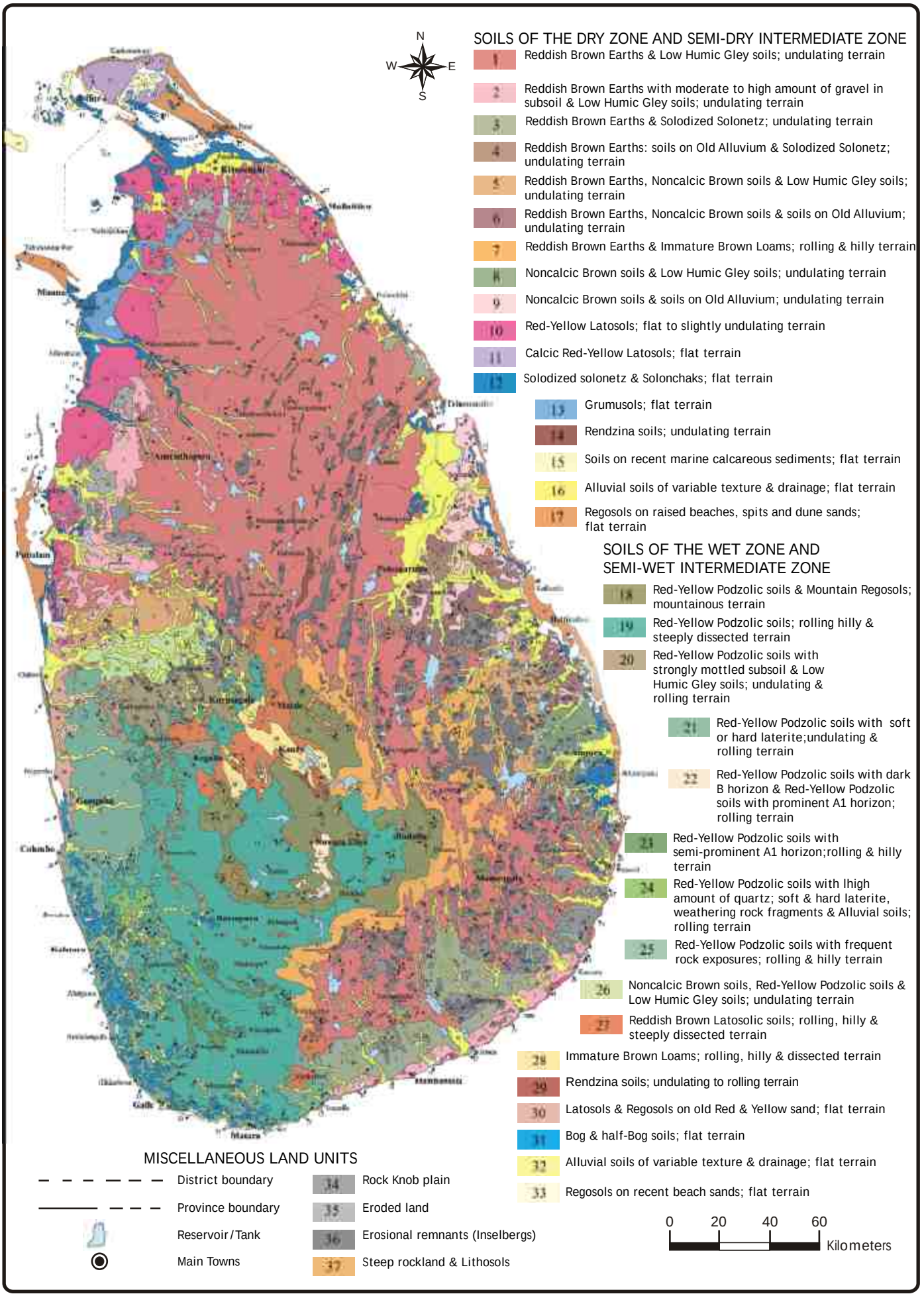


Figure 5. Soils of Sri Lanka.

Prepared by N.T.S. Wijesekera (National Atlas of Sri Lanka, Survey Department base data)

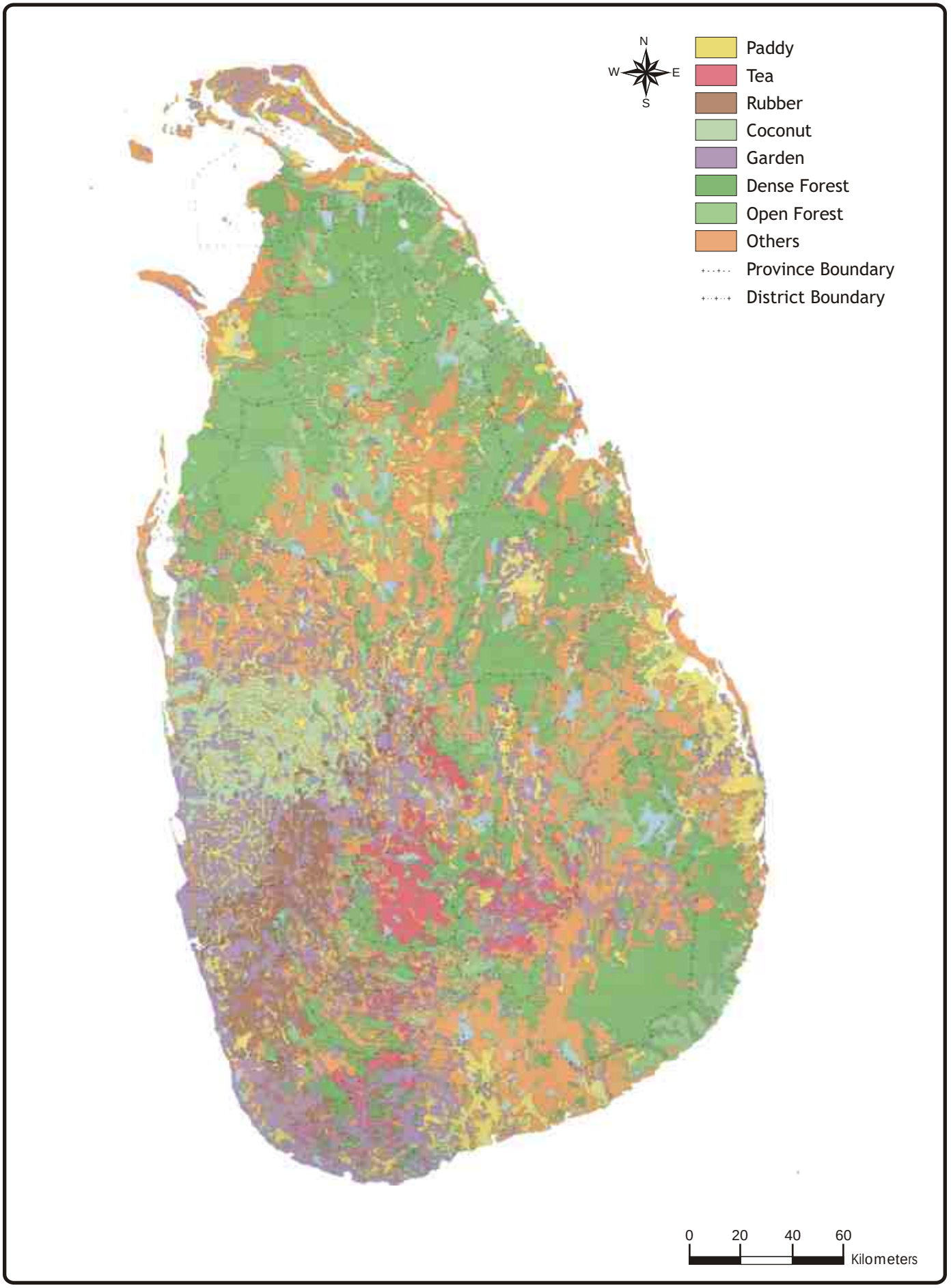


Figure 6. **Land use map**

Prepared by N.T.S. Wijesekera (National Atlas of Sri Lanka, Survey Department base data)

Population

According to the results of 2001 Census, the population of Sri Lanka was approximately18.7 million people. The district-wise population and the number of urban population in each district are shown in Table 3 (DCS, 2004c). The current population (projected population in 2004) is estimated as 19.5 million (CBSL, 2005).

It is noteworthy that Sri Lanka, with about 300 persons per square kilometre, is one of the most densely populated countries in the world. The density of population has shown a significant increase over the past 50 years with the number of persons per square kilometre rising from 232 in 1981 to 297 in 2004. A significant density variation is observed across districts, with Colombo, Galle, Jaffna, Kalutara, Kandy, and Matara being the most densely populated districts. The highest density is recorded in the Colombo district at 3000 persons per square kilometre. In the sparsely populated districts the density is below 100 persons per square kilometre (CBSL, 1998).

In Sri Lanka, 75.4 % of the households have access to potable water and 72.6% have access to some level of sanitation and sewage facilities (Table 4).

Economic activities

The per capita Gross Domestic Product (GDP) had varied between US$ 759 and US$ 856 during the five-year period of 1996 to 2000. There was an average growth rate of a 5% for GDP during 1990-2000. Sri Lanka was included in the lower-middle-income category of countries during the latter part of this period (CBSL, 2001). GDP in real terms grew by 5.4% in 2004. The per capita GDP increased to US$ 1,031, and exceeded the US$ 1000 for the first time in 2004 (CBSL, 2005). Living standards, poverty level, employment status, GDP and other key economic indicators are given below in Table 4.

Table 4. Key economic indicators

Indicator	Value and Unit	Year
Population Growth Rate*	1.20%	2002
Population Density	307 persons/sq.km	2003
Urbanisation rate**	14.6% of Total Population	2001
Labour Force (LF)	7.1 Million	2002
Unemployment***	8.8% of LF	2002
Employment by Economic Activity		
Agriculture, Forestry and Fishery	34.5 % of Total Employed	2002
Industry	22.4 %of Total Employed	2002
Services	43.1% of Total Employed	2002
Average Hours Worked	41.5 per Week	2002
Minimum Wage	111.17 Sri Lankan Rupees	2002
Child (<5 year) Mortality Rate	20.8 per 1000 live births	2000
Maternal Mortality Rate	0.3 per 1000 live births	1997
GDP per Capita	864 US$	2002
Inflation Rate - Consumer Price Index	6.30%	2003
Paddy Productivity in Agriculture	6000 Mt/ha	2002
Gross Domestic Investment (GDI)	22.6% GDP	2002
Private Investment	81.38 % GDI	2002
Public Investment	11.15 % GDI	2002
Access to improved Sanitation Facilities***	72.6% of households	2000
Access to Potable water ***	75.4% of households	2000
Access to sewerage connection***	72.6% of households	2000
Access to Electricity***	68.2% of households	2000
Life Expectancy at Birth - Male	71.7 Years	2001
Life Expectancy at Birth - Female	76.4 Years	2001

**- Provisional; ** - Urban Sector comprises of municipal and Urban Councils only*
****- Excluding North and Eastern Provinces*
(DCS: 2004a)

Table 5. Estimated poverty lines for Sri Lanka

Estimated poverty lines for Sri Lanka based on 1995/96 survey and projected for proceeding years CCPI				
Year	Colombo Consumer Price Index		Poverty Line	
	All Items	Food Items	at current prices in SLRs.	
			Total	Food
1995/96	1775.7	1937.9	953	591
1997	2089.1	2336.9	1122	712
1998	2284.9	2592.1	1227	790
1999	2392.1	2695.4	1284	822
2000	2539.8	2815.8	1364	858
2001	2899.4	3244.7	1557	989
2002	3176.4	3589.9	1705	1094

Source: Vidyaratne and Tilakaratne, 2003

The Annual Report of the Central Bank for 2003 indicates that about 6.6 % of the population received less than one US dollar per day and about 45 % receive less than two US dollars per day (Weerasena et al, 2005). The national poverty line, as defined by the Department of Census and Statistics, is based on the ability of a household to purchase the minimum food and non-food requirements. (See Table 5) For this purpose, the national calorie requirement is considered as 2030 kcal/capita/day. Based on this, a food poverty line is defined first and non-food poverty line is added to give the total poverty line (Vidyaratne and Tilakaratne, 2003).

Cultural background

Sri Lanka's culture is influenced by the four main religions - Buddhism (69%), Hinduism (15%), Islam (8%), and Christianity (8 %). For the past 2,500 years, the society of Sri Lanka remained mainly rural and agriculture based. As a result, there are many festivals and traditional activities closely linked to religion and agriculture. Some of the rites and rituals indicated below are associated with water and irrigated agriculture (Dissanayake, 2000).

- Ceremony performed to protect the irrigation reservoir from breaching in times of heavy rains
- Ceremony performed in gratitude to gods when the harvest is gathered (Aluth Sahal Mangallaya)
- Rites performed to cause rain when the Tanks run dry
- Rites performed at the beginning of the cultivation season(Mutti Nameema)

Many of these rites are yet being observed in rural communities.

Water based recreation had been an important feature of the Sri Lankan culture, with many references in literature and history. Sigiriya, a UNESCO World Heritage site is the location for famous water gardens formed through an intricate network of water pools, fountains, moat and underground conduits. Communal bathing in rivers, common wells and reservoirs is very popular in rural Sri Lanka. Such facilities are meant not only for basic needs but caters for recreation and social interaction as well.

Water plays a role in every significant event of the life of an average Sri Lankan. It performs a purifying function with ritual baths being part of many important religious and cultural functions, and rites of passage. It is both seen as a symbol of fertility and in some cases denotes a transfer of the ownership. Sacred water is believed to have the power to protect and to destroy evil. The significant role played by water in the cultural life of people is indicated by the belief that rains will fall in time when the rulers are righteous (Dissanayake, 2000).

Invocation used for blessing

May the rains fall in time
May the fields flourish
May all beings be well and happy
May the rulers be just

The scenic beauty of the island is closely linked with water. Waterfalls constitute a major attraction for those who seek water-centred recreation. There are 15 waterfalls with more than 100 m in height, the highest one being Bambarakanda (263 m) (Dissanayake, 2000).

Numerous reservoirs enhance the natural beauty and provide opportunities for recreation. Most of the inland tourist resorts are located near the reservoirs and streams. Sri Lanka is actively promoting eco-tourism and benefits of this approach to the environment have been observed.

Education

Continuous investment in the social welfare of people has resulted in an increase of the national literacy rate from 69% in 1953 to 83% in 1981 and to 92.5% in 2003/04. There is a considerable spatial variation and the values vary from the lowest of 68% in Batticaloa District to 95% in Gampaha. The literacy rate is generally low in the Eastern part of the country and high in the Western part (DCS, 2003a).

The literacy rate among females is about 90.6% compared to 94.5% among males (CBSL, 2005), and therefore, in general, does not show a negative gender bias with respect to educational opportunities. In fact, the literacy rate among males was already much higher than that of the females (by 68%) in 1953, compared to only 14% in 1981 (CBSL, 1998). However, there is a considerable spatial variation (DCS, 2003a) indicating the existence of spatially distributed social, economic and political factors that result in gender discrimination. The total number of students in schools in 2001 was about 4.3 million, which is 23% of the population. There were 10,548 schools in the country and the number of schools shows a slightly decreasing trend from 1996. The majority (94%) were Government schools. The pupil/teacher ratio is about 22 (DCS, 2003a).

Table 6 shows the educational attainment of the population of 30 years or over, reflecting that only about 2.3% of total population possesses qualifications of a university degree or a higher educational qualification. It can also be noted that while 8.7% of the total population has never attended any school, and 26.3% leaves school at primary level. Therefore more than 50% of the students who are in secondary schools do not receive a higher education. Only 8% of the total population appears for the university entrance examinations after completing their formal education.

Health

The broad objectives of the health policy of the Sri Lanka government are to increase the life expectancy and improve the quality of life. This is to be achieved by controlling preventable diseases and by health promotion activities. In Sri Lanka, both public and private sectors provide health care. The public sector health care comprises Western, Ayurvedic and Homeopathy systems, while the private sector consists of practitioners of Western, Ayurvedic, Siddha, Unani, and Homeopathy systems. The government provides free health care services including specialised and intensive services through an extensive network of health care institutions (Shanmugarajah, 2005).

The government expenditure on health as a percentage of the total government expenditure was 4.3 in 1995. This percentage has increased to 5.6 by 1999. Every year the Ministry of Health receives foreign aid - in 1999 this constituted 5% of the total health expenditure. Per capita health expenditure increased from Rs. 582.00 in 1995 to Rs. 946.00 in 1999 (DCS, 2002a). The total government health expenditure as a percent of GDP was 1.53% in 1990s (WHO, 2002).

Life expectancy, nutrition and mortality rate

Sri Lankan life expectancy at birth was about 70 years in 1981, and has risen slightly in 2004 to 71.7 years for males and 76.4 years for females. This records a considerable increase from 1963, when it was only 63.5 years. The crude death rate was about 6 per 1000 people in 2001. The infant mortality was 12.2 per 1000 live births during the same period (DCS, 2003a). Malnutrition is still considered to be a major

Table 6 Educational attainment (30 years and over)

Educational attainment	Male (%)	Female (%)	Total (%)
No schooling	5.4	13.7	8.7
Primary	25.8	24.7	26.3
Secondary	42.8	37.8	37.2
GCE (OL)	17.5	16.8	17.5
GCE (AL)	6.1	5.7	7.9
Degree or Higher	2.4	1.5	2.3
Other	-	-	-
Total	100	100	100

Source: DCS, 2001
Note: This survey has been not conducted in Northern and Eastern provinces.

public health concern in Sri Lanka with the nutritional status indicators varying according to districts. There is a clear relationship between malnutrition and environmental sanitation. It has been shown that poor sanitary conditions and unhygienic practices are associated with diarrhoeal diseases and vector borne diseases, which in turn have an impact on the nutritional status[2]. Malnutrition is also impacted upon by food availability- availability of water for agricultural and industrial purposes plays a greater role in this issue (Shanmugarajah 2005).

According to the above data, the percentage of all three indicators of under nutrition among children less than 5 years of age are higher in the estate and rural sectors where incidence of diarrhoeal diseases are high among the children of the same age group. A major contributory factor to this situation may be the poor access to clean water supply and sanitation, but adequate research material is not available to confirm this assumption (Shanmugarajah, 2005).

Historical background to water resources management

Early history of water use

There are references to early inhabitants of the country in ancient chronicles such as Ramayana and Mahabharata. According to this evidence, these communities made a living through fishing, hunting and agriculture (Parker 1909). The Indo-Aryan settlements that are believed to have originated in the fifth century BC were initially located on the west-central coast and on the banks of Malwatu Oya. Subsequently the people moved inland and settlements were formed along Mahaweli River and in Rohana (Ruhuna) in the south (de Silva 2003). These settlements were the cradles of the ancient hydraulic civilization of Sri Lanka.

The achievements in the field of irrigation are given much prominence in the discussions concerning ancient hydraulic civilization. However, there is evidence to show that similar achievements were made in the fields of drinking water supply, sanitation, urban development and environmental management.

Ancient settlements and sanitation

It may be noted that Sri Lanka's first Aryan settlements were on the banks of Malwatu Oya, and Anuradhapura was the first Sri Lankan capital in recorded history. The level of development of this settlement is seen by the fact that it had elaborate arrangements for urban sanitation. Historical records show that during the reign of king Pandukabhaya (377-307 B.C.) the city of Anuradhapura employed 500 scavengers, 200 workers to clean the sewers, 150 persons for carrying the dead bodies to cemeteries and 150 as watchers. This king also built a reservoir to supply water to the city (Rev Walpola Rahula, 1956).

During times of prosperity, the kings built huge monasteries for the Buddhist priests. It is reported that there were 8,000 monks in two monasteries in Anuradhapura, as well as another 2,000 in Mihintale (Rev Walpola Rahula, 1956). When the lay population of the city is included, the provision of drinking water and sanitation is seen to have required much investment and organizational capacity. The information obtained from Anuradhapura museum shows that monasteries were equipped with toilets with a flushing system. In order to prevent contamination of groundwater, urine was passed through a filtering system of clay pots before being discharged to the ground.

Environmental and ecosystems management

The information available at the Anuradhapura museum and the ruins of Anuradhapura and Polonnaruwa cities reveal that the cities had been landscaped to minimize soil erosion. The storm water was drained from one level to another through a spout, which allowed for settling of soil particles before draining. Weeramantry (2000) states that control of silt accumulation in reservoirs was a major concern. Therefore reservoir systems were equipped with erosion control tanks to trap silt before it entered the main reservoir.

Furthermore, keeping with the Buddhist philosophy of all living beings having a right to life and land, King Devanampiyatissa (307 BC) started sanctuaries for wild animals. Legal protection was granted to fauna and flora, and it was recognized that maintenance of forest cover is vital to the occurrence of rains (Weeramantry, 2000).

Table 7. Prevalence of under nutrition by sectors based on DHS survey, 2000

Sector	Stunting (%)	Wasting (%)	Under weight (%)
Colombo	7	10	18
Other Urban	9	6	21
Rural	13	16	31
Estate	34	10	44

Source: DCS, 2002a[3]

2 According to the WHO statistics, half of the childhood -deaths occurring in the world are attributed to malnutrition and out of them 19% are attributed to diarrhoeal diseases. (Senahasa, 1999, cited in Shanmugarajah 2005).

3 The Sri Lanka Demographic and Health Survey (DCS, 2002a) excluded the Northern and Eastern Districts.

Water management techniques

The ancient irrigation systems were designed in such a manner that facilitated drainage or excess water from one system to be captured at a downstream system. This system of hydrologically connected reservoirs is called a "cascade". In the case of small reservoirs or village tanks of Sri Lanka, much research has been carried out to date (Panabokke et al 2002, Madduma Bandara, 1985).

Seneviratne (2002) states that lands and irrigation systems were gifted to Buddhist monasteries and the revenue from irrigation works were donated to the monks so that they could obtain their requisites. The ancient records indicate several means of revenue related to water, such as irrigation dues, share of fish in the reservoir and canals that indicate a highly systematised management. The reservoirs belonged to the State, private individuals, communities and temples. The ancient rules and regulations stipulated specific action which should be taken in situations such as damage to irrigation structures, theft of water and fish and using water out of turn. The stone inscription at Kondavattuvan by King Dappula IV (939-940 AD) stipulates fines for offences related to activities such as failure to supply of water to fields and irregularities in ploughing.

There is also evidence that there was a system of measuring water flows. According to available Buddhist literature, a person who has breached an embankment should be punished according to the amount of water that flowed out. The judgment made by King Mahinda IV (956-972 A.D.) regarding the right of Isurumuniya monastery to waters of the Tissa reservoir, refers to a water level marked on a stone pillar in front of the sluice gate (Seneviratne, 2002).

Such an elaborate set of rules required a large number of officials for administration. The ancient inscriptions refer to various levels of officials including irrigation engineers, those who supervised agricultural activities, system water managers etc. The ancient rock inscriptions also refer to an office of the "twelve great reservoirs" during the time of Mahapa Dapul (918 A.D.), and an Inspector of Reservoirs during the reign of Sena II (853-887 A.D.) (Seneviratna, 2002). Some of these water related occupations are yet reflected in the Sinhala clan names (eg Diyabalanage- water manager).

Water resources development in ancient times - the vision

The vision behind the ancient hydraulic civilization of Sri Lanka was based on scientific principles of integrated water resources management with recognition of common property rights. According to the ancient chronicles, Arahat Mahinda, the monk son of Emperor Asoka of India who brought Buddhism to Sri Lanka, is recorded in the Mahawamsa as advising the then king of Sri Lanka that the land belongs to the people and all living beings, while the ruler is only the guardian of the land (Weeramantry, 2000). Subsequently, King Parakramabahu the Great (1153-1186 AD) decreed that " ……let not even a drop of water obtained from rain, flow to the sea without benefiting mankind", thereby emphasizing the importance placed on water resource utilization in ancient Sri Lanka (Brohier, 1934).

Evolution of irrigation reservoirs

There are several theories on the evolution of Sri Lanka's hydraulic civilization. According to the Presidential address to the Engineering Association of Ceylon, (quoted by Mendis 2001), R.L. Brohier stated that the evolution and the development of ancient irrigation systems in Sri Lanka had four stages of development, namely,

1. Rainwater tanks, from which water has been baled out
2. Small village tanks
3. Large reservoirs, each submerging a number of small tanks
4. Augmentation of large reservoirs by diversions from river.

According to Mendis (2001), the ancient irrigation systems of Sri Lanka could be termed as man-made water and soil conservation ecosystems that had evolved and developed in seven stages by a process akin to natural selection. These have been listed as,

1. Rain fed agriculture
2. Seasonal or temporary river diversion and inundation irrigation
3. Permanent river diversion and channel irrigation
4. Development of weirs and spillways on irrigation channel
5. Invention of the sluice (Sorowwa) with its access tower (Biso Kotuwa)
6. Construction of storage reservoirs
7. Damming a perennial river

The first reservoirs were the numerous small tanks in the foothills near fields or terraces to catch the runoff water, which was baled out as needed. Then a number of small dams and bunds were built, often in a series on the upper reaches of tributaries of the greater rivers, thus retaining annual or inundator flow and

discharge as desired through small canals along the valley sides. Building and maintenance of village tanks had been a collective effort undertaken by the entire community of the particular village and was done on the basis of village planning. These tanks were well established in the dry zone of Sri Lanka during the first century BC, and formed the basis of the well-known tank-civilization of Sri Lanka (Wijesuriya, 2005). Even today, most of the small villages in the dry zone are identified with the reservoir, which is maintained mainly by the village community.

Technological advances

The high variation of water resources with time and space has subsequently necessitated building of larger diversion structures and reservoirs for water impoundment and storage. The reservoir called "Panda Wewa" built in 450 BC in the north-western province of Sri Lanka could possibly be the first ever reservoir with an embankment, built using the principles of reservoir construction (Parker 1909). Sri Lankan engineers had also invented the sluice about 2100 years ago with a mechanism to dissipate hydraulic energy and control water flow, and this invention had enabled them to build very large reservoirs (Brohier, 1934). While there were major reservoirs associated with the large cities, there were small reservoirs or "village tanks" built for each village settlement.

Since European colonization

Sri Lanka was colonized by European powers in the 16th Century. The first to arrive were the Portuguese in 1500 AD, who ruled the southern, western and northern coastal areas of the country for about 150 years. They were mainly interested in commercial and missionary activities and historical records do not show any significant water resources developments. In 1658, the Dutch wrested the power in the coastal areas from Portuguese. During their period there was a considerable technology transfer in the form of drainage of coastal low-lying areas. They built several canals for drainage and transport, which exist even at the present time (Perera, 1955).

The British took over the control of maritime Sri Lanka in 1796 and annexed the remaining territories ruled by Sri Lankan Kings in 1815 (Perera, 1955). Their rule had mixed impacts on water resources. The clearing of upper watershed areas for plantation agriculture such as tea and coffee resulted in considerable negative implications on the water sources. Similarly, the introduction of administrative reforms without due regard to the traditional, self-sustaining governance system had disastrous effects on the agriculture-based and water-dependent rural livelihoods, and gave rise to unrest and rebellion (Perera, 1955). However since 1855, the British Governors showed significant interest in the restoration of ancient irrigation works.

The first restoration works had included the village tanks in the Uva and Matale areas and major irrigation works in the South and Eastern parts of the country. The Irrigation Department established in 1900 carried out infrastructure development including reservoir construction, diversion structures, flood protection and salt-water exclusion structures. The Iranamadu reservoir constructed from 1902 -1922 is recorded as the first new construction by the Irrigation Department. Major irrigation works including irrigation facilities in Kirindi Oya basin, Minipe Anicut in Mahaweli Basin, and Giritale and Minneriya resevoirs in the North Central Province were also restored by the Irrigation Department during this era that followed. However the records indicate that the resettlement of peasants in irrigation settlements had been implemented much later. Apart from the irrigation facilities, the water resources development in the early parts of the 20th century comprised flood control works and drainage control structures for the low-lying coastal areas (Arumugam, 1969).

Sri Lanka gained independence from the British in 1948. During the period of 1948-2000, the Irrigation Department contributed heavily to the development of irrigation infrastructure. The Senanayake Samudra reservoir built in 1949-52 remains the largest reservoir in Sri Lanka (950 MCM). These developments resulted in substantial benefits outside agriculture, such as flood control, hydropower generation and domestic water supply.

The Mahaweli Development Project, which was completed in the mid 1980's, is the largest water resources development project undertaken by Sri Lanka. The Project resulted in harnessing the water resources of Mahaweli Ganga, a main tributary-Amban Ganga and the adjacent Maduru Oya. The benefits extended to adjacent Malwatu Oya, Yan Oya and Kala Oya basins. The land area contained under these river basins is about 30% of the total land area of Sri Lanka. The project resulted in increasing the water storing reservoir capacity of the country by 2760 MCM, the hydropower generating capacity by 660 MW along with a substantial increase of drinking water availability. Other benefits of the Mahaweli project include flood and drought mitigation (Seneviratne & Handagama, 2005, Wijesuriya, 2005).

However, the water resources development programs in the recent past have raised several environmental and social concerns.Recently

formulated projects have run into snags and undue delays due to such problems as well as heavy construction cost. The development concepts adopted in the recent projects such as Mau Ara-Malala Ara Diversion Project and Weli Oya Project could be a solution to this situation. A special feature of these projects is to make the optimum use of the existent village tank systems for storage, thus obviating the need for large-scale reservoirs and accompanied displacement of the people.

Chapter 02

Water Resources of Sri Lanka

Throughout the history of Sri Lanka water has played a key role in development of the country, economic status of its people and also in shaping the culture and traditions. This chapter discusses the major characteristics of the resource and the parameters that influence its behavior, and makes a brief historical sketch of the development of water resources.

Climate

Sri Lanka is located close to the equator and endowed with a tropical climate. The temperatures, humidity, evaporation and rainfall are the major parameters that define the climate. Soil types, geology and topography, which were described earlier, combine with the climate to characterize the occurrence of surface and groundwater resources.

Temperature

The monthly average temperature together with the mean diurnal range in respect of selected stations with a general coverage of the entire country is given in Table 8. This clearly indicates an evenly balanced temperature throughout the year, without any significant differences of temperature from month to month in temporal terms. The annual temperature range (which is defined as the difference between the average temperatures of the warmest and coldest month) provides further proof of the even behaviour of temperature throughout the year. The annual range of temperature varies from a maximum of 4.6^{O}C at Vavuniya to a minimum of 1.4^{O}C at Ratnapura. The coldest month with respect of mean monthly temperature is generally January and the warmest months are April and May. In the lowland Sri Lanka, the mean minimum temperature does not generally fall below 21^{O}C in any month of the year. However, it decreases markedly in the highlands with increasing altitude. At Nuwara Eliya, the mean minimum temperature in January, February and March are 9.4, 9.5 and 10.2^{O}C respectively *(*Jayatillake *et al*, 2005*)*.

The Figures 7and 8 illustrate the behaviour of maximum and minimum temperature at selected stations. The annual average maximum temperature and minimum temperature has a significant spatial variation. On average the annual maximum temperature in the studied stations vary between 26 and 36 degrees Celsius. The annual average minimum temperature at the same locations varies between 14 and 28 C°. Monthly temperatures both maximum and minimum do not show a great variation with time though the month of August has a peak in most of the stations. In some stations the month of April shows a peak.

Table 8. Monthly average air temperature (^oC) and diurnal range of selected locations

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Anuradapura	25.3 (8.7)	26.5 (10.4)	28.3 (10.9)	29.2 (10.2)	28.8 (8.1)	28.8 (7.8)	28.8 (8.5)	28.8 (8.8)	28.6 (9.0)	27.7 (8.7)	26.4 (7.8)	25.5 (7.2)	27.7 (8.8)
Badulla	21.3 (7.5)	21.9 (9.7)	23.4 (10.8)	24.6 (10.6)	25 (11.0)	24.8 (11.9)	24.6 (12.1)	24.5 (12.0)	24.2 (11.7)	23.8 (10.2)	22.8 (8.1)	22 (6.9)	23.6 (10.2)
Batticaloa	25.5 (4.6)	26 (5.2)	27.2 (5.7)	28.5 (6.3)	29.4 (7.3)	29.8 (8.4)	29.4 (8.1)	29.1 (8.0)	28.5 (7.4)	27.6 (6.6)	26.5 (5.5)	25.8 (4.6)	27.8 (6.5)
Colombo	26.6 (8.6)	26.9 (8.6)	27.7 (8.0)	28.2 (7.2)	28.3 (5.6)	28 (4.9)	27.6 (4.8)	27.5 (4.9)	27.5 (5.4)	27 (6.0)	26.7 (6.9)	26.6 (7.5)	27.4 (6.5)
Galle	25.9 (6.2)	26.5 (6.9)	27.3 (6.7)	27.7 (5.8)	27.6 (4.3)	27.1 (3.8)	26.7 (3.8)	26.5 (3.7)	26.6 (3.8)	26.4 (4.6)	26.3 (5.5)	26.1 (6.0)	26.7 (5.1)
Hambantota	26.3 (7.0)	26.6 (7.2)	27.4 (7.0)	28.1 (6.2)	28.1 (5.2)	27.8 (5.1)	27.7 (5.9)	27.3 (5.5)	27.2 (5.4)	27.1 (5.8)	26.7 (6.2)	26.4 (6.3)	27.2 (6.1)
Kandy	23.3 (9.9)	24.2 (11.4)	25.6 (11.7)	26.1 (10.1)	25.6 (8.3)	24.8 (6.8)	24.5 (6.7)	24.4 (7.2)	24.3 (8.1)	24.4 (8.4)	24.2 (8.4)	23.7 (8.3)	24.6 (8.8)
Kankesanturai	25.8 (5.5)	26.2 (7.3)	27.6 (8.4)	29.5 (7.8)	30.1 (6.4)	29.8 (5.8)	29.4 (6.4)	29.1 (6.5)	28.9 (6.4)	27.8 (6.1)	26.6 (5.4)	26 (4.7)	28.1 (6.4)
Kurunegala	25.8 (10.1)	27 (12.2)	28.4 (12.0)	28.6 (9.9)	28.3 (7.9)	27.6 (6.7)	27.4 (6.9)	27.4 (7.2)	27.4 (7.9)	27 (8.4)	26.5 (8.8)	25.9 (8.4)	27.3 (8.9)
Mannar	26.3 (5.3)	26.9 (6.8)	28.1 (7.5)	29.2 (6.9)	29.6 (5.0)	29.2 (3.8)	28.6 (4.2)	28.4 (4.3)	28.5 (4.6)	27.8 (5.4)	27.1 (5.0)	26.4 (4.5)	28 (5.2)
Nuwara Eliya	14.7 (10.6)	15.3 (11.6)	16.3 (8.3)	17.1 (11.4)	17.1 (8.6)	16.1 (5.7)	15.7 (5.7)	15.7 (6.0)	15.7 (6.9)	15.8 (8.0)	15.6 (8.2)	15.2 (8.4)	15.9 (8.7)
Puttalam	25.7 (9.5)	26.7 (10.6)	28.1 (10.1)	28.7 (8.5)	29 (6.5)	28.8 (5.3)	28.5 (5.8)	28.5 (6.0)	28.5 (6.3)	27.6 (5.9)	26.6 (7.5)	25.9 (7.8)	27.7 (7.6)
Ratnapura	27.2 (9.0)	27.8 (12.0)	28.3 (11.4)	28.5 (10.1)	27.9 (8.1)	27.3 (7.3)	27.1 (7.2)	27.1 (7.3)	27 (7.8)	27.1 (8.4)	27.1 (9.1)	27.1 (9.5)	27.5 (9.1)
Vavuniya	24.6 (9.2)	25.7 (10.8)	27.8 (11.9)	29.1 (10.7)	29 (9.1)	29.2 (9.0)	29.1 (9.7)	29 (9.8)	28.7 (9.8)	27.5 (8.9)	26.1 (8.0)	25.1 (7.4)	27.6 (9.5)

Source: Meteorology Department, cited in Jayatillake et al, 2005
Note: mean diurnal range given within brackets, units-degrees centigrade

Humidity

The humidity values for 2002 pertaining to several stations are given in Table 9, and Figures 9 and 10 thereby demonstrating the monthly average daytime and night time humidity, variation through the year and in spatial variation.

Table 9 Humidity at selected stations

Day and Night Relative Humidity	Colombo		Trincomalee		Hambantota		Ratnapura		Anuradhapura		Nuwara Eliya	
	D	N	D	N	D	N	D	N	D	N	D	N
Mean	75	88	69	83	74	86	77	95	70	91	79	89
January	69	87	79	86	70	83	74	95	75	94	76	80
February	69	86	74	81	69	83	69	93	72	94	74	83
March	70	88	71	84	70	83	71	96	64	93	62	76
April	74	93	72	87	75	87	81	98	73	95	78	93
May	79	88	64	82	80	89	82	96	71	91	82	91
June	77	86	60	79	71	87	77	90	65	87	81	91
July	77	86	53	76	72	86	79	90	63	85	86	93
August	76	85	57	77	76	87	76	92	61	85	85	93
September	73	84	57	77	75	85	70	94	56	87	77	89
October	79	93	75	90	75	85	82	97	75	93	84	94
November	79	94	83	92	78	89	82	98	79	95	82	93
December	75	91	84	88	78	88	81	97	81	95	84	90

Source: DCS, 2003a

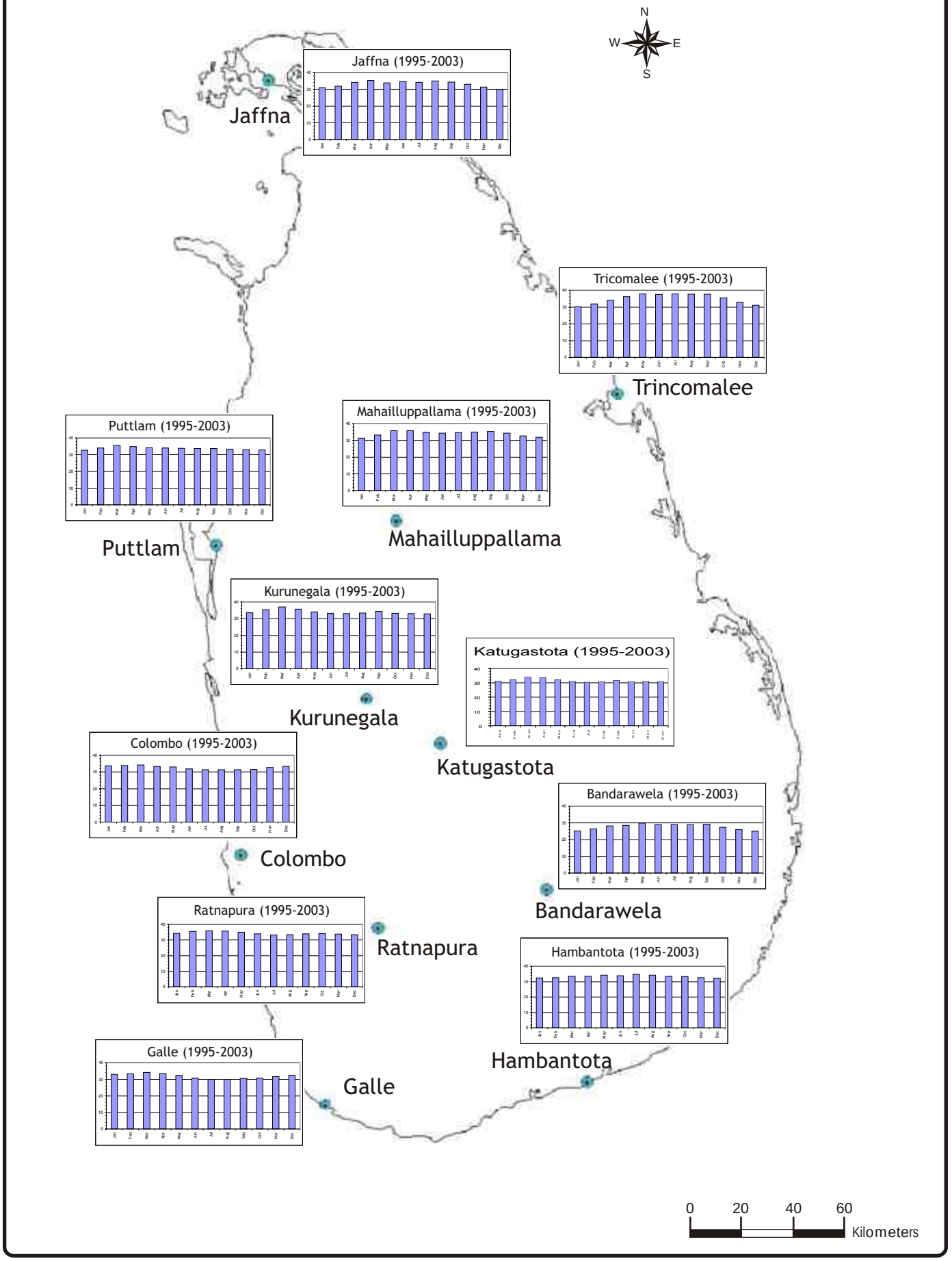


Figure 7. Monthly average maximum temperature

Prepared by N.T.S. Wijesekera (Department of Meteorology base data)

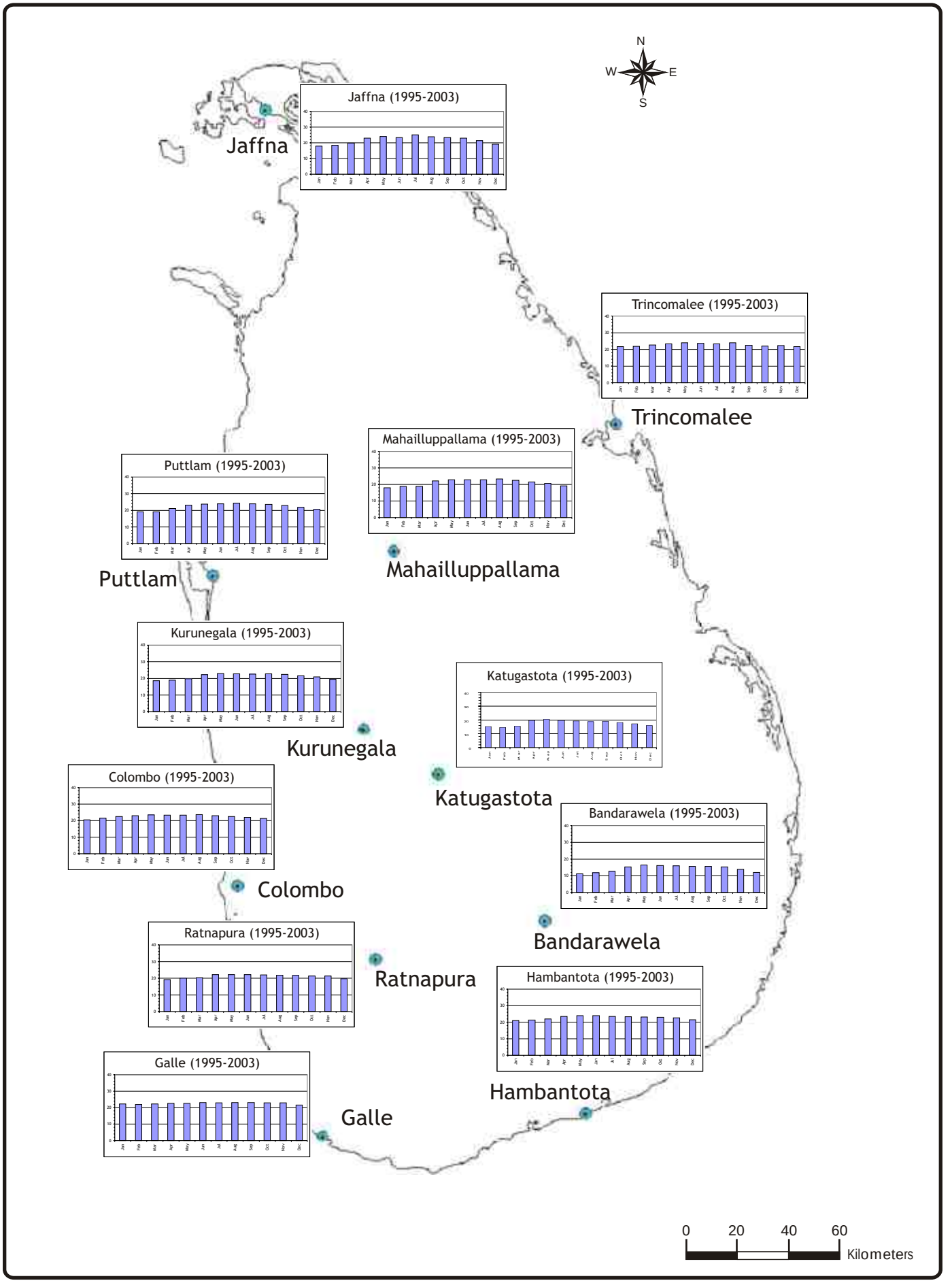


Figure 8. Monthly average minimum temperature

Prepared by N.T.S. Wijesekera (Department of Meteorology base data)

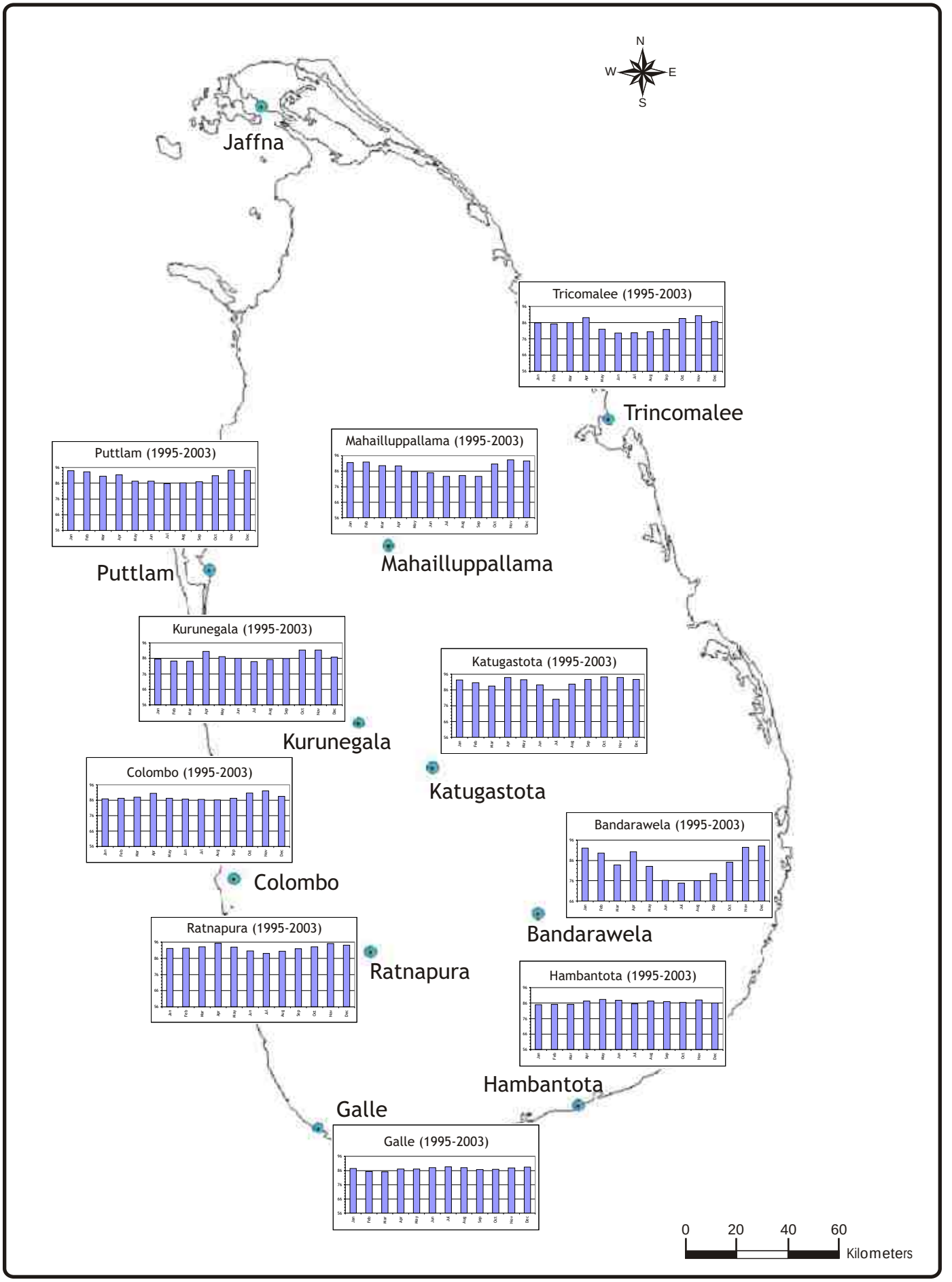


Figure 9. Monthly average night time relative humidity

Prepared by N.T.S. Wijesekera (Department of Meteorology base data)

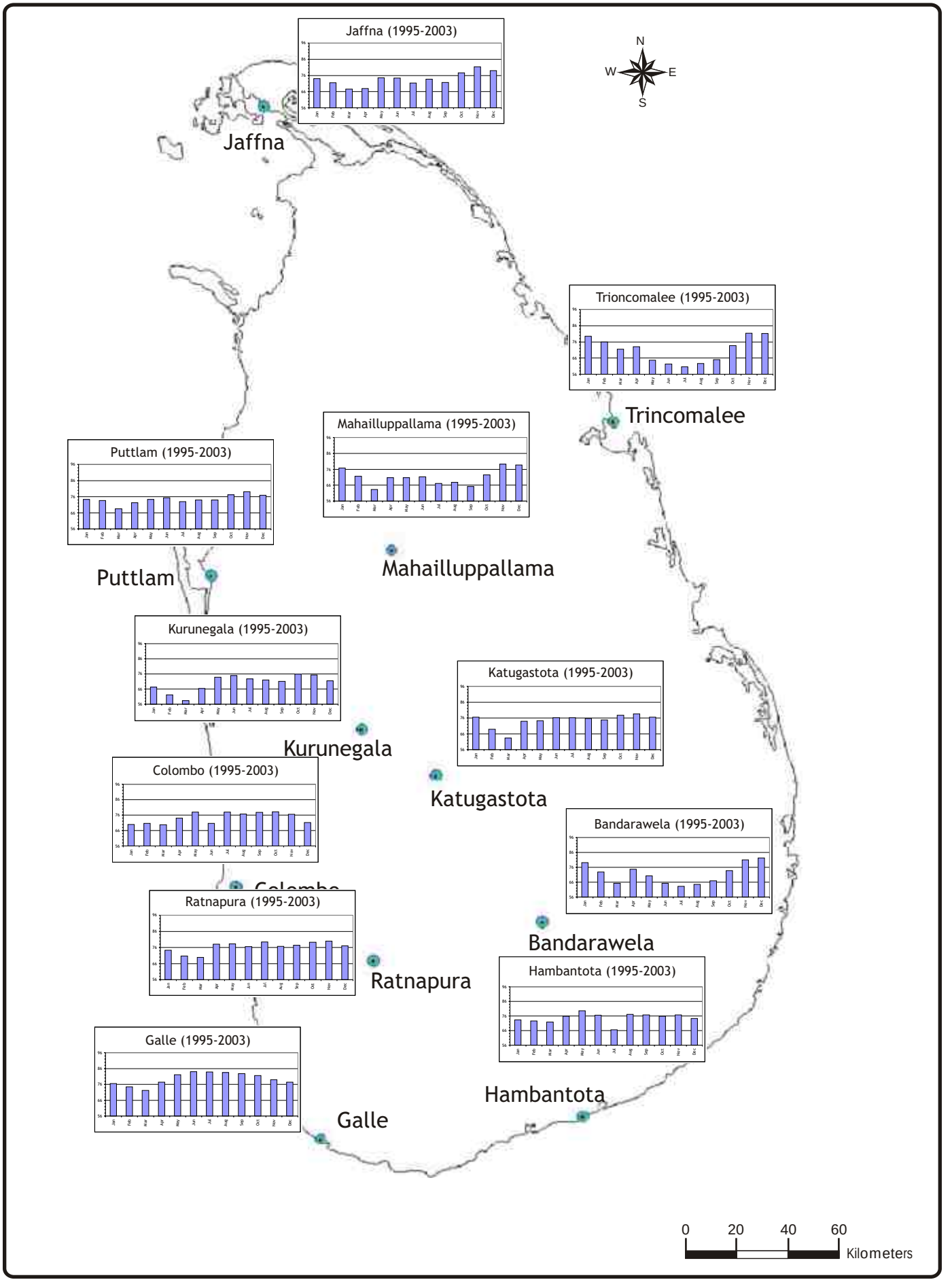


Figure 10. Monthly average day time relative humidity

Prepared by N.T.S. Wijesekera (Department of Meteorology base data)

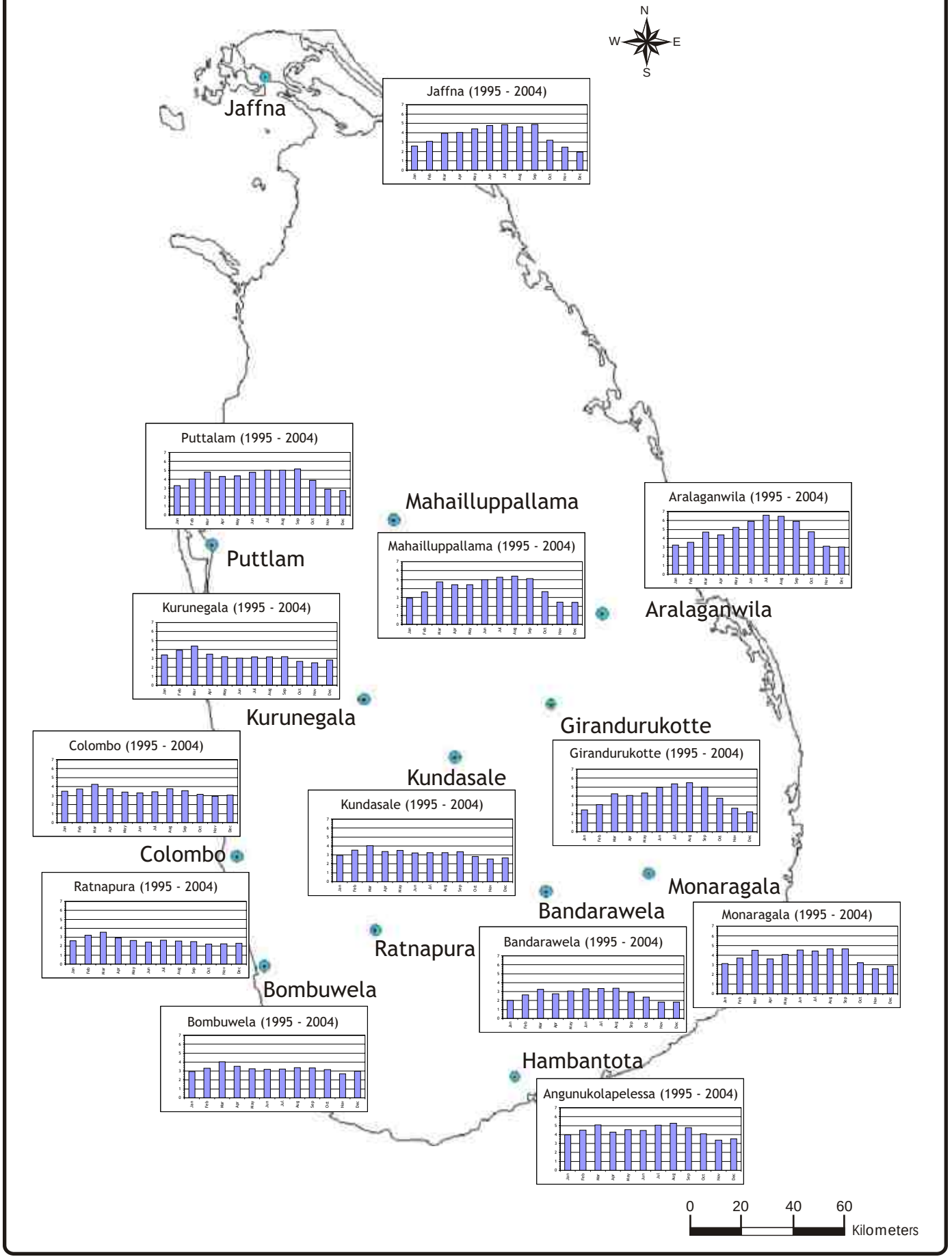


Figure 11. Average monthly pan evaporation (mm/day)

Prepared by N.T.S. Wijesekera (Department of Meteorology base data)

Nighttime relative humidity shows significantly higher values when compared with the daytime values. The average annual nighttime relative humidity in the country varies between 74% and 95%, while the daytime variation is between 53% and 86%. The annual values of several studied stations show significant variation of night and daytime values between years, while the monthly values of both day and night time relative humidity show a two peak fluctuation pattern. The minimum humidity values are usually between March and April, or during July each year with a pattern that has a significant spatial variation.

Evaporation

The annual pan evaporation values within Sri Lanka indicate that there is a significant spatial variation, and the values vary between 1900 and 795 mm per year. There is a significant year-to-year variation of the annual pan evaporation values at a given station. Between 1995 and 2004 the difference between maximum and minimum annual values has ranged from about 85 mm/year at Bombuwela to 367 and 366 mm/year at Jaffna and Ratnapura respectively. The monthly average variation over a year also shows a wide spatial variation ranging from 2.72 to 4.75 mm per day at Bandarawela and Aralaganwila respectively.

The two peak spatial variation of monthly values show that there is a clustered similarity in the fluctuation pattern within an average year. The stations in Jaffna, Mahailluppallama, Puttalam, Girandurukotte and Aralaganwila show a similarity with a larger peak in the July-August period. Kurunegala, Colombo, Bombuwela, Ratnapura and Kundasale however, show a larger peak during the month of March. Moneragala, Bandarawela, and Angunukolapellessa show similar two peaks in March and August. The temporal and spatial variation of pan evaporation values is shown in Figure 11.

Average annual reference crop evapotranspiration at several stations in the country indicates that the values vary between 2.4 mm/day and 5.2 mm/day (ID, 1999).

The temporal and spatial variation of pan evaporation values are further illustrated in Figure 11.

Climatic variation and long term projections

Temperature changes An analysis of temperature records for a period of over 100 years show an increase in air temperature in all the meteorological observation stations during the period from 1961 to 1990 (Fernando and Chandrapala, 1992). The rate of increase of mean air temperature in Sri Lanka during this period is of the order of 0.016 ^{O}C per annum (Chandrapala, 1996) or 1.6^{O}C per 100 years, which is much above the global average. The variation of mean annual air temperature of Sri Lanka since 1930, in terms of the variation from the 1961-1990 baseline-mean given in Figure 12, reflects a constant warming trend during the recent few decades.

Although it is difficult to interpret directly the recent temperature rises in Sri Lanka in terms of their causes and effects, it is likely that some of these changes that have taken place in Sri Lanka are integral impacts of global scale climate change. Local effects such as deforestation, urbanization and changes in land use patterns too may have contributed to the temperature rises observed in Sri Lanka, in addition to the effects of global scale phenomena (Jayatillake et al, 2005).

Rainfall fluctuations The graphical illustration of the rainfall fluctuations during the period since 1880 till 2003, in terms of the departure from the 30-year average of Sri Lanka's mean annual rainfall is in Figure 13. One of the distinct characteristics of rainfall in Sri Lanka is its high annual variability. Alternating

Table 10 Reference crop evapotranspiration at selected stations

	Reference Crop Evapotranspiration (Penman for 1999) in mm/day											
	January	February	March	April	May	June	July	August	September	October	November	December
Lunugamvehera	3.3	3.6	4.2	4.1	4	3.9	4.3	4.2	4	3.7	3	2.8
Padiyatalawa	2.9	3.3	3.7	3.8	3.8	3.6	3.9	4.2	3.9	3.5	2.8	2.43
Pollonnaruwa	3	3.7	4.5	4.5	4.6	4.4	4.5	4.6	4.8	3.9	3.1	2.9
Udawalawe	3.2	3.8	4.3	4.2	4.3	4.7	5.6	5.2	4.7	3.5	3.4	3.5
Mean	3.1	3.6	4.2	4.2	4.2	4.2	4.6	4.6	4.4	3.7	3.1	2.9

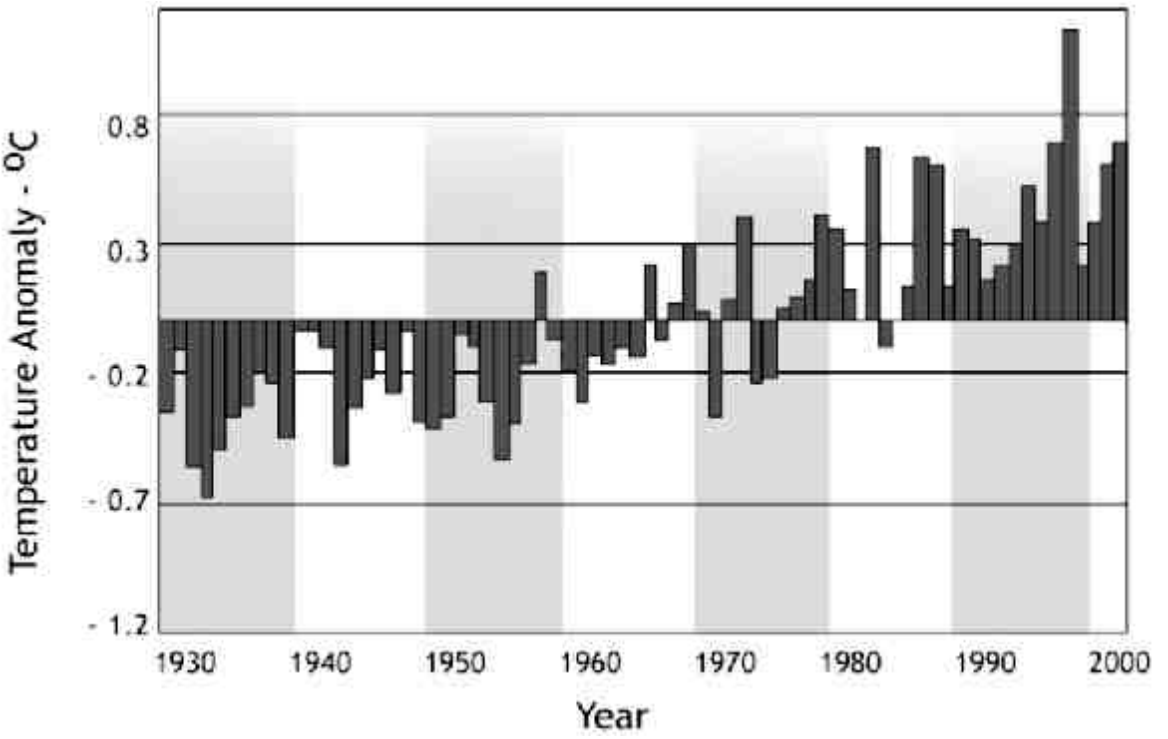


Figure 12. Deviation of Sri Lanka's mean annual air temperature from mean of 1961- 90

Source: Jayatilleke et al (2005)

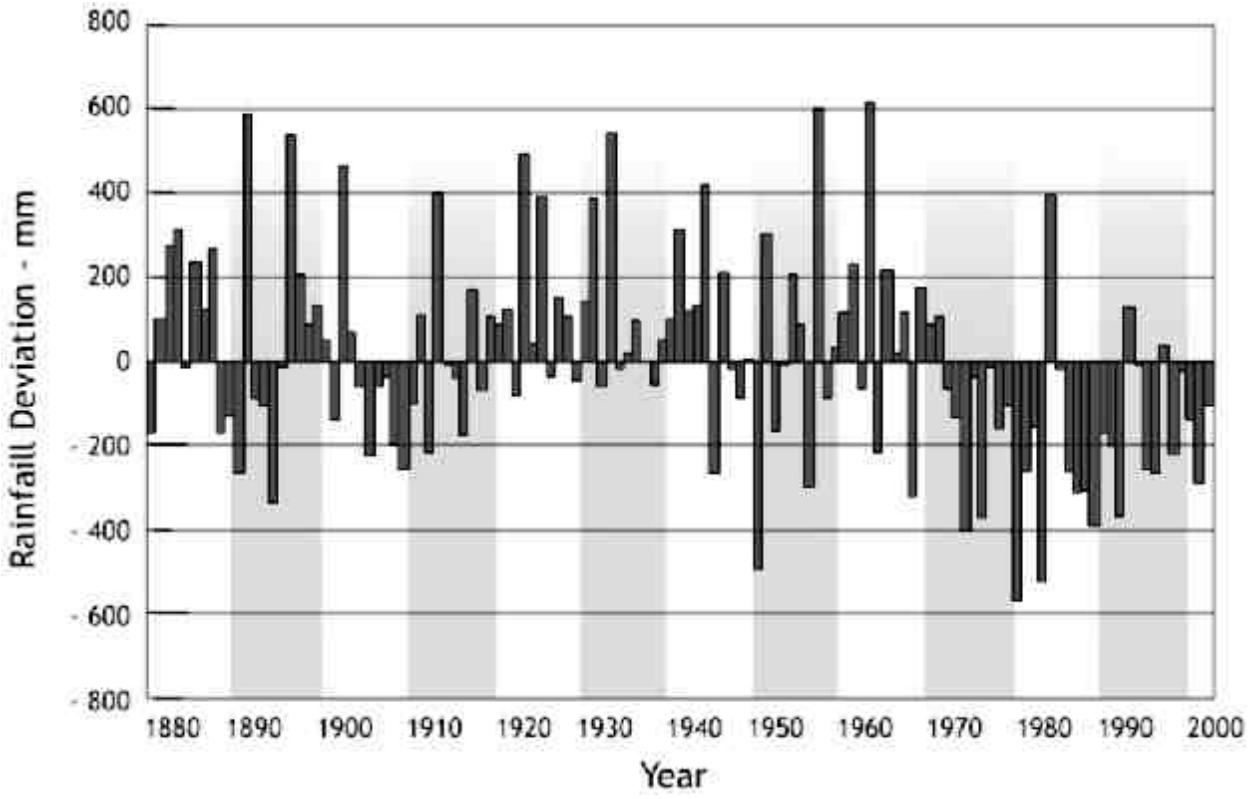


Figure 13. Deviation of Sri Lanka's Average Annual Rainfall from Mean of 1961-90

Source: Jayatilleke et al (2005)

dry and wet periods are noticed from 1880 until about 1970 with a significant reduction of rain thereafter. During this 30-year period, the average annual rainfall has fallen below the mean of 1961-1990 (with the exception of three years).

However comparison of the annual averages alone would not reveal the cause for the decline as rainfall mechanisms and patterns differ during the various rainfall seasons. A comparison of changes and variability in terms of the different rainfall seasons would provide a better understanding of the nature and magnitude of changes that have taken place (Jayatillake *et al*, 2005), and is analysed further in Chapter 9.

Studies done with rainfall data of Colombo and sea levels at Colombo Harbour for a 50-year period have indicated a significant downward trend in the rainfall and an increased trend in the sea level (Dharmasena and Premasiri, 1998).

A study of observed rainfall and stream-flow time series of the Gin Ganga catchment in the Southern Province of Sri Lanka since 1927 has shown a downward trend of 183mm during 68 years in the annual rainfall series, and an increase of 3.01% in the runoff rainfall ratio during the same period (Dharmasena and Premasiri, 1998).

The rainfall depth duration frequency studies for Sri Lanka that enable the identification of return period rainfall developed by Baghirathan and Shaw in 1977 were updated with recent data, and rainfall depth duration actually measured for shorter intervals less than 3 hours, and longer intervals more than 24 hours. The stations selected for analysis are shown in Table 11 (Dharmasena and Premasiri,1990).

Table 11 Rainfall intensity study stations and data durations

Rainfall Station	Duration of Records	Elevation (meters MSL)
Anuradhapura	1965 - 1987	95.0
Kurunegala	1961 - 1987	150.0
Nuwara Eliya	1957 - 1982	1917.0
Baticaloa	1963 - 1987	2.0
Hambantota	1963 - 1987	5.0
Kankasanturai	1957 - 1982	5.0
Katugastota	1966 - 1982	486.0
Colombo	1960 - 1985	2.0
Puttalam	1950 - 1982	2.0
Galle	1962 - 1983	2.0

Source : Dharmasena and Premasiri (1990

Global climactic phenomena: Impacts on Sri Lanka

The El Niño Southern Oscillation (ENSO) Phenomenon is a primary reason for climate anomalies that last a season or more in many parts of the world. The weakening and even reversal of the normal pattern of rising air over Asia and sinking air over the eastern Pacific during an El Niño event alters the circulation of neighbouring tropical regions, especially in areas across the Indian Ocean to Africa and over South America to the Atlantic Ocean. The shift in tropical convection, and thereby the dominant heating locations of the atmosphere triggers long waves or pulses in the middle and high latitude westerly winds. These large scale waves or pulses in the atmosphere change the locations of the jet streams and middle latitude storm tracks, altering weather patterns.

Weather over Sri Lanka too shows a high correlation with ENSO. During El Niño events it is very common for Sri Lanka to receive excess rainfall during the October-November period, followed by a long dry spell (Jayatillake *et al*, 2005).

Atmospheric brown cloud The discovery during the INDOEX experiment conducted in the Indian Ocean during the period 1996-1999, of the so-called South Asian Haze amply demonstrated the magnitude of the aerosol pollution faced by the countries in the South, South-East and East Asia. At present, biomass burning and fossil fuel burning are considered to be the major sources of this pollution cloud.

It has been identified that the most direct effect of haze is a significant reduction in the solar radiation reaching the surface rsulting in a 50 to 100% increase in solar heating of the lower atmosphere. Possible direct effects also include a reduction in the precipitation efficiency by inhibiting the formation of larger raindrop size particles; diminished agricultural productivity due to reduction of available sunlight for photosynthesis, and adverse health effects. Indirect effects of haze include cooling of the land surface; increase in the frequency and strength of the thermal inversion that can trap more pollution; perturbation of the winter time rainfall patterns; and an overall reduction in the average tropical (20^0N to 20^0S) evaporation and precipitation. The impact of these pollution particles on the hydrological cycle of the tropics and the sub tropics has implications related to water availability and quality, which are major environmental concerns of Sri Lanka for the 21st century (Jayatillake *et al*, 2005).

Rainfall

Table 12. Average annual rainfall and equivalent water volumes for each district

District	Annual Rainfall (mm)	Equivalent Water Volume (bcm)
Ampara	1601	6.9
Anuradhapura	1368	9.6
Badulla	2060	5.8
Batticaloa	1643	4.4
Colombo	3254	2.1
Galle	3371	5.5
Gampaha	2575	3.6
Hambantota	1131	2.9
Jaffna	1238	1.2
Kalutara	3980	6.3
Kandy	2375	4.5
Kegalle	3612	6.1
Kilinochchi	1285	1.6
Kurunegala	1701	8.2
Mannar	1140	2.3
Matale	1942	3.9
Matara	2540	3.3
Moneragala	1607	8.9
Mullaitivu	1364	2.7
Nuwara Eliya	2638	4.5
Polonnaruwa	1693	5.5
Puttalam	1251	3.8
Ratnapura	2982	9.7
Trincomalee	1587	4.2
Vavuniya	1407	3.5
Sri Lanka	**1861**	**120.0**

(Source: Jayatillake et al, 2005)

Variability of rainfall

Rainfall in Sri Lanka has multiple origins of monsoons, convections and depressions, which contribute a major share of the annual rainfall. The mean annual rainfall is 1861 mm, which is approximately equivalent to a rainfall volume of 120 bcm (billion cubic meters) of rainwater over the land area of Sri Lanka (Table 12). The rainfall ranges from under 1000 mm in the driest parts to over 5000 mm in the wettest parts of the country, and the spatial distribution of annual rainfall in Sri Lanka are depicted in Figure 15 (Jayatillake *et al* 2005).

Seasonal distribution of rainfall

While the rainfall during the two monsoons depends on the wind direction associated with the movement of the Inter Tropical Convergence Zone (ITCZ), the predominant feature during the two inter-monsoonal or the transitional seasons of March - April and October - November, is the convectional thunder activity. These thunderstorms usually develop inland around mid-day, and gradually spread towards the coastal regions during the afternoon and evening. During the October-November inter-monsoonal period, cyclones and depressions which form in the South Bay of Bengal and the South Arabian Sea, affects the weather over Sri Lanka. While the low-pressure systems associated with cyclonic activity remain in the immediate vicinity of the island, heavy rain accompanied by strong winds are experienced over most parts of the island. The contributions made during each of these seasons to the island's annual rainfall for the reference period 1961-90 are given in Table 13.

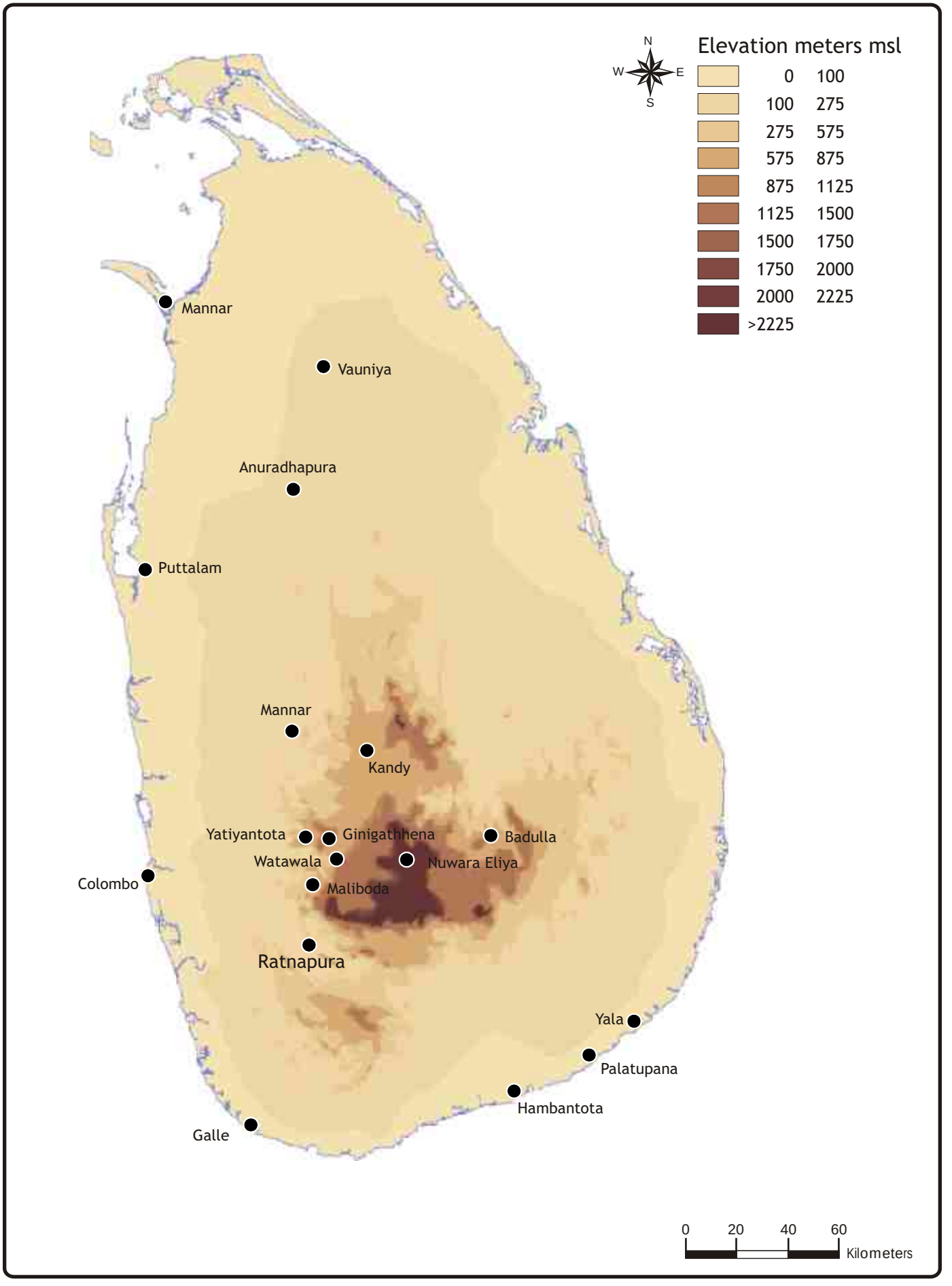


Figure 14. Rainfall stations referred to in the text

Prepared by N.T.S. Wijesekera (Jayatillake et al, 2005 base data)

The contribution of rainfall to the mean annual rainfall over the country from the two monsoon periods is approximately 55 % and that from the two inter-monsoon periods is approximately 45%.

The south-western sector of Sri Lanka and the central highlands stands out clearly as the wettest part of the island. A small spatial extent that receives the highest annual rainfall (Maliboda - 5330 mm,

Table 13. Average rainfall during different rainfall seasons for 1961-90

Rainfall Season	Period	Average Rainfall (mm)	% of Annual Total
First Inter-Monsoon	March - April	268	14
South - West Monsoon	May - September	556	30
Second Inter-Monsoon	October - November	558	30
North -East Monsoon	December - February	479	26
Annual	**January - December**	**1861**	**100**

The first inter-monsoon is concentrated on the south-west slopes of the country, while the second inter-monsoon impacts the north and north-west. The south-west monsoon concentrates on western and south-western parts while north-east monsoon falls mainly on the north, north central and eastern parts (Figure 16 and Table 13). The second inter-monsoon period of October November is the wettest of the four seasons throughout the entire island.

Spatial distribution of rainfall

The rainfall pattern has divided the country into two main climatic regions: wet zone which receives an annual average rainfall of about 2,400 mm and the dry zone where the annual average rainfall is about 1450 mm (Arumugam, 1969). Manchanayake and Madduma Bandara (1999) define the dry zone as an area where the average annual rainfall is less than average annual potential evapo-transpiration. These two zones are generally demarcated at the 2000 mm annual average rainfall isohyet. The dry zone is further divided into an intermediate zone. This demarcation can be observed in Figure 16 depicting the agro-ecological regions. Approximately 20% of the country is thus in the wet zone.

Yatiyantota - 5259 mm, Ginigathena - 5086 mm, Watawala - 5024 mm) is situated in the western slopes of the highlands, below the altitude of 1000 meters. From this area, rainfall decreases very rapidly in the direction of higher elevations, with Nuwara Eliya having an elevation of 1800 meters registering an annual rainfall of only 1905 mm. The decrease of rainfall is less rapid towards the south-western coastal plains. On the eastern slopes, the rainfall decreases to even less than 2000 millimeters in the Uva Basin (Badulla - 1761.6 mm). Restricted areas on the eastern flanks of the Knuckles-Rangala range of hills receive rainfall in excess of 3000 mm per year. In a major part, the annual average rainfall is between 1250 - 2000 millimeters. Notable exceptions are the south-eastern and north-western coastal areas, which are the driest parts of the island with annual rainfall under 1000 millimeters (Yala - 927.0 mm, Palatupana - 970.0 mm, Mannar - 963.4 mm) (Jayatillake et al, 2005).

The spatial distribution of rainfall in Sri Lanka during different rainfall seasons shows a wide variation (Figure 16). The south-western sector receives more rain during the south-west monsoon while the north-east monsoon brings more rain to the northern and eastern sectors. During the inter-monsoonal periods rainfall is experienced over most

Table 14 Rainfall in the two zones of Sri Lanka

Zone	Average Rainfall (mm)	Range of Rainfall values	Area Sq. km
Dry	1450mm	Less than 2000mm	52,385
Wet	2400mm	More than 2000mm	12,205

Source: Manchanayake and Maddumabandara, 1999

parts of the island. However, the quantity of rain received over the northern and eastern parts of the country during the north-east monsoon is less than the amount received over south-west during the south-west monsoon. Therefore a major part of the country is dry relative to the south-western region (Jayatillake et al, 2005).

Agro-ecology

The agro-ecological regions are defined in terms of rainfall regime, elevation, landform, land use and soils. The country is divided into several zones at three stages:

i. wet zone, intermediate zone and dry zone, denoted by W,I and D
ii. low country (below 300 m MSL), mid country (300 to 900 m elevation) and up country (above 900 m MSL) denoted by L, M and U
iii. further division according to rainfall, landform (terrain) and use, and soils (Panabokke, 2002)

The agro-ecological regions are widely used for agricultural and irrigation engineering designs and scheduling (Figure 17).

Surface water

Main tributaries, lakes, reservoirs

The 36 major river basins out of the 103 distinct natural river basins of Sri Lanka have been classified in to three groups as, 1) south-west monsoonal, 2) north-east monsoonal and 3) both monsoonal basins (Arumugam, 1969)

The important rivers in Group 1 are, the Kelani, Kalu, Bentota, Gin, Nilwala Rivers and the Maha Oya and Attanagalu Oya. These wet zone rivers carry about half the annual surface runoff. There are 26 rivers that fall into Group 2, and cover a significant spatial extent of the country. The Group 2 rivers are in a dry/arid area, and irrigation which is a priority in this zone necessitates construction and rehabilitation of irrigation reservoirs. There are two river basins that fall into to the third group receiving rainfall from both monsoons. They are the Mahaweli and the Walawe Rivers. The Deduru Oya though not strictly a bi-monsoonal river, too has been classified under this group.

There are only a few natural lakes of importance. One of these is the Mundal lake in Puttalam district which is a shallow brackish water lagoon separated from the sea by a sandy ridge (CEA/ARCADIS/ EUROCONSULT, 1999). Another is the Bolgoda Lake which is part of the Bolgoda River. It spreads over about 1,500 ha (Arumugam, 1969). The other water bodies include coastal systems comprising estuaries, lagoons and mangrove swamps. The inland systems include rivers, streams and man-made reservoirs. The latter category, mainly constructed for irrigation, extends over 1,700 sq. km (CEA/ARCADIS/EUROCONSULT,1999), and constitutes 59% of the total area under water bodies.

It is estimated that there are about 13,000 man-made reservoirs in the country. Out of these 80 are classified as large dams (SLNCOLD Database, 2005 and Kamaladasa, 2005). There are about 85 major diversion structures in Sri Lanka. In addition, there are about 11,250 small reservoirs (village tanks) and 12,950 small scale diversion weirs (anicuts) which command an agricultural area less than 80 ha (DAS, 2000) These reservoirs provide several services to rural communities such as water for agriculture, drinking, sanitation and livestock. In addition they provide environmental sustainability and ecosystem support.

The Mahaweli Ganga which is the longest river in Sri Lanka with a length of 355 km has a basin area of 10,448 sq km. Next longest is Malwatu Oya (Aruvi Aru) which is 164 km long. The other long rivers are as follows:

Table 15 Lengths of some major rivers

River	Length (km)
Kala Oya	148
Kelani Ganga	145
Yan Oya	142
Deduru Oya	142
Walawe Ganga	138
Maduru Oya	135
Maha Oya	134
Kalu Ganga	129
Kirindi Oya	117
Kumbukkan Oya	116
Menik Oya	114
Gin Ganga	113
Mi Oya	109
Gal Oya	108

Source: http:/www.mysrilanka.com/ travel/lanka/geography/rivers.htm, 2005

The collective length of the 103 rivers is estimated as 4,560 km (UNEP, 2005). Sri Lanka has two cultivation seasons associated with the two major rainy seasons, the south-west monsoon period from May to September and the north-east monsoon period from December to February. These two seasons are called Maha and Yala respectively. The rest of the rainfall comes from inter-monsoonal periods due to convectional and depressional climatic activities. The annual rainfall ranges from 500 mm in driest parts to

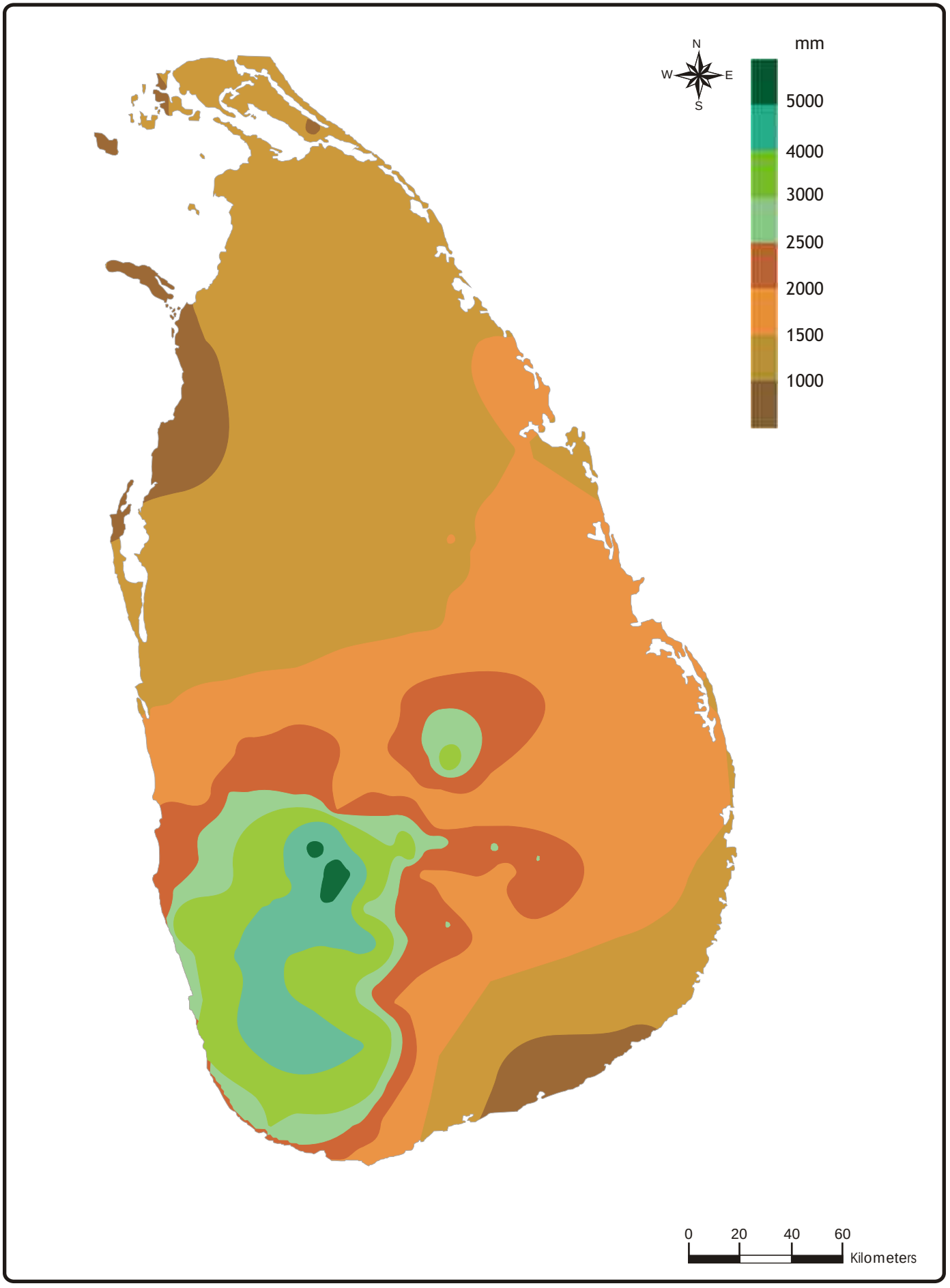


Figure 15. Distribution of mean annual rainfall (1961-90) (mm)
Source: Jayathillake, et al (2005)

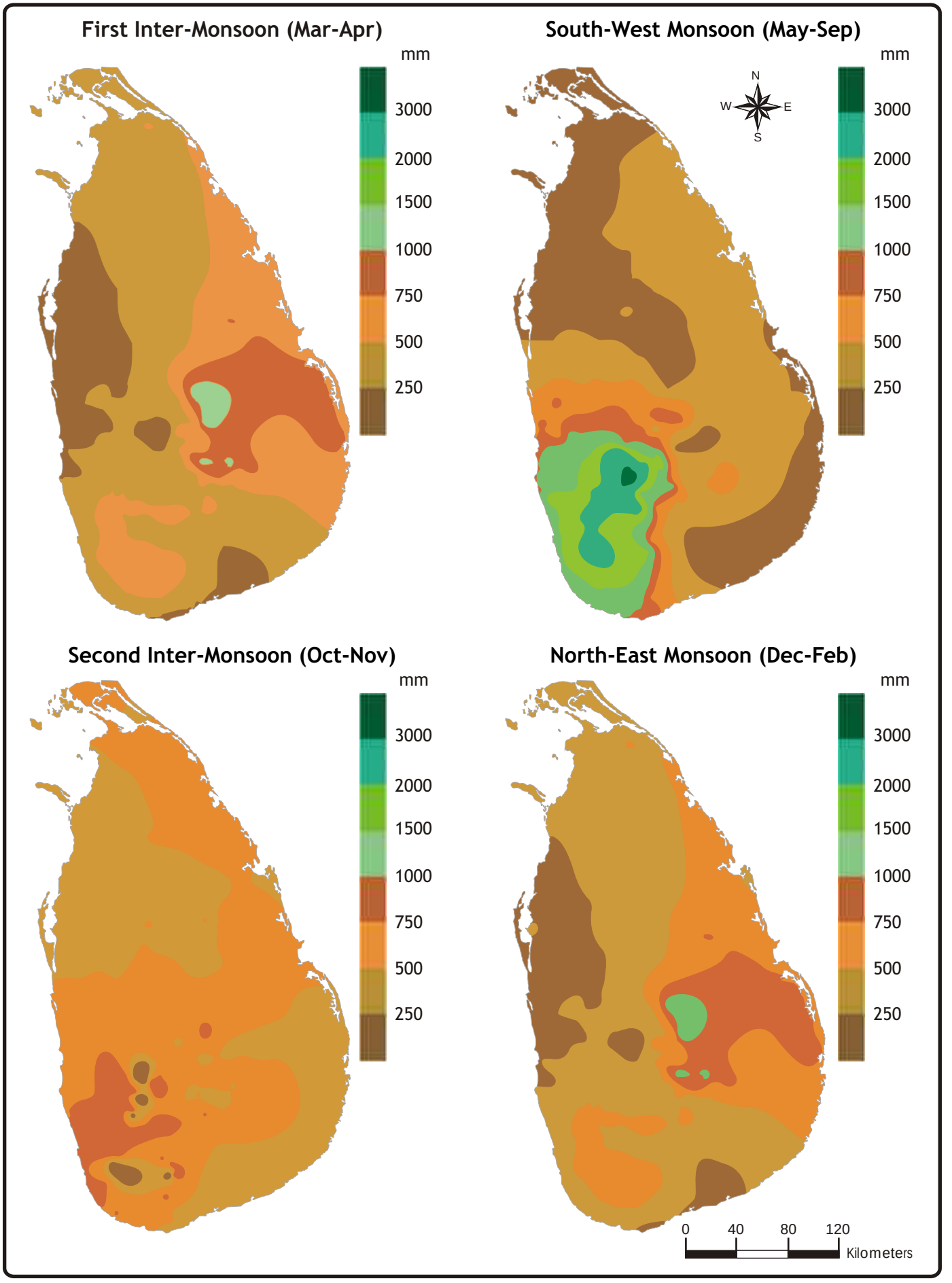
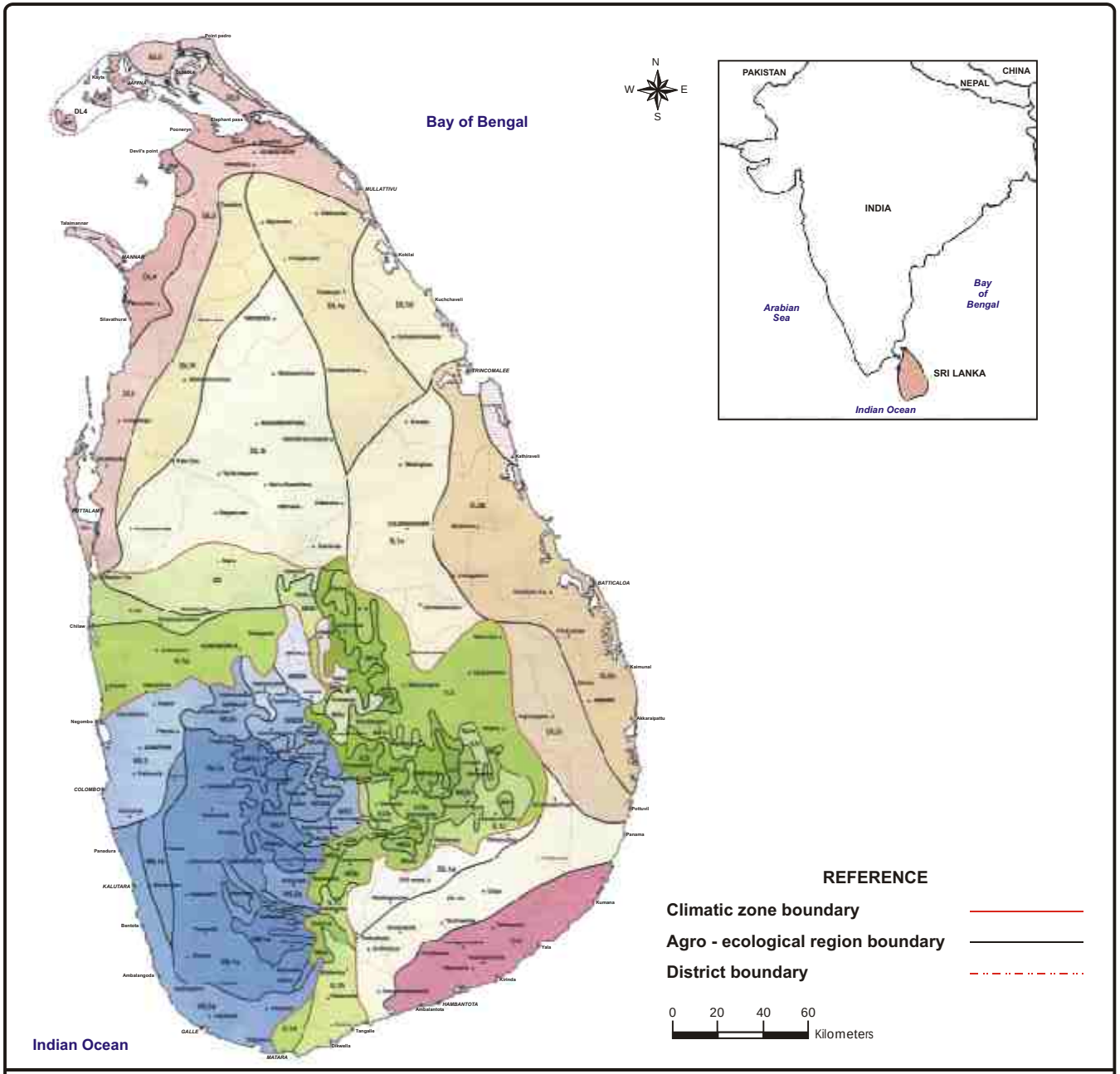


Figure 16. Distribution of seasonal rainfall (mm)
Source: Jayathillake, et al (2005)



Research Team :
Dr.B.V.R.Punyaeardena
Mr.T.M.J.Bandara
Mr.M.A.K.Munasinghe
Mr.Nimal Jayaretna Banda

Advisor :
Vidya Jyothi Dr.C.R.Panabokke

Digital map production :
Mr.S.M.Vipula Pushpakumara

Cartography :
Mr.T.M.K.Wijesinghe

Original Concept (1975) :
Dr.C.R.Panabokke & Dr.(Mrs.) R.P.K.Kannangara

CLIMATIC ZONE	AGRO - ECOLOGICAL REGION		MONTHLY HISTOGRAMS OF 75% RAINFALL PROBABILITY FOR RESPECTIVE REGIONS (mm)	75% EXPECTANCY VALUE OF ANNUAL RAINFALL (mm)
WET ZONE	UP COUNTRY	WU1		> 3,100
		WU2a		> 2,400
		WU2b		> 2,200
		WU3		> 1,800
	MID COUNTRY	WM1a		> 3,300
		WM1b		> 2,900
		WM2a		> 2,200
		WM2b		> 1,800
		WM3a		> 1,600
		WM3b		> 1,400
	LOW COUNTRY	WL1a		> 3,200
		WL1b		> 2,800
		WL2a		> 2,400
		WL2b		> 2,200
		WL3		> 1,700
INTERMEDIATE ZONE	UP COUNTRY	IU1		> 2,400
		IU2		> 2,100
		IU3a		> 1,900
		IU3b		> 1,700
		IU3c		> 1,600
		IU3d		> 1,300
		IU3e		> 1,400
	MID COUNTRY	IM1a		> 2,000
		IM1b		> 2,000
		IM1c		> 1,300
		IM2a		> 1,800
		IM2b		> 1,600
		IM3a		> 1,400
		IM3b		> 1,200
		IM3c		> 1,100
	LOW COUNTRY	IL1a		> 1,400
		IL1b		> 1,100
		IL1c		> 1,300
		IL2		> 1,600
		IL3		> 1,100
DRY ZONE	LOW COUNTRY	DL1a		> 1,100
		DL1b		> 900
		DL1c		> 900
		DL1d		> 900
		DL1e		> 900
		DL1f		> 800
		DL2a		> 1,300
		DL2b		> 1,100
		DL3		> 800
		DL4		> 750
		DL5		> 650

Figure 17. Agro ecological regions of Sri Lanka.
Sources: Department of Agriculture, Dr. B.V.R. Punyawardana

DISTINGUISHING CHARACTERISTICS OF THE AGRO - ECOLOGICAL REGIONS

AGRO-ECOLOGICAL REGION	TERRAIN	MAJOR SOIL GROUPS	LAND USE
WU 1	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Forest plantations, Natural Forest
WU 2a	Steeply dissected, hilly & rolling	Red Yellow Podzolic soils	Tea, Forest plantations
WU 2b	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Forest plantations, Vegetables
WU 3	Hilly & rolling	Red Yellow Podzolic soils with prominent A1 horizon & Red Yellow Podzolic soils with dark B horizon	Tea, Vegetables, Pasture, Home gardens, Forest plantations
WM 1a	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic soils with semi prominent A1 horizon & Lithosol soils	Tea , Natural Forest
WM 1b	Steeply dissected, hilly & rolling	Red Yellow Podzolic soils with semi prominent A1 horizon & Lithosol soils	Tea, Natural Forest, Mixed Home gardens
WM 2a	Steeply dissected, hilly & rolling	Red Yellow Podzolic, Reddish Brown Latosolic & Low Humic Gley soils	Tea, Mixed Home gardens, Export Agricultural Crops, Natural Forest, Paddy
WM 2b	Steep, hilly & rolling	Reddish Brown Latosolic, Immature Brown Loam, Low Humic Gley & Red Yellow Podzolic soils	Mixed Home gardens, Paddy, Export Agricultural Crops, Tea
WM 3a	Steep, hilly & rolling	Reddish Brown Latosolic, Immature Brown Loam, Low Humic Gley & Lithosol soils	Mixed Home gardens, Export Agricultural Crops, Tea, Paddy, Rubber
WM 3b	Hilly, rolling, undulating & steep	Reddish Brown Latosolic, Immature Brown Loam & Low Humic Gley soils	Mixed Home gardens, Export Agricultural Crops, Tea, Vegetables, Paddy
WL 1a	Rolling, undulating & hilly	Red Yellow Podzolic, Red Yellow Podzolic soils with semi prominent A1 horizon & Low Humic Gley soils	Tea, Rubber, Mixed Home gardens, Paddy, Export Agricultural Crops (Cinnamon)
WL 1b	Undulating & rolling	Red Yellow Podzolic soils with soft & hard laterite & Low Humic Gley soils	Rubber, Mixed Home gardens, Paddy
WL 2a	Rolling, undulating & flat	Red Yellow Podzolic, Red Yellow Podzolic soils with strongly mottled sub soil, Low Humic Gley & Bog & Half-Bog soils	Rubber, Tea, Coconut, Mixed Home gardens, Paddy, Export Agricultural Crops (Cinnamon)
WL 2b	Steeply dissected, rolling & undulating	Red Yellow Podzolic, Red Yellow Podzolic soils with strongly mottled sub-soil, Reddish Brown Latosolic & Low Humic Gley soils	Rubber, Coconut, Mixed home gardens, Paddy
WL 3	Rolling & undulating	Red Yellow Podzolic soils with soft and hard laterite, Low Humic Gley & Regosol soils	Coconut, Fruit Crops, Mixed home gardens, Paddy
IU 1	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Export Agricultural Crops (Cardamom), Natural Forest, Forest plantations
IU 2	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Vegetables, Mixed home gardens, Natural forest, Forest plantations
IU 3a	Steeply dissected, hilly & rolling	Red Yellow Podzolic & Mountain Regosol soils	Tea, Forest Plantations
IU 3b	Mountainous, steeply dissected & hilly	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Natural Forest, Forest plantations
IU 3c	Steeply dissected, hilly & rolling	Red Yellow Podzolic & Low Humic Gley soils	Tea, Vegetables, Paddy
IU 3d	Steep, hilly & rolling	Red Yellow Podzolic & Mountain Regosol soils	Tea, Vegetables, Forest Plantations, Natural forest
IU 3e	Steeply dissected, hilly & rolling	Red Yellow Podzolic & Low Humic Gley soils	Tea, Vegetables, Paddy, Mixed home gardens

AGRO-ECOLOGICAL REGION	TERRAIN	MAJOR SOIL GROUPS	LAND USE
IM 1a	Very Steep & hilly	Reddish Brown Latosolic, Red Yellow Podzolic, Immature Brown Loam, Low Humic Gley & Lithosol soils	Tea, Vegetables, Mixed home gardens, Paddy, Forest Plantations
IM 1b	Hilly, rolling & undulating	Reddish Brown Earth, Reddish Brown Latosolic, Low Humic Gley, Mountain Regosol & Lithosol soils	Natural forest, Mixed home gardens, Paddy, Grasslands
IM 1c	Very Steep, hilly & rolling	Reddish Brown Latosolic, Immature Brown Loam, Mountain Regosol & Lithosol soils	Natural forest, Vegetables
IM 2a	Steep, hilly & rolling	Reddish Brown Latosolic & Red Yellow Podzolic soils	Export Agricultural Crops, Mixed home gardens, Tea, Vegetables
IM 2b	Very steep, hilly & rolling	Reddish Brown Latosolic, Immature Brown Loam, Red Yellow Podzolic, Low Humic Gley & Lithosol soils	Natural forest, Mixed home gardens, Paddy, Tea, Vegetables
IM 3a	Hilly, rolling & Steep	Immature Brown Loam, Reddish Brown Latosolic & Low Humic Gley soils	Mixed home gardens, Export Agricultural Crops, Paddy
IM 3b	Rolling & undulating	Reddish Brown Latosolic, Reddish Brown Earth & Low Humic Gley soils	Mixed home gardens, Export Agricultural Crops, Rubber, Vegetables, Paddy
IM 3c	Steeply, dissected, hilly & Rolling	Reddish Brown Latosolic & Immature Brown Loam soils	Vegetables, Tea, Mixed home gardens, Export Agricultural Crops
IL 1a	Rolling, undulating & Flat	Red Yellow Podzolic soils with strongly mottled sub-soil, Red Yellow Podzolic, Low Humic Gley, Reddish Brown Latosolic & Regosol soils	Coconut, Mixed home gardens, Export Agricultural Crops, Paddy, Rubber
IL 1b	Rolling, undulating & Flat	Red Yellow Podzolic, Reddish Brown Latosolic, Reddish Brown Earth, Low Humic Gley & Regosol soils	Coconut, Paddy, Mixed home gardens, Export Agricultural Crops
IL 1c	Rolling, undulating & Flat	Reddish Brown Latosolic, Reddish Brown Earth, Low Humic Gley & Immature Brown Loam soils	Mixed home gardens, Rubber, Paddy, Sugar cane
IL 2	Rolling, hilly & undulating	Reddish Brown Earth, Low Humic Gley & Reddish Brown Latosolic soils	Mixed home gardens, Paddy, Rainfed Upland Crops, Scrub, Sugar cane, citrus
IL 3	undulating	Non Calcic Brown, Reddish Brown Earth & Low Humic Gley soils	Coconut, Paddy, Mixed home gardens
DL 1a	Rolling & undulating	Reddish Brown Earth & Low Humic Gley soils	Mixed home gardens, Paddy, Forest Plantations, Scrub, Sugar cane, Natural forest
DL 1b	undulating	Reddish Brown Earth & Low Humic Gley soils	Rainfed Upland Crops, Paddy, Scrub, Mixed home gardens, Forest plantations
DL 1c	undulating	Reddish Brown Earth & Low Humic Gley soils	Rainfed Upland Crops, Paddy, Scrub, Natural forest, Forest plantations, Sugar cane
DL 1d	undulating & flat	Reddish Brown Earth, Regosol & Low Humic Gley soils	Rainfed Upland Crops, Scrub, Paddy
DL 1e	Undulating	Reddish Brown Earth & Low Humic Gley soils	Rainfed Upland Crops, Paddy, Scrub
DL 1f	Undulating	Reddish Brown Earth, Low Humic Gley & Grumusol soils	Rainfed Upland Crops, Paddy, Scrub, Natural forest
DL 2a	Undulating	Non Calcic Brown, Reddish Brown Earth, Low Humic Gley & Old alluvial soils	Rainfed upland Crops, Paddy, Natural forest, Sugar cane, Scrub
DL 2b	undulating & flat	Non Calcic Brown, Reddish Brown Earth, Old alluvial, Low Humic Gley, Regosol & Solodized-Solonetz soils	Paddy, Rainfed Upland Crops
DL 3	Flat & slightly undulating	Red Yellow Latosol & Regosol soils	Cashew, Coconut, Condiments, Scrub, Natural forest
DL 4	Flat	Solodized-Solonetz, Solonchaks & Grumusol soils	Scrub, Paddy, Rainfed Upland Crops
DL 5	undulating & flat	Reddish Brown Earth soils with high amount of gravel in sub-soil, Low Humic Gley & Solodized-Solonetz soils	Scrub, Natural forest, Rainfed Upland Crops, Paddy

DISTINGUISHING CHARACTERISTICS OF THE AGRO - ECOLOGICAL REGIONS

AGRO-ECOLOGICAL REGION	TERRAIN	MAJOR SOIL GROUPS	LAND USE
WU 1	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Forest plantations, Natural Forest
WU 2a	Steeply dissected, hilly & rolling	Red Yellow Podzolic soils	Tea, Forest plantations
WU 2b	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Forest plantations, Vegetables
WU 3	Hilly & rolling	Red Yellow Podzolic soils with prominent A1 horizon & Red Yellow Podzolic soils with dark B horizon	Tea, Vegetables, Pasture, Home gardens, Forest plantations
WM 1a	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic soils with semi prominent A1 horizon & Lithosol soils	Tea , Natural Forest
WM 1b	Steeply dissected, hilly & rolling	Red Yellow Podzolic soils with semi prominent A1 horizon & Lithosol soils	Tea, Natural Forest, Mixed Home gardens
WM 2a	Steeply dissected, hilly & rolling	Red Yellow Podzolic, Reddish Brown Latosolic & Low Humic Gley soils	Tea, Mixed Home gardens, Export Agricultural Crops, Natural Forest, Paddy
WM 2b	Steep, hilly & rolling	Reddish Brown Latosolic, Immature Brown Loam, Low Humic Gley & Red Yellow Podzolic soils	Mixed Home gardens, Paddy, Export Agricultural Crops, Tea
WM 3a	Steep, hilly & rolling	Reddish Brown Latosolic, Immature Brown Loam, Low Humic Gley & Lithosol soils	Mixed Home gardens, Export Agricultural Crops, Tea, Paddy, Rubber
WM 3b	Hilly, rolling, undulating & steep	Reddish Brown Latosolic, Immature Brown Loam & Low Humic Gley soils	Mixed Home gardens, Export Agricultural Crops, Tea, Vegetables, Paddy
WL 1a	Rolling, undulating & hilly	Red Yellow Podzolic, Red Yellow Podzolic soils with semi prominent A1 horizon & Low Humic Gley soils	Tea, Rubber, Mixed Home gardens, Paddy, Export Agricultural Crops (Cinnamon)
WL 1b	Undulating & rolling	Red Yellow Podzolic soils with soft & hard laterite & Low Humic Gley soils	Rubber, Mixed Home gardens, Paddy
WL 2a	Rolling, undulating & flat	Red Yellow Podzolic, Red Yellow Podzolic soils with strongly mottled sub soil, Low Humic Gley & Bog & Half-Bog soils	Rubber, Tea, Coconut, Mixed Home gardens, Paddy, Export Agricultural Crops (Cinnamon)
WL 2b	Steeply dissected, rolling & undulating	Red Yellow Podzolic, Red Yellow Podzolic soils with strongly mottled sub-soil, Reddish Brown Latosolic & Low Humic Gley soils	Rubber, Coconut, Mixed home gardens, Paddy
WL 3	Rolling & undulating	Red Yellow Podzolic soils with soft and hard laterite, Low Humic Gley & Regosol soils	Coconut, Fruit Crops, Mixed home gardens, Paddy
IU 1	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Export Agricultural Crops (Cardamom), Natural Forest, Forest plantations
IU 2	Mountainous, steeply dissected, hilly & rolling	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Vegetables, Mixed home gardens, Natural forest, Forest plantations
IU 3a	Steeply dissected, hilly & rolling	Red Yellow Podzolic & Mountain Regosol soils	Tea, Forest Plantations
IU 3b	Mountainous, steeply dissected & hilly	Red Yellow Podzolic, Mountain Regosol & Lithosol soils	Tea, Natural Forest, Forest plantations
IU 3c	Steeply dissected, hilly & rolling	Red Yellow Podzolic & Low Humic Gley soils	Tea, Vegetables, Paddy
IU 3d	Steep, hilly & rolling	Red Yellow Podzolic & Mountain Regosol soils	Tea, Vegetables, Forest Plantations, Natural forest
IU 3e	Steeply dissected, hilly & rolling	Red Yellow Podzolic & Low Humic Gley soils	Tea, Vege tables, Paddy, Mixed home gardens

AGRO-ECOLOGICAL REGION	TERRAIN	MAJOR SOIL GROUPS	LAND USE
IM 1a	Very Steep & hilly	Reddish Brown Latosolic, Red Yellow Podzolic, Immature Brown Loam, Low Humic Gley & Lithosol soils	Tea, Vegetables, Mixed home gardens, Paddy, Forest Plantations
IM 1b	Hilly, rolling & undulating	Reddish Brown Earth, Reddish Brown Latosolic, Low Humic Gley, Mountain Regosol & Lithosol soils	Natural forest, Mixed home gardens, Paddy, Grasslands
IM 1c	Very Steep, hilly & rolling	Reddish Brown Latosolic, Immature Brown Loam, Mountain Regosol & Lithosol soils	Natural forest, Vegetables
IM 2a	Steep, hilly & rolling	Reddish Brown Latosolic & Red Yellow Podzolic soils	Export Agricultural Crops, Mixed home gardens, Tea, Vegetable s
IM 2b	Very steep, hilly & rolling	Reddish Brown Latosolic, Immature Brown Loam, Red Yellow Podzolic, Low Humic Gley & Lithosol soils	Natural forest, Mixed home gardens, Paddy, Tea, Vegetables
IM 3a	Hilly, rolling & Steep	Immature Brown Loam, Reddish Brown Latosolic & Low Humic Gley soils	Mixed home gardens, Export Agricultural Crops, Paddy
IM 3b	Rolling & undulating	Reddish Brown Latosolic, Reddish Brown Earth & Low Humic Gley soils	Mixed home gardens, Export Agricultural Crops, Rubber, Vegetables, Paddy
IM 3c	Steeply, dissected, hilly & Rolling	Reddish Brown Latosolic & Immature Brown Loam soils	Vegetables, Tea, Mixed home gardens, Export Agricultural Crops
IL 1a	Rolling, undulating & Flat	Red Yellow Podzolic soils with strongly mottled sub-soil, Red Yellow Podzolic, Low Humic Gley, Reddish Brown Latosolic & Regosol soils	Coconut, Mixed home gardens, Export Agricultural Crops, Paddy, Rubber
IL 1b	Rolling, undulating & Flat	Red Yellow Podzolic, Reddish Brown Latosolic, Reddish Brown Earth, Low Humic Gley & Regosol soils	Coconut, Paddy, Mixed home gardens, Export Agricultural Crops
IL 1c	Rolling, undulating & Flat	Reddish Brown Latosolic, Reddish Brown Earth, Low Humic Gley & Immature Brown Loam soils	Mixed home gardens, Rubber, Paddy, Sugar cane
IL 2	Rolling, hilly & undulating	Reddish Brown Earth, Low Humic Gley & Reddish Brown Latosolic soils	Mixed home gardens, Paddy, Rainfed Upland Crops, Scrub, Sugar cane, citrus
IL 3	undulating	Non Calcic Brown, Reddish Brown Earth & Low Humic Gley soils	Coconut, Paddy, Mixed home gardens
DL 1a	Rolling & undulating	Reddish Brown Earth & Low Humic Gley soils	Mixed home gardens, Paddy, Forest Plantations, Scrub, Sugar cane, Natural forest
DL 1b	undulating	Reddish Brown Earth & Low Humic Gley soils	Rainfed Upland Crops, Paddy, Scrub, Mixed home gardens, Forest plantations
DL 1c	undulating	Reddish Brown Earth & Low Humic Gley soils	Rainfed Upland Crops, Paddy, Scrub, Natural forest, Forest plantations, Sugar cane
DL 1d	undulating & flat	Reddish Brown Earth, Regosol & Low Humic Gley soils	Rainfed Upland Crops, Scrub, Paddy
DL 1e	Undulating	Reddish Brown Earth & Low Humic Gley soils	Rainfed Upland Crops, Paddy, Scrub
DL 1f	Undulating	Reddish Brown Earth, Low Humic Gley & Grumusol soils	Rainfed Upland Crops, Paddy, Scrub, Natural forest
DL 2a	Undulating	Non Calcic Brown, Reddish Brown Earth, Low Humic Gley & Old alluvial soils	Rainfed upland Crops, Paddy, Natural forest, Sugar cane, Scrub
DL 2b	undulating & flat	Non Calcic Brown, Reddish Brown Earth, Old alluvial, Low Humic Gley, Regosol & Solodized-Solonetz soils	Paddy, Rainfed Upland Crops
DL 3	Flat & slightly undulating	Red Yellow Latosol & Regosol soils	Cashew, Coconut, Condiments, Scrub, Natural forest
DL 4	Flat	Solodized-Solonetz, Solonchaks & Grumusol soils	Scrub, Paddy, Rainfed Upland Crops
DL 5	undulating & flat	Reddish Brown Earth soils with high amount of gravel in sub-soil, Low Humic Gley & Solodized-Solonetz soils	Scrub, Natural forest, Rainfed Upland Crops, Paddy

Figure 18. Major reservoirs and hydropower plants

Prepared by U.R. Ratnayake (Irrigation Department, Survey Department and Ceylon Electricity Board base data)

around 5000 mm in wettest parts (DCS 2003a).

The total volume of surface water availability has been assessed at 43,000-45,000 MCM annually. Annual runoff is estimated to be around 35-40% of the annual rainfall. However, there are considerable variations of the individual values across rivers. The highest rainfall/runoff ratio is recorded in Mahaweli Ganga. Very low ratios are observed in most of the dry zone rivers; generally less than 35%. However, there is a significant spatial variation of the ratio within a river. As many rivers have only a single gauging station, such spatial variation presents a major challenge to the water resources planner. (Table 16: Rainfall-runoff characteristics)

Groundwater

Main types of aquifers

The groundwater resources in Sri Lanka are considered to be lesser than surface water resources. The estimated groundwater potential is 7,800 MCM per annum (UNEP, 2005). The demand for groundwater development is specially for domestic water needs. However, the coastal sand aquifer area in the north-western region is being extensively used for agriculture. Industrial estates in the wet zone are also heavily dependent on groundwater. Seven main types of groundwater aquifers have been identified:

1. Shallow karstic aquifer
2. Deep confined aquifer
3. Shallow coastal sand aquifer
4. Alluvial aquifer
5. Shallow regolith aquifer in the hard rock region
6. South-western laterite aquifer
7. Miscellaneous types

Figure 19 shows the types of groundwater aquifers present in Sri Lanka. Both the quantity and quality issues have restricted the use of groundwater resource. Recent studies carried out in the Ruhuna Basins reveal that nearly half the tested wells contain fluoride levels higher than the permissible levels. The concentrations are higher in the deep tube wells.

In Sri Lanka, groundwater is widely used for domestic, smallscale irrigation, industrial and other uses. Based on studies conducted over the past 50 years, several types of both shallow and deep groundwater aquifers have been identified. Each of these aquifers has distinct characteristics. Shallow aquifers play an important role in providing domestic supplies from traditional wells of between 6 and 9 meter depth, and also in discharging water to rivers and other water bodies during low flow periods. They also support wetlands and native vegetation. Shallow aquifer regions of Sri Lanka are densely populated and intensively cultivated. Abstraction of groundwater is largely uncontrolled in these regions and is excessive in some places causing brackish water intrusions as well as major concerns for pollution (Panabokke and Perera , 2005).

Shallow karstic aquifer of Jaffna Peninsula

The whole of Jaffna peninsula is underlain by Miocene limestone formations, which are generally 100 to 150 m thick, distinctly bedded, well jointed and are highly karstified. The shallow aquifer of the peninsula occurs in the channels and cavities (karsts) of this Miocene limestone. All the shallow groundwater found within the karstic cavities originates from the infiltration of rainfall; this shallow groundwater forms mounds or lenses floating over the saline water. These water mounds or lenses reach their peak during the monsoon rains of November December. The aquifer boundary expands and contracts through the wet and dry seasons respectively. This aquifer gets fully recharged by the November December rains of the north east monsoon. With little rains following February, the stored water within the mounds of the karstic cavities drops rapidly in less than three months. This significant loss of groundwater is because of the considerable karstification, which intensifies the sub surface flow which has been identified as the main problem in the Jaffna peninsula aquifer, especially around the coastal region. Here the fresh water lens gets rapidly reduced in thickness thus limiting water supplies in the dry season which extends up to August September. After the 1980s with rapidly increasing demands for both agriculture as well as urban and domestic uses within the peninsula, the usually available amount of good quality water had become restricted by June July (Panabokke and Perera, 2005).

Out of the annual recharge of groundwater, around fifty percent eventually drains out to sea, and from the remainder approximately 80 percent is used for high-value agriculture and the remaining 20 percent for domestic use(including demands for flush toilets) in urban areas. Water quality studies have reported enhanced levels of nitrate pollution in domestic wells situated in the densely populated Municipal areas of the peninsula (Nagarajah et al 1988 cited in Panabokke and Perera, 2005).

Table 16: Rainfall-runoff characteristics

	Name of the River	Name of the Station	Basin area at Gauging Point Sq. Km.	Average annual rainfall (mm) 1992/93 to 2002/03	Average annual runoff (mm) 1992/93 to 2002/03	Average annual R.O/R.F Ratio%	Number of Rainfall stations used for Averaging
1	Deduru Oya	Chilaw	2610	1611	947	59	3
2	Gin Ganga	Agaliya	681.2	3460	2503	72	4
3	Gin Ganga	Tawalama	276.9	3997	2789	70	3
4	Kala Oya	Dambula	189.0	1499	408	27	3
5	Kalu Ganga	Putupaula	2597.8	3970	2371	60	12
6	Kalu Ganga	Ellagawa	1393	3790	2469	65	9
7	Kalu Ganga	Millakanda	780.3	4204	2997	71	5
8	Kalu Ganga	Kukulegama	334.1	5644	2814	50	2
9	Kelani Ganga	Deraniyagala	183	4572	2884	63	2
10	Kelani Ganga	Glencourse	1463	3664	2031	55	10
12	Kelani Ganga	Holombuwa	155	2939	1474	50	3
13	Kelani Ganga	Norwood	96.6	2703	1129	41	2
14	Kelani Ganga	Kitulgala	383	3263	2419	74	6
15	Kirindi Oya	Tanamalwila	749.1	1491	317	21	5
16	Kirindi Oya	Wellawaya	172.4	1990	679	34	2
17	Heda Oya	Siyabalanduwa	295.3	1804	438	24	2
18	Mahaweli Ganga	Calidoniya	148	1896	1434	76	3
19	Mahaweli Ganga	Talawakele	316	2254	1211	54	6
20	Mahaweli Ganga	Nawalapitiya	176	3568	2379	67	4
21	Mahaweli Ganga	Loggal Oya	201.5	2635	17	66	3
22	Mahaweli Ganga	Padiyatalawa	159.2	2245	860	38	2
23	Mahaweli Ganga	Welimada	104	2019	911	45	3
24	Mahaweli Ganga	Manampitiya	7417.8	2213	342	15	29
25	Menik Ganga	Kataragama	787.4	1375	263	19	3
26	Mee Oya	Galgamuwa	299	1320	66	5	1
27	Nilwala Ganga	Pitabeddara	332.8	3114	1592	51	2
28	Walawe Ganga	Panamura	81.3	1437	304	21	2
29	Walawe Ganga	Tibolketiya	266.7	1356	370	27	3
30	Yan Oya	Harowapothana	720	1336	189	14	2
31	Badulu Oya	Demodara	77.5	2154	597	28	2

Sources: Dias, 2005 and Irrigation Department

Deep confined aquifer

A number of distinct and confined aquifers occur within the sedimentary limestone and sandstone formations of the north-western and northern coastal plains. These are relatively more than 60 m deep aquifers, with a relatively high recharge rate. The sedimentary limestone is highly faulted, and it separates the aquifer into a series of isolated blocks thus forming a number of separate groundwater basins. Seven distinct aquifer basins have been identified, studied and mapped at different scales from the late sixties to the early eighties. Aquifer boundaries have been roughly demarcated, and the average depth of wells reaching the artesian aquifer in the well-defined basins range from 30 to 50 m, and the yields of these wells are around 3-10 litres /sec. This aquifer dips towards the sea, and the depth to the aquifer is around 70 90 m in some places close to the sea (Wijesinghe, 1973, quoted in Panabokke and Perera, 2005).

Safe abstraction rates have been studied and estimated for three of the aquifer basins and are listed with other details in Table 17.

Table 17. Characteristics of main deep confined aquifers

Basin	Depth to Limestone (m)	Depth to Hardrock (m)	Safe Yield (MCM per year)
Vanathavillu	15	225	3.0
Kondachchi	15	60	Not Known
Murunkan	5	167	Not Known
Mulankavil	0	240	9.0
Paranthan	6	76	8.0

Sources: (Panabokke and Perera, 2005)

Coastal sand aquifers

Panabokke and Perera (2005) discuss two important types of coastal sand aquifers recognized and characterized in Sri Lanka. The total extent of these two types is estimated at around 125,000 ha and this supports an intensive human settlement, a high value intensive agriculture and a flourishing tourist industry. These aquifers are - 1) shallow aquifers on coastal spits and bars as found in the Kalpitiya peninsula and the Mannar Island in the north west of Sri Lanka; and 2) shallow aquifers on raised beaches as found in the Nilaveli-Kuchchaweli, Pulmoddai and Kalkuda in North Eastern region. These aquifers expand during the rainy season and contract during the dry season with fluctuating brackish and saline boundaries.

The aquifer in the Kalpitiya peninsular on a coastal spit has a thinner lense of fresh water and is more easily subject to depletion or eutrophication than the Nilaveli type aquifer, which is located on a raised beach type of landform and is thereby of a more robust nature.

Alluvial aquifers

The set of alluvial aquifers of Sri Lanka constitute one of the most diversified forms in the tropical region. These alluvial deposits occur over several diversified alluvial landforms such as coastal and inland flood plains, dissected and depositional river valleys, buried river channels, small rivulets and stream beds with shallow alluvial deposits, and inland valleys of varying shape, form and size with fine and coarse depositional in-fill materials. The deeper and larger alluvial aquifers occur along the lower reaches of the major rivers that cut across the various coastal plains surrounding the low country regions of the country. Rivers such as Mahaweli Ganga, Kelani Ganga, Deduru Oya, Mi Oya, Kirindi Oya, and Malwathu Oya have broad and deep alluvial beds of variable texture and gravel content in their lower reaches. Old buried riverbeds with high groundwater yields are present in the lower Kelani river aspects. The alluvial formations of these larger rivers may vary from between 10 to 15 m and up to 35 m in thickness, and may extend to several hundreds of meters on either side of the riverbeds. A reliable volume of groundwater can be extracted from these alluvial aquifers throughout the year.

In the wet zone, the shallower and smaller alluvial aquifers occur within the alluvial deposits of the minor rivers (oyas) and streams. These aquifers are generally shallow and are directly connected to the surface water in stream and rivers. Even in periods of low surface flow, these aquifers are quickly recharged.

The alluvial aquifers of the larger river systems, especially those that flow out to sea in the south-western part of the country do not get significantly reduced during extremes of drought because they are deeper and have a wider alluvial fill. Considerable underflow of groundwater also takes place in the very wide alluvial tracks of the Mahaweli Ganga at Manampitiya (Cooray, 1984).

Shallow regolith aquifer of the hard rock region

It has been recognized that the groundwater potential in the hard rock region of this country is limited because of the low groundwater storage capacity and transmissivity of the underlying crystalline basement hard rock (Sirimanne 1952, cited in Panabokke et al, 2005). Groundwater in the hard rock region is found in the weathered rock zone and is called as the shallow regolith aquifer, which generally ranges from 2 - 10 m in thickness. In the hard rock zone, there exists a deep fracture zone aquifer in the fracture zone of the basement rocks located at depths of more than 30 - 40 m (Panabokke 2003). The traditional hand-dug wells have been abstracting water from this regolith aquifer for village domestic requirements for more than 2000 years in the ancient Rajarata landscape, and it has been reported that these aquifers have relatively low yields. The agro-well farming in the north central and northwestern provinces is dependant on this shallow groundwater resource (Karunaratne and Pathmarajah, 2002).

South-western lateritic (cabook) aquifer

The laterite formations called "cabook" of southwestern Sri Lanka have considerable water

holding capacity, depending on the depth of the formation. The aquifer found within this vesicular laterite responds very rapidly to the initial rains following the usual dry season of February March, and then keeps filling up with the monsoon rains.

Due to the highly dissected nature of the macro landscape in this region, the water table or the aquifer itself is highly fragmented into a number of discreet, low mounds, within the residual landscape, which is separated from each other by intervening valley floors. As such, one could demarcate and map out a mosaic of interconnected aquifers in this landscape rather than a single continuous aquifer (Panabokke and Perera, 2005).

In general, these vesicular laterities support relatively shallow aquifers that are easily accessible to dug wells as well as shallow 'tube' wells. In some areas with a high density of settlements as in some of the Colombo suburban areas, during prolonged dry periods of more than 65 days, the water table could recede to depths beyond 15m below ground level. This vesicular laterite aquifer of the southwest wet zone faces the most severe over exploitation especially in the area of outer Colombo and adjacent districts. Enhanced nitrate levels have been observed from some of the domestic wells around Colombo and its suburbs (Panabokke and Perera, 2005).

Threats to groundwater

Predominantly in the dry zone, shallow groundwater that occurs under the small tank cascade systems is now being subjected to severe stress of over extraction. The use of this groundwater through large diameter dug wells or agro- wells for growing high value cash crops has increased at an accelerated pace over the last decade. This shallow groundwater is very limited in its quantity and is of a very ephemeral nature. If it is over exploited it could lead to long term desertification which in turn would lead to disastrous ecological consequences in the North and Western provinces of the country (Weerasinghe et al, 2005).

Shrimp aquaculture uses extensive farm areas on land close to lagoons or in the immediate hinterland in the Chilaw area of the North Western Province. These farms are freely drawing substantial volumes of fresh water from deep tube wells; adversely affecting the level and the quality of water in shallow wells and causing conflicts with domestic water supplies.

In the Vanathavillu basin, the deep confined limestone aquifer which has been intensively used for irrigated agriculture has shown increased electrical conductivity of the tube well water since 1978 Leaching of salts from the cultivated soils to the groundwater table has been identified as the major cause (Kuruppuarachchi and Fernando, 1999).

Since the introduction of mechanical pumps, largely in the 1960s, pumping in excess of safe yields from the shallow limestone aquifers in Jaffna Peninsula has led to over-extraction. Most of the groundwater pumped comes from the stored water below sea level. As a result, the fresh-water interface continues to rise (Weerasinghe et al, 2005). Approximately 80 percent of the groundwater in Jaffna peninsula is being used for high-value agriculture and the remaining 20 percent for domestic use including flushing demands of toilets in urban areas of Jaffna. Water quality studies have shown enhanced levels of nitrate pollution in domestic wells situated in the more densely settled Municipal areas of the peninsula as reported by Nagarajah et al 1988 (Panabokke & Perera, 2005). Nitrate pollution results from high use of agrochemicals as well as of the disposal of sewage effluent from pit latrine soak ways and septic tanks; the latter causes bacterial contamination of groundwater as well. In agricultural and non-agricultural areas in the Jaffna Peninsula, nitrate concentrations over 170 mg/l of nitrate (NO_3) have been recorded (UNEP, 2005).

Similarly in the intensively cultivated and irrigated areas in the Kalpitiya Peninsula, considerable aquifer contamination by nitrates and chlorides has been recorded. Peak seasonal concentrations in these places have reached four times the WHO guideline values. During the last 25 years, concentrations in dug well water have increased from 2 mg/l to 40 to 50mg/l in the case of chlorides, and 50-120mg/l to over 200 ml/g for nitrates. Groundwater contamination from agricultural washouts and pit latrine soak-ways have been recorded in Jaffna Peninsula, where 80% of the well water monitored in one study showed unacceptable bacterial quality due to sewage (Weerasinghe et al, 2005).

Shallow aquifers on coastal spits and bars as found in the Kalpitiya peninsula and the Mannar Island in the north west of Sri Lanka and shallow aquifers on raised beaches as found in the Nilaveli-Kuchchaweli, Pulmoddai and Kalkuda in north eastern region too are vulnerable to over extraction. Although the total extent of these two types of aquifers is estimated at around 125,000 ha, it supports basic needs and livelihoods of the area. These aquifers are re-charged mainly during the 3-4 months of rain in the wet 'maha' season. The volume of fresh water in these aquifers usually expands during the rainy season and contracts during the dry season with fluctuating brackish and saline boundaries. Any over extraction from these fresh water lenses results in the coning or entering of the underlying brackish water in to the fresh water.

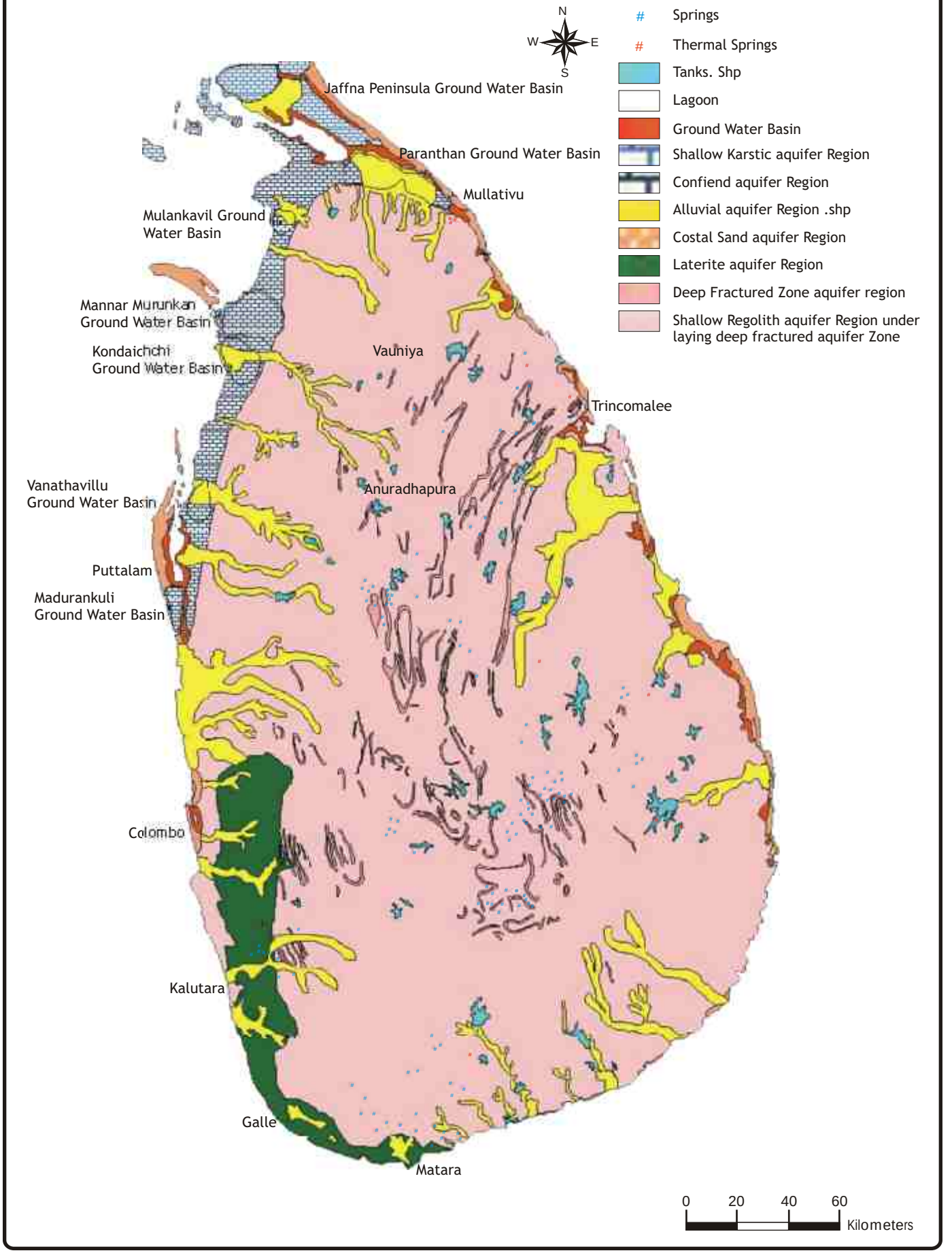


Figure 19. Different types of groundwater aquifers in Sri Lanka

Source: R.N. Karunaratne, Water Resources Board

Intense urban development and agricultural activity in the densely populated western part of Jaffna peninsula have resulted in groundwater overdraft far in excess of replenishment. Some areas of the peninsula are experiencing high chloride concentrations. The serious implications of these trends in a peninsula essentially devoid of sufficient fresh water, at least in the dry season, require restrictions on new wells including careful regulation of size, diameter and the distance between wells (Weerasinghe et al, 2005)

In summary, the introduction of hand pumps for agriculture, construction of a large number of dug wells in northern and north western areas, shrimp aquaculture in the coastal areas of North Western Province resulting in salinity intrusion are some of the threats to groundwater.

Water quality

Surface water quality

Several causes of water pollution in urban and rural areas have been identified in Sri Lanka. In the urban areas, the major causes are inadequate waste disposal facilities in highly populated urban areas and industrial waste. It is reported that about 57% of the daily collection of waste is produced in the western province and waste generation is expected to increase with a growth rate of 1.2%. Many local authorities in urban areas use low-lying areas as open dumps for the waste. Such dumping methods reportedly contribute to the reduction of flood retention areas and pollution of water. This practice also contributes to mosquito breeding and other adverse health impacts.

Domestic waste is also a contributory factor to water pollution in the cities. It is estimated that nearly half the population in Colombo live in low-income settlements (ME&NR, 1998a), where waste disposal facilities are inadequate. Out of the total wastewater generated in the Greater Colombo Area, about 75% return to the environment. The Kelani River receives heavy loads of organic matter due to the discharge of untreated faecal matter in the last 50 km stretch. It is estimated that the river discharges about 36,000 kg/day of Chemical Oxygen Demand (UNEP 2005).

Industrial waste also contributes substantially to the water pollution in urban areas. The lower reaches of Kelani River, Beira Lake and Bolgoda Lake in the western province are heavily polluted due to such wastes. Pollution from the oils used in motor garages and service centers is also a concern in urban and suburban areas. The discharge of industrial pollutants to Lunawa lagoon (near Colombo) had severely affected the fishing industry in the lagoon, and it is reportedly devoid of aquatic life.

In the case of rural areas, excessive use of agrochemicals contributes to the pollution of water. Nutrient-related pollution has been reported in reservoirs such as Kotmale (Mahaweli system), Kandy Lake and Lake Gregory in the up country, Nuwarawewa and Tissawewa (in Anuradhapura) and many other reservoirs in Anuradhapura and Polonnaruwa Districts (UNEP, 2005). In the upper reaches of the rivers, fertilizer used for tea estates contributes to the concentration of agro chemicals in water.

The salt-water intrusion into rivers, especially in the western coast is a contributing factor to water pollution. Excessive sand mining and the resultant lowering of the riverbed is one of the reasons for this problem. In Kelani Ganga, this has affected the drinking water supply to Colombo city (UNEP, 2005).

Groundwater quality

In the case of groundwater, agricultural chemicals and chemical properties in the soils affect the water quality. It is estimated that about 40% of the tube wells constructed during the last decade of the 20th century were abandoned due to contamination from iron, manganese and fluorides. In the Jaffna peninsula, nitrate concentrations of over 200 mg/l have been reported. Bacterial pollution from pit latrine soak-ways is also reported in the peninsula (UNEP, 2005).

Over-exploitation of groundwater and resultant salt-water intrusion has been reported in such areas as Puttalam, Mannar, Paranthan, Kilinochchi and Mullaitivu. The agricultural chemicals are reported as the cause for high concentrations of chloride, nitrate and potassium in Kalpitiya Peninsula (UNEP, 2005).

The geo-chemical composition of the soils and rocks heavily influence the properties of groundwater. A study carried out in early 1980s (Dissanayake and Weerasooriya, 1985) reveals that the northern coastal region is subjected to salt water intrusion. TDS values here range between 1,200 to 1,900 ppm (in the slightly saline range) and in extreme cases go up to 30,000 ppm. However, except for the northern region and small areas near Hambantota and Puttalam, the rest of the country does not experience a significant problem with respect to salinity.

However, hardness of water measured in terms of ppm of $CaCO_3$ is an issue in most parts of the country. High values in excess of 850 ppm occur in the northern sedimentary formation. In the areas having reddish brown earth soils, mostly in the dry zone, the hardness ranges between 250-500 ppm. In the wet zone, the problem of hardness is hardly present (Dissanayake and Weerasooriya, 1985).

The fluoride concentrations constitute another problem associated with groundwater. The low fluoride areas of less than 0.1 ppm are located mainly in the wet zone. A considerable area in the southwest and northwest and central part of the country have concentrations less than 0.5 ppm. High concentrations exceeding 3.0 ppm are found in eastern and north-central dry zone, especially Anuradhapura, Polonnaruwa where concentrations less than 0.5 ppm increases the incidence of dental caries and concentrations in excess of 1.5 ppm contributes to discoloration of teeth of children (Dissanayake and Weerasooriya, 1985).

Impacts

The major social and economic impacts of water pollution have been identified to include the cost of disease prevention and treatment, clean-up costs, impact on livelihoods such as fishing, and loss of land values. The cost of water pollution in Colombo metropolitan area (comprising Colombo, Gampaha and Kalutara) has been estimated as Rs. 1845 million in 2002 (UNEP, 2005).

Data and information on water resources

Hydrological and meteorological observation stations

A water data survey and a user interview conducted and published by Wijesekera et al (2000) summarises the status of water data in Sri Lanka. Among the state organisations collecting water data, hydrological data is collected and managed by the Irrigation Department, water quality data by the Central Environment Authority, groundwater data By Water Resources Board and the National Water Supply and Drainage Board, and climate data by the Meteorological Department. Other organisations such as universities, corporations and NGOs also contribute to the data collection process.

Surface water data Irrigation Department currently maintains 69 hydrometric stations in 17 river basins, for which discharge-stage rating curves have been developed for 39 gauging stations. Out of these 35 are in the wet zone, 10 in the intermediate zone and 24 in the dry zone.

River gauging stations mostly located at potential reservoir sites monitor the hourly water level observations. Reservoir data are also collected by the Irrigation Department and consists of daily issues of water for irrigation or hydropower purposes and the inflow into the reservoirs. The Irrigation Department has the majority of its hydrological records such as river water gauge readings, rating tables, rainfall data and station details stored in hardcopy format.

Operational data The Water Management Secretariat (WMS), Ceylon Electricity Board (CEB) and Irrigation Department use daily operational data on reservoir levels and river levels extensively. The data required for these purposes are viewed by these agencies as being satisfactory for current operational requirements. The data are read manually and transmitted by telephone, radio or facsimile to operations centres within the respective agencies, to help water sharing specially in the Mahaweli River reservoir system.

Table 18. Hydrometric station details

Description	Quantity
Number of rivers gauged	17
Number of river gauging stations	69
River gauging stations with Automatic Water Level Recorders	16
River gauging Stations with Cable Ways	16
Number of Rain Gauging stations	33
Number of Automatic Rain Gauging stations	08
River Gauging Stations Equipped with Ordinary Rain Gauges	20
River Gauging Stations equipped with Automatic Rain Gauges	08
Number of Evaporation Pans	11
Number of Weather stations	04

(Source :Irrigation Department)

Water quality data Current water quality data collected by the Central Environment Authority (CEA) is undertaken in specific areas to address local needs and for local development projects. The (CEA also collects and analyses water quality data and information to meet the agency's licensing requirements, for project work and for dealing with complaints concerning water quality. There are other organisations such as universities, Institute of Fundamental Studies (IFS), private companies and NGOs who posses project specific water quality data. There is no annual 'Status of the Rivers' reporting on water quality or environmental health of rivers across the nation.

Groundwater data There is no baseline groundwater quantity or quality-monitoring program for resource assessment and utilization. Both the Water Resources Board (WRB) and the National Water Supply and Drainage Board (NWSDB) collect geological and spatial data on bores, agro-wells and water supply wells which they construct and maintain databases of hydro-geological information. Both organizations carry out drilling programs and there is opportunity for rationalization of these activities.

Water usage data Significant surface water and groundwater usage in Sri Lanka is for irrigation, hydro-electricity generation, industrial use, and domestic purposes (Table 19).

In comparison to the major users, the need for water resource utilisation for recreation, tourism, transport and fishing could be considered as insignificant. However there is now a growing concern related to the usage of water for recreation and tourism. Issues such as the use of water for hydroelectric generation depleting major waterfalls, has drawn public attention in recent times.

Groundwater usage is mainly used for industries and water supply schemes, but island wide there is a heavy reliance on groundwater to fulfil the domestic water requirements. The Agricultural Development Authority is presently executing a significantly large program for the development of shallow large diameter dug wells (agro wells) for irrigated agriculture in the dry zone of Sri Lanka. However there have been concerns regarding over exploitation of groundwater resources

Surface water is mainly tapped for the use of irrigation and hydro-electricity generation. Water supply schemes and industries scattered around the country, which are mostly located closer to cities, extract surface water in significant quantities. NWSDB maintains water extraction data from surface and groundwater sources for water supply schemes.

The Ceylon Electricity Board collects water release data from the major reservoirs. Either the Mahaweli Authority or Irrigation Department maintains irrigation water extraction data in some schemes. Water usage data of the smaller irrigation schemes or of the agro-wells are not being regularly collected.

Table 19. Status of water usage data (based on Wijesekera et. al 2000)

Purpose	Organisations Involved in Promotion / Management / Administration	Water Source	Water Usage Data Collection
Irrigation	Irrigation Department	Surface water	Some Schemes
	Department of Agrarian Services	Surface water	Occasionally
	Provincial Irrigation Department	Surface water	Occasionally
	Mahaweli Authority	Surface water	Some Schemes
Hydro-Power Generation	Ceylon Electricity Board	Surface water	Yes
Domestic Water Supply	National Water Supply and Drainage Board	Surface water Groundwater	Yes Yes
Industrial use	Local Government	Surface water Groundwater	Yes None
	National Water Supply and Drainage Board	Surface water	Yes
	Board of Investment	Surface Water Groundwater	In Industiral Zones None

System performance

A comparison of the current station densities of both the Irrigation Department and Meteorological Department with WMO guidelines has been as shown as satisfactory (Table 20). However it was observed that only a few stations were in the Northern and Eastern regions of Sri Lanka (Wijesekera et al, 2000).

In addition, Department of Agriculture maintains 19 weather and climatic data collection stations.

At present, in Sri Lanka, water resources data and information are organised and managed in a traditional manner within the various government agencies. However, there is a need to integrate the various water data archives into a coherent water resources information system. There is no water database being developed at present where all the data classes are brought together and integrated. Significant gaps in data collection programs such as quality, technology, coverage etc can be identified for further action.

There is a need for coordination, planning, improved access, publication, and quality assurance and pricing of data, to gain the full benefit from the data already collected. The water data users often express concerns regarding the data availability, data quality and accessibility. It is thus necessary to carry out a review of the surface water monitoring network and procedures. In the case of water quality especially, there is a need to implement a national water quality monitoring program, and link this program with other national water data monitoring programs for surface water and groundwater, along with a compatible modern database system for the storage, management and linking of such data to the archives maintained for other water data.

Table 20. Station densities compared with WMO standards (Wijesekera et. al 2000)

Organisation	Network Type	Number of Stations	Effective Area (SqKm)	Station Density (SqKm per Station)	Respective WMO Standard Density Km2/Station	WMO Inforhydro 1991 Standard	Satisfactory by WMO standards	Remarks
Irrigation Department	River Gauging (After 94/95 Water Year)	48	65531	1365	1875 For interior planes and hilly areas	1000	Yes	Very few stations at northern and eastern areas
Meteorology Department	Daily rainfall (Non Recording)	350	65531	187	575 For hilly areas	200	Yes	Very few stations at northern and eastern areas
	Automatic rainfall gauging stations (Recording)	22	65531	2979	5750 For interior plains and hilly areas		Yes	Very few stations at northern and eastern areas
	Evaporation (Agromet)	38	65531	1725	50000 For interior plains and hilly areas		Yes	Very few stations at northern and eastern areas

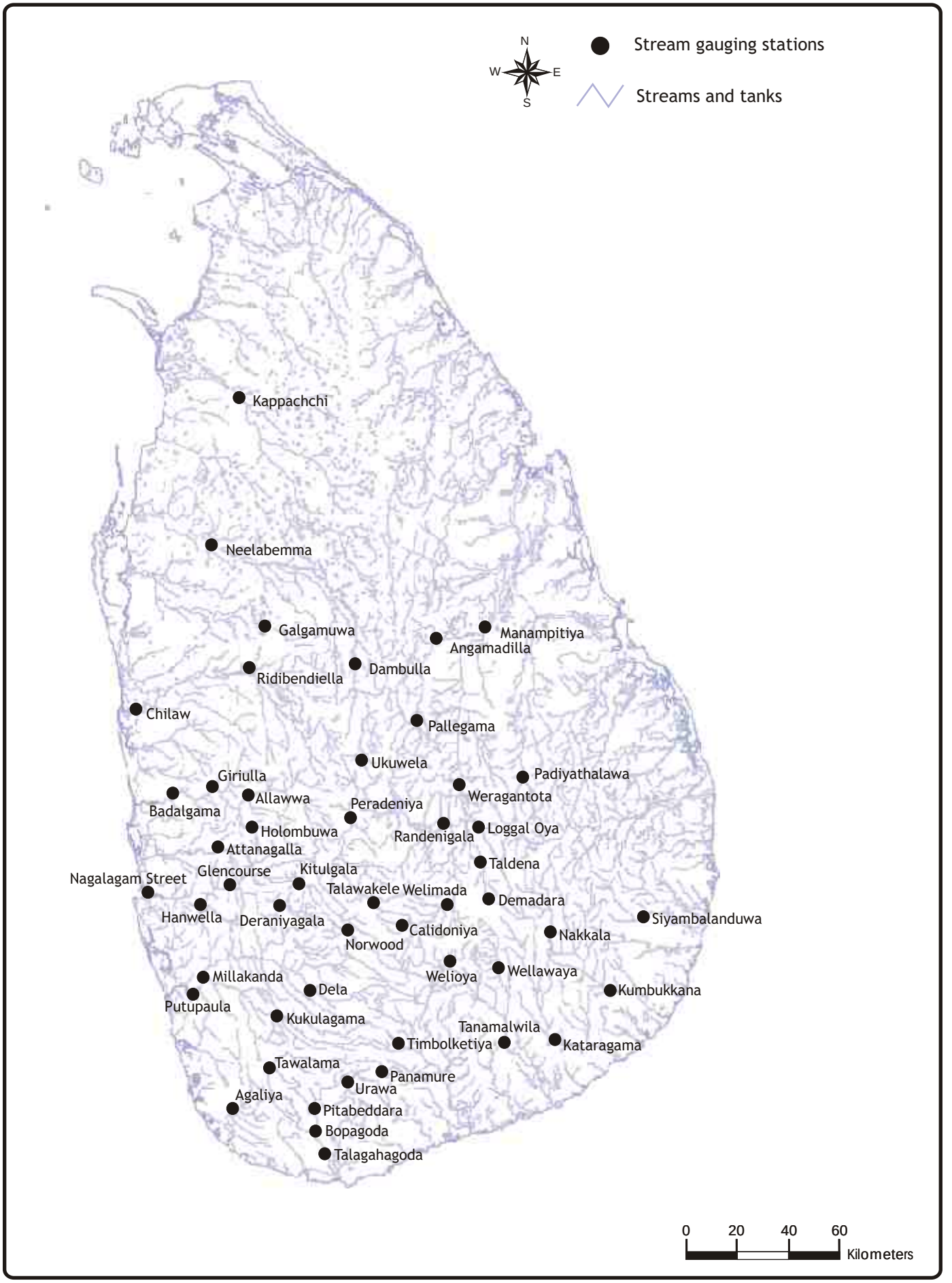


Figure 20. Stream gauging stations

Prepared by N.T.S. Wijesekera (Irrigation Department base data)

The national hydrological archive is at the Irrigation Department and mostly retained in hard copies. There is a backlog of processing continuous climatic data. The computerised climatic data is in a suitable format for integrating into a water resources information system. In the case of groundwater a long-term monitoring of water levels on a seasonal and yearly basis has to be introduced for assessment and sustainable management decisions. A nationwide groundwater-monitoring program of water level and water quality data needs to be implemented together with the integration of the available data into a single system. The absence of water usage data at smaller irrigation systems prevents carrying out important water budget computations of rational water resources management. (Wijesekera et.al, 2000)

Human impacts on water resources- dams and diversions

Sizes and storage capacity

A total of 16 out of the 103 rivers of Sri Lanka are classified as wet zone rivers. These wet zone rivers carry about half of the annual surface runoff (Manchanayake and Madduma Bandara, 1999). Building numerous reservoirs and diverting water to the dry zone compensated the unequal distribution of surface water. Sri Lanka's most ambitious water resources development effort, the Mahaweli development project, enabled diversion of about 750 MCM of water annually to the dry zone at Polgolla, the main diversion point (Meegastenne, 2005).

In addition, there are a large number of major and minor diversion structures. The Irrigation Department, Mahaweli Authority of Sri Lanka and Ceylon Electricity Board are the national institutions managing major reservoirs. There are 80 dams, which qualify under the major dams category as defined by the International Commission of Large Dams (SLNCOLD Database, 2005 and Kamaladasa, 2005). The number of major reservoirs is estimated to be about 309 (UNEP, 2005). The Irrigation Department and Mahaweli Authority of Sri Lanka manage the majority of them. In addition, there are about 11,250 small dams, mostly maintained by the village communities, under the purview of Provincial Councils. The highest density of these small reservoirs is observed in the North-Western Province, while the majority of large reservoirs and inland water bodies are present in the North Central Province. There are few medium-size dams, which do not qualify as large dams, but are maintained by the state agencies as well.

The storage capacity of smaller reservoirs is not accurately computed. However, it is tentatively estimated that the total volume of man-made reservoirs is about 7000 MCM.

Dams and effects on environment

The studies show that almost one-third of the country is subjected to soil erosion. The problem is more prominent in the hills and the causes are mainly related to agricultural activities. Market gardens (vegetables and potatoes) and shifting cultivations and tobacco contribute heavily to soil erosion, the annual erosion rates being 100 -150 tons/ha in the

Table 21 Fifteen largest reservoirs in Sri Lanka

No.	Name	Year	River Basin	Gross Capacity (MCM)
1	Senanayake Samudra	1956	Gal Oya	949.78
2	Randenigala	1986	Mahaweli	863.84
3	Victoria	1984	Mahaweli	723.24
4	Maduru Oya	1983	Maduru Oya	598.29
5	Samanala wewa	1992	Walawe	278
6	Udawalawe	1973	Walawe	269.41
7	Lunugamwehera	1984	Kirindi Oya	225.73
8	Kotmale	1985	Mahaweli	173.49
9	Ulhitiya	1982	Mahaweli	145.51
10	Kantale	1869	Per Aru	140.62
11	Minneriya	1903	Mahaweli	135.68
12	Parakrama Samudra	1952	Mahaweli	134.45
13	Kaudulla	1960	Mahaweli	128.28
14	Moussakelle	1969	Kelani Ganga	123.95
15	Kalawewa	1887	Kala Oya	127.75

Source: Wijesuriya, 2005

Note - * denotes ancient irrigation resevoirs of which the date of restoration is given.

Mahaweli upper watershed. About 80% of this area is eroded at various levels due to steep slopes, erodible soils and intense rainfall. Nearly one-third of the land in upper Mahaweli watershed is estimated to be thus degraded.

It is also reported that organic and chemical waste flowing into the reservoirs result in water pollution. Most of the shallow irrigation reservoirs are affected by eutrophication and the situation worsens during dry periods (Jacobs Gibb Ltd, 2003).

It is estimated that 10 out of the 18 endemic freshwater fish species are present in the Mahaweli River basin. It is feared that reduction of flow velocity, increase in sediment loads and restrictions to migration imposed by Mahaweli Development Project could affect these fish populations negatively (Steele et al, 1997). Sri Lanka is an active Partner and a Forum member in the Dams and Development Project of UNEP with activities carried out by the Ministry of Irrigation and Mahaweli Development and the Irrigation Department. These activities are expected to promote stakeholder participation in the dam construction field, and thereby minimize the adverse social and environmental impacts.

Main problems

The main problems concerning water resources are the climatic changes resulting in high-intensity short-duration rains and the reducing trend of rainfall, inadequate water resources development, aging water infrastructure, inadequate dam safety arrangements and the outdated hydro meteorological information systems. Lack of a comprehensive policy for the water sector, and inadequate institutional arrangements are also identified as major issues.

The proposed National Water Management Improvement Project by the Ministry of Agriculture, Irrigation, Mahaweli Development, to be implemented with the assistance of the World Bank, is expected to provide solutions to many of these issues. The activities planned under the Project are

i) Modernization and rehabilitation of dams and head works

ii) Upgrading and modernization of the country's Hydro - Meteorological Information System (HMIS), and its utilization in effective river basins planning, development, irrigation management;

iii) Preparation and rationalization of a water management master-plan for both surface water and ground water in river basin and management plans and specific basin development proposals;

iv) Building national institutional capacity and human resources skills for sustainable HMIS management, dam safety assurance and risk management, water resources development planning and management (Official documents of the MAIMD)

Indicators

- Annual per-capita water resources = 2,300 m^3
- Number of large dams = 80
- Percentage of Annual Water Resources developed for use = 20-25%
- Density of river gauging stations = 1365 sq.km./station
- Density of recording automatic raingauge stations = 2979 sq.km./station
- Volume of water diverted to dry zone = 750 MCM/year
  (5 year average at Polgolla from 2000-2004)

Chapter 03

Water for Basic Needs and Health

The need to recognize that access to safe and sufficient water and sanitation are basic human needs, and are essential to health and well being of human beings is universally accepted. The fact that Sri Lanka has invested substantially in the health sector during the past 50 years shows the commitment made by successive governments on enhancing and sustaining the health and well being of the people.

Molden et al (2001) estimate that total water withdrawals in Sri Lanka in 1995 as 10.2 km^3 or 10,200 MCM. Considering the subsequent water resources development it can be estimated that about 11,000 MCM of water are developed and are being utilized annually (about 1,600 litres/capita/day). Out of this total withdrawal, 85% or more is used for irrigated agriculture. Therefore it appears that the present level of development of water for basic needs is small compared to annual water requirements.

Average water consumption

Quantity

The non availability of adequate data for computation of per capita water consumption has been cited in a study done in 1998 (Amarasinghe, Mutuwatte and Sakthivadivel 1998) where under several assumptions, the per capita, per day domestic and industrial water withdrawals in the dry zone have been computed as 26 and 8 litres respectively for year 1991. The parallel withdrawals for the wet zone have been computed as 35 and 49 litres respectively. The same study has also identified that in the Maha season, irrigation water withdrawals for the dry zone and wet zone for 1991 had been 89% and 11% out of a total of 4.11 km^3. The Yala season irrigation withdrawals for dry and wet zones for 1991 had been 97% and 3% of a total of 5.27 km^3.

The Sri Lankan population is expected to reach 23 million in 2025 and it is estimated that the demand for safe drinking water will be approximately 4.6 million cubic meters per day. Out of this approximately 3.3 MCM per day will be the requirements of the urban population (George, 2005).

Quality

Apart from the natural impurities from the environment, water pollution caused by human activity is causing concerns among health authorities in Sri Lanka. Among the common sources of pollution are 1) sewage which contains decomposable organic matter and pathogenic agents, 2) industrial wastes that contains toxic agents resulting from metal salts to complex organic chemicals, 3) agricultural pollutants which comprise of fertilizers and pesticides, 4) physical pollutants such as radioactive substances and heat (Shanmugarajah, 2005).

Biological hazards These are caused by viruses (e.g. viral hepatitis, viral diarrhoeas), bacteria (e.g. cholera, typhoid, paratyphoid, and bacillary dysentery), Protozoa (e.g. Amoebiasis, giardiasis), helminthes (e.g. round worm, whipworm, thread worm) leptospirosis or by an aquatic host such as Cyclops in fish tapeworm infection etc (Park, 1995).

Chemical hazards Chemical pollutants of diverse nature derived from industrial and agricultural practices are increasingly finding their way into public water supplies. These pollutants include detergent solvents, cyanides, heavy metals, minerals, and organic acids, nitrogenous substances, bleaching agents, dyes, pigments, sulphides, ammonia, toxic and biocidal organic compounds of great variety (Shanmugarajah 2005). The recommended level of fluorides in drinking water is 0.5- 0.8 mg / l. The main sources of fluorides in natural waters are weathering of fluorine containing minerals. It has been found that water in deep wells constructed in fractured crystalline rocks in the dry zone region contain excessive amount of fluoride. (Chandrajith et al, 2004 cited in Shanmugarajah 2005).

Standards and monitoring mechanisms

Standards

Several indicators adopted by the Sri Lanka Standards Institute (SLSI) are used to check the quality of water. Those indicators are established for the different types of water including packaged/-bottled water (Table 22) (Shanmugarajah 2005).

Table 22. Indicators used to measure quality of water

Potable (Drinking) water taken from the pipe born public water supplies:	Potable (Drinking) water from individual or small community supplies including wells, bores and springs	Packaged / bottled drinking water	Natural mineral water at the time of bottling/ packaging
APC -- No standard for Sri Lanka	APC - No Standard for Sri Lanka	APC - less than 100 cfu / ml (new)	APC - less than 100 cfu per 1ml at 20^{0}C to 22° C x 72 hours.
PCC -- Throughout any year 95% of the samples shall not contain any coli forms in 100 ml.	PCC - Should be less than 10 per 100 ml.	PCC - Should be less than 10 coli forms per 100 ml.	APC - less than 20 cfu per ml at 37^{0}C x 24 hours.
None of the samples examined shall contain more than 3 coli forms per 100 ml.	ECC - Should not be detected / 100 ml.	ECC - should not be detected per 100 ml.	PCC - less than 2 per 250 ml (new).
Coli forms shall not be detected in 100 ml of any 2 consecutive samples.			ECC - Should not be detected per 250 ml (new).
ECC - Should not be detected / 100 ml.			Faecal Streptococciless than 2 per 250 ml.(new)
			Pseudomonas Aeruginosa - less than 2 per 250 ml.
			Sulphite reducing Clostridia- less than 2 per 250 ml.

Source Shanmugarajah 2005

Note: APC-Aerobic Plate Count Number of Bacterial Colonies Colony Forming Units (CFU) from 1ml of water after 48hours incubation at 37^0 C.
PCC-Presumptive Coli form Count Probable number of presumptive coli form bacteria present in 100 ml of water after 48 hours incubation at 37^0 C.
ECC-Escherichia coli Count Probable number of E. coli present in 100 ml of water after 48 hours incubation at 44^0 C.

The Food Control Administration of the Ministry of Health has proposed certain standards for bottled/ packaged water in the regulations under the Food Act which is to be published soon. These regulations are pending authorisation by gazette notification.

Monitoring mechanisms

The Department of Health Services and the provincial health sector encompass the entire range of preventive, curative and rehabilitative care with the support of the laboratory and other ancillary services.

Sri Lanka possesses an extensive network of health care institutions. The majority of the population has easy access to healthcare facilities. Accessibility to a health care facility is on an average is 1.4 km from any home. Government maintained free of charge, western type of health care services are available within 4.8 km of a patient's home (Annual Health Bulletin, 2001 quoted in Shanmugarajah, 2005).

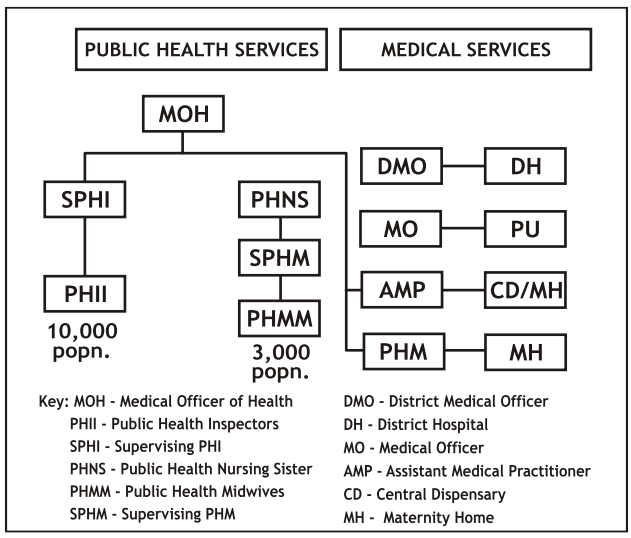


Figure 21. Diagrammatic representation of the divisional level health system
(Shanmugarajah 2005)

Administratively, the State health services are divided into Central and Provincial health sectors. At central level the Ministry of Health is headed by the Minister of Health and the Department of Health services function under the Director General of Health Services.

Specialised preventive health campaigns are carried out for the control of tuberculosis, malaria, filaria, leprosy, STD/AIDS, rabies etc, while curative institutions such as teaching hospitals, general hospitals and special institutions fall within the administrative purview of the line ministries.

At provincial level, the Provincial Minister of Health Services heads the Provincial Ministry of Health while the Provincial Director of Health Services heads the Provincial Department of Health. Curative care is provided by medical institutions such as base hospitals, district hospitals, peripheral units, maternity homes and central dispensaries, while the preventive health services are provided by the Medical Officer of Health and his staff consisting of Public Health Inspectors, Public Health Nursing Sisters and midwives. The Medical Officer of Health is responsible for the health and sanitation of the area.

At divisional level, where the community level interventions are undertaken, health care is provided through a network of medical institutions including district hospitals and a network of health units providing public health services.

The data on morbidity and mortality are collected from the hospitals by the Medical Statistics Unit of the Health Ministry using the indoor morbidity and mortality quarterly returns. Data on outbreaks and waterborne diseases are investigated at the field level by the Public Health Inspectors (PHI) and sent to the epidemiological unit through the Medical Officer of Health (MOH) and the regional epidemiologist. Data on water supply and environmental health is collected and recorded in the sanitation registers maintained by the PHI. However, the level of accuracy and completeness of these records are inadequate (Shanmugarajah, 2005).

The Food and Water Division of the Medical Research Institute and the City Analysts in Colombo and Kandy are the only institutions currently carrying out bacteriological analysis of water. These tests are carried out on request of authorities and individuals. Chemicals are checked at the Government Analyst Department. Food labs at Anuradhapura and Kalutara of the National Institute of Health Services are not currently carrying out microbiological analysis though equipped to do so, due to the lack of microbiologists. Both the National Water Supplies & Drainage Board (NWSDB) and the Water Resources Board (WRB) have central and regional laboratories in each province. Though the physical infrastructure is available, the services are grossly inadequate due to the above mentioned reasons, and needs strengthening in terms of trained staff, equipment and financial provisions (Shanmugarajah, 2005).

Basic services

Drinking water and sewage system coverage

The lack of access to safe drinking water has been identified as an important factor contributing to high morbidity from diarrhoeal diseases in Sri Lanka.

Table 23. Sources of safe drinking water and service coverage

Type of Supply	Percentage of population Served	
	Source: DCS,(2002a)	Source: NWSDB
Pipe-borne	23.4	28.4
Hand pump/tube wells	4.8	7.7
Protected dug wells	47.2	34.1
Other means (eg rainwater harvesting)	1.3	Na

The available data indicates that, in general, about 75% households have access to safe drinking water. This percentage varies across sectors. About 75% of the urban population and 14% of the rural population are served by pipe-borne water (DCS, 2002a). However, a 24-hour service is not always available, and duration of service varies with the location and climatic factors. This may influence people to use unsafe sources occasionally, thereby being exposed to water related health hazards. Table 23 describes the sources of safe drinking water supply.

The Demograhic and Health Survey (DCS, 2002a) data indicates that 47.2% of households get their water from protected wells, 4.8 % from tube wells, 23.4 % from pipelines. These three sources are considered to be safe (Shanmugarajah, 2005).

The future targets of NWSDB are as follows:

- Access to sufficient and safe drinking water is to be provided to 85% of the population by 2010 and to 100% in 2025
- Piped water supply to 100% of urban population in 2010 (George, 2005).

Sanitation

The access to safe sanitation varies according to the type of access and the type of latrine. The available data indicates that about 93-94% of people had access to some type of latrine, while 72% had access to water-seal type latrines (DCS, 2002a). The major sewerage system operating in the country is designed for Colombo. It is reported that only 19% of the Colombo Metropolitan Area is served by the piped sewerage system (UNEP, 2005).

The future targets of NWSDB for sanitation coverage are as follows:

- Access to adequate sanitation is to be provided to 100% of the population in 2035
- Major rehabilitation of the sewerage system of Greater Colombo area to be completed by 2010
- Piped sewerage systems in major urban areas to be completed by 2015 (George, 2005).

Affordability of water services

The NWSDB provides water supply for most of the urban areas. Cost recovery is through a nationally adopted tariff structure based on the volume of consumption. However, the stand posts, which supply water for the under-served communities, are not metered. The structure has different tariff rates for the different "slabs" of tariff, with rates increasing with higher consumption. There are different tariff rates for different consumer categories, such as domestic, commercial and industrial (Senaratne, 2002), with domestic water consumers often benefiting with cross-subsidies.

The availability of safe drinking water varies across societal sectors. The estate sector, where prevalence of diarrhoeal diseases is high, has poorer access to the safe drinking water than other sectors.

Studies carried out for Ruhuna Basins comprising Walawe, Kirindi Oya and Menik Ganga (Sri Lanka case study for WWDR I) indicate that irrigation development positively impacts on drinking water availability. The water resources of the lower western and middle portions of these river basins are substantially developed and irrigation facilities are available, except for a few patches of land. The upper reaches of the river basins are located in the wet zone and the lower reaches are in the driest parts of the country. However, it is observed that water availability is better in the dry zone areas with irrigation development.

Water related diseases

Water borne

Diarrhoeal diseases are still a major public health problem in Sri Lanka being one of the ten leading causes for hospitalization. There were several outbreaks of diarrhoeal diseases in the past few years, a major contributory factor being the scarcity of water during the dry season and lack of proper sanitary facilities in the affected areas. Acute diarrhoeal diseases are caused by viruses such as rota viruses, astroviruses, enteroviruses, and bacterias such as E.coli, Shigella, Salmonella, vibrios and other organisms such as amoebae.

Table 24. Prevalence of diarrhoeal diseases among children according to the sector

Sector	Children with diarrhoea in the past (%)		No. of children surveyed
	24 hours	2 weeks	
Colombo Metropolitan	2.5	5.4	355
Other Urban	4.1	4.9	243
Rural	2.3	2.3	1923
Estate	4.7	6.7	239

Source: DCS, 2002a

In recent years, after initiating oral re-hydration therapy, mortality due to diarrhoeal diseases showed a sharp decline. However the morbidity has not shown a significant reduction and it is still a major cause of hospitalization in almost all districts (Annual Health Bulletin, 2001, quoted in Shanmugarajah, 2005).

According to the findings of Demographic and Health Survey -2000 (DCS, 2002a), 3% and 6.7% of children less than 5 years of age have suffered from diarrhoeal diseases in the 24 hours and 2 weeks prior to the interviews respectively (Shanmugarajah, 2005). A study conducted in the estate sector of Kandy district also revealed a diarrhoea prevalence of 4.7% among preschool children (Amarasekara, 2001, cited in Shanmugarajah 2005).

An important factor contributing to the high morbidity from diarrhoeal diseases is the lack of access to safe drinking water. The estate sector, where prevalence of diarrhoeal diseases is high, is noted for its poorer access to the safe drinking water than other sectors. There were several out breaks of diarrhoeal diseases in the past few years where a major contributory factor has been identified as the scarcity of water during the dry season and lack of proper sanitary facilities to the areas affected. Improved practices in personal hygiene such as hand washing, using boiled and cooled water, proper sanitation measures such as improved waste disposal, proper excreta disposal, provision of adequate supply of clean water for drinking and other purposes, clinical management of cases and carriers are essential components in the prevention and control of diarrhoeal diseases (Shanmugarajah, 2005).

Vector borne

In Sri Lanka, most of the vector borne diseases occurs due to mosquitoes, with Anopheles culicifacies being considered as the predominant species in Sri Lanka contributing to diseases. Environmental and climatic factors such as temperature, humidity and rainfall often cause optimal conditions for the increase of vector density and thereby result in an increase in the spreading of the disease. Out of vector borne diseases, malaria and Japanese encephalitis are considered as the diseases most often associated with irrigation systems and hence have a greater public health importance. Vector of malaria breed in sun lit, clean stagnant water pools formulated in riverbeds (Shanmugarajah, 2005).

Malaria incidence is normally associated with the dry zone. Konradsen et al (2000) studied the relationship of rainfall to the transmission of the disease. It is reported that the disease transmission reaches a peak from October to February, which is the rainy season in the dry zone. In the wet zone, failure of the southwest monsoon creates a conducive environment for the disease. It is also reported that irrigation development-induced migration of people to dry zone, run a higher risk of contacting the disease, due to their lack of immunity.

Malaria continues to be a major public health problem and socio economic burden in Sri Lanka with several countrywide epidemics occurring in the past. One of the reasons attributed to the collapse of Sri Lanka's ancient hydraulic civilization in the 13th century is malaria. The worst epidemic in the recent times was in 1934/35, when it affected 5 million people and killed 80,000 people.

Spraying of DDT was started in 1946 and a malaria eradication program was introduced in 1958 (Konradsen et al, 2000). After the introduction of DDT spraying, the incidence of malaria has been drastically reduced and it had achieved near-eradication status by mid 1960s. However due to a multitude of factors, resurgence of the disease has occurred during the past few years. A significant technical problem was the emergence of DDT resistant forms of the vector mosquito. Hence the use of Malathion was introduced for spraying since 1977. Although, control measures were intensified, the incidence of malaria has not

declined to a low level during the past decade (Shanmugarajah 2005).

However, on the positive side, the incidence has not reached the pre-eradication levels. From 1991-2000, incidence of malaria ranged between 9-23 cases per 1000 people. Mortality due to malaria is also very low (Konradsen, 2000). In the year 2000, the mortality rate was 0.36 per 1000 patients (Fernando, 2001). Only 2 deaths from malaria had been reported in year 2003. The number of cases of malaria reported to Anti Malaria Campaign up to November of year 2004 has been less than 3000 cases (Shanmugarajah, 2005).

During the year 2001, out of the high number of cases reported, the incidence of malaria was most significant in the North Eastern province, which had 66% of all reported cases. According to sources from the Anti Malaria Campaign, the reported cases dropped significantly in 2003 but most were reported from places such as Batticaloa, Trincomalee, Polonnaruwa, and Mannar of the North and East (Shanmugarajah, 2005). This decreased incidence of malaria during the past few years has been attributed to the effective vector control programme launched in north and eastern areas as well as early case detection and treatment in the areas mentioned above.

Japanese encephalitis, which is frequently encountered in Sri Lanka, is also due to a mosquito borne virus. The vector (Culicine mosquito) usually grows in clean water with green vegetation such as irrigated paddy fields. There were 133 cases of Japanese encephalitis reported in 2003 and these cases were mainly from Colombo and Ratnapura. The incidence of this disease has been declining during the past few years due to effective immunization programme for children in high risk areas and vaccination of the primary host pigs (Shanmugarajah 2005).

Fluoride and fluorosis

Chemical pollutants not only affect human health directly, but also accumulate in aquatic life (such as fish) used as human food. Excess fluorides in drinking water may give rise to dental fluorosis in some children. When present in much higher concentrations, they may eventually cause endemic cumulative fluorosis with resultant skeletal damage in children and adults (Park, 1995 cited by Shanmugarajah 2005).

High fluoride concentrations in drinking water and resultant diseases have become a common geo-environmental problem in the dry zone areas in Sri Lanka. Areas such as Maha Oya, Monaragala, Sevanagala, and UdaWalawe are known as high fluoride areas (Chandrajith et al, 2004 cited in Shanmugarajah, 2005). An analysis of several studies carried out on the subject has revealed that prevalence rates of dental fluorosis range from 51% to 76 %. Another study conducted in Anuradhapura among fifteen-year-old school children indicates a very high prevalence rate such as 93.75% (Shanmugarajah, 2005). The ingestion of water which contains nitrates in excess of 45 mg / l may also give rise to infantile methaemoglobinaemia (Park, 1995 quoted in Shanmugarajah, 2005).

Water and health issues

Safe drinking water during droughts

Most of the disease outbreaks in recent years occurred during droughts caused by inadequacies of safe water for drinking purposes and for lack of basic hygienic practices. As such, there is a need to establish a system to provide an adequate safe water supply throughout the year.

Environmental health information system

Data on water supply and environmental health is collected and recorded in the sanitation registers maintained by the Public Health Inspectors, which have been often claimed to be lacking in accuracy and comprehensiveness. It is necessary to organise systems, which will improve comprehensiveness, accuracy and timeliness of community-based health related data.

Lab services

Apart from the Municipal Councils of Colombo and Kandy, the Food and Water division of the Medical Research Institute is the only laboratory carrying out bacteriological analysis of water. Chemicals are checked at the Government analyst department. Food labs at Anuradhapura and Kalutara, though equipped, do not carry out microbiological analysis due to lack of microbiologists. Therefore lab services should be strengthened in the periphery by establishment of laboratory facilities, provision of adequate trained staff and equipment. Though the NWSDB manage laboratories in each province, it has been shown that the services are grossly inadequate in terms of trained staff, equipment and financial resources (Shanmugarajah, 2005).

Water quality surveillance system

Periodic checking of water sources should be done for the purpose of monitoring and to control

outbreaks. It would also be desirable to have an 'on demand' service so that the communities could check the quality of water sources they use. Therefore a well-coordinated and efficient water quality surveillance system is needed. Currently, the NWSDB in coordination with the Health Ministry is attempting to set up such a system (Shanmugarajah, 2005).

Water pollution from industrial waste

The open economic policies have helped to expand industries and influenced the growth of the economy and created employment, but it has also contributed to severe pollution of water sources and air from industrial waste. This crisis has to be addressed as a national priority through formulation of a policy, which would also encourage stakeholder participation and promote inter-sectoral linkages. The present national policies on solid waste and hazardous waste management need to be strengthened to ensure regular monitoring and framing of necessary legislations (Shanmugarajah 2005).

Pesticide and fertilizer use

Agricultural use of pesticides and fertilisers should be done in an environmentally friendly manner by creating awareness among agricultural sector employees and farmers regarding good agricultural practices. These practices should be strengthened through regular monitoring supported by effective regulatory mechanisms and be further supported by promotion of alternate options like organic farming and integrated pest management practices.

Environmental management for vector control

Environmental management for vector control implies the reduction of the vector density below the disease transmission threshold limit through environmental management. Knowledge regarding ecology, population dynamics and epidemiology of diseases should be improved among health personnel in order to achieve this objective. In addition, provision of relevant staff like entomological assistants in adequate numbers need to be recruited to carry out regular surveys while improved inter-sectoral collaboration and networking of available resources is required (Shanmugarajah, 2005).

Disaster management and emergency response

Availability of adequate supply of drinking water and sanitation should be improved during floods and other natural calamities.

Community awareness

Promotion of awareness in the community regarding waterborne diseases, personal hygiene, sanitation, control of vectors, and the importance of maintaining a clean environment through health education programmes should be strengthened with special attention being paid to vulnerable populations. Such programs should be aimed at bringing an attitudinal and behavioural change of the community for sustainability of improved practices.

There must be a change in the attitudes and perceptions among community and political and religious leaders in order to accommodate linkages between water, sanitation, health and poverty in favour of economic and social development for poverty alleviation and uplifting of the community (Shanmugarajah, 2005).

Sanitation and water

Urbanization leads to a shift from the use of latrines and septic tanks to sewage systems that can cause contamination of water systems. Though dilution of pollutants minimizes the health risk, accumulation in aquatic forms such as shellfish, prawns etc can cause outbreaks of diseases. Although health facilities are provided free of charge in Sri Lanka, a cost analysis may need to be carried out to identify the economic benefits to be gained by controlling morbidity through safe drinking water than expending resources for treatment of sicknesses caused by water pollution.

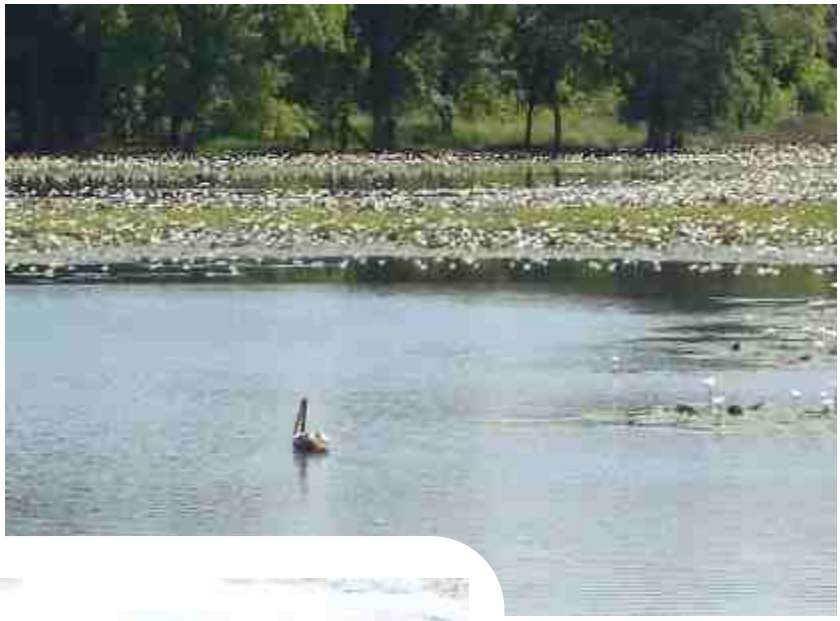
Indicators

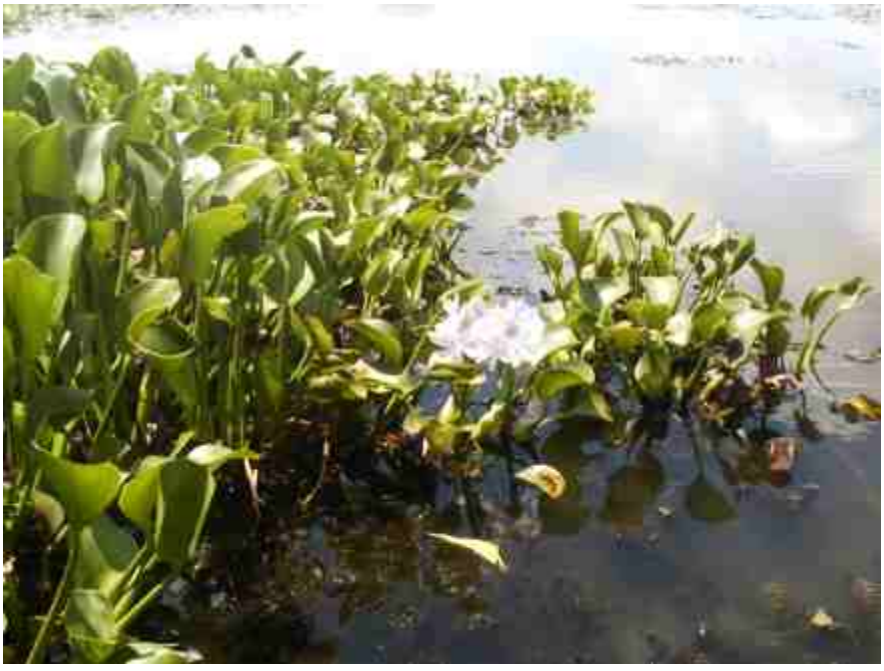
Incidence of dental fluorisis : needs urgent attention (51%-76% in some areas of the dry zone)

- Availability of safe drinking water = 75.4% of the population
- Availability of safe sanitation = 87%
- Availability of safe drinking water and sanitation for the poor = needs improvement
- Periodic outbreak of water related and water borne diseases = needs attention
- Malaria morbidity rate : 9-23 cases per 1000 people from 1991 - 2000
- Malaria mortality rate : 0.36 per 1000 patients in 2000

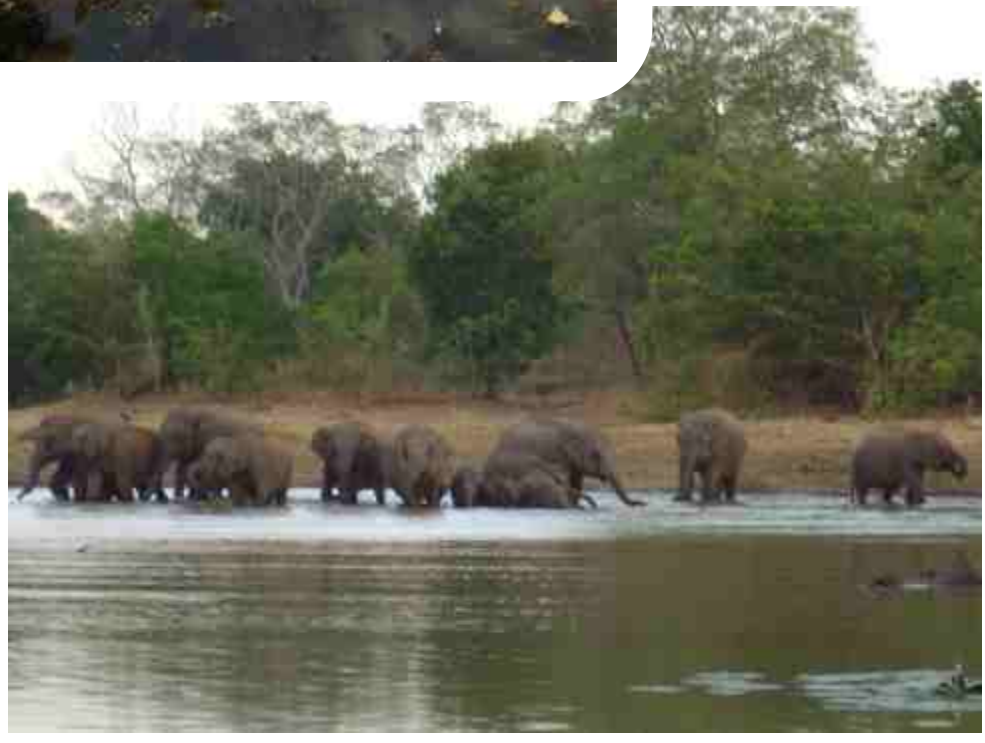
Expenditure in health sector: 1.53% of the GDP in 1990s; 1.56% in 2003; 5.6% of the total government expenditure in 1999.

Chapter 04





Water and Ecosystems



Ensuring the integrity of ecosystems through good water resources management is essential for the sustainability of water resources as well as its development. Sri Lanka has a high degree of bio diversity within her small land area. This chapter discusses the positive and negative impacts of different water use practices on the ecosystems and the measures for environmental management.

Major ecosystems

Present status of the Sri Lanka's biodiversity can be assessed on the basis of several indicators covering various aspects. The rich natural ecosystem diversity of Sri Lanka consists of (a) forest and related ecosystems, (b) inland wetland ecosystems, (c) coastal and marine ecosystems, and (d) agricultural ecosystems.

Several ecosystems in Sri Lanka have won international recognition, that is, the four Man and Biosphere Reserves (MAB), one National Heritage Wilderness Area site and three Ramsar Wetland sites. Another 41 Wetland sites of Sri Lanka are included in the Asian Wetland Directory.

The Western Ghats of India and southwest Sri Lanka as a contiguous system is recognized as one of the 25 global biodiversity hotspots (Gamage, 2005 quoted in Batagoda, 2005). Of the natural habitats, the most important ecosystems are the wetlands, natural forests, inland water bodies and the coastal zone. Climatic changes together with increased population density and expansion of the human environment have increasingly threatened Sri Lanka's biodiversity.

Forest ecosystems

Among the multitude of ecosystems found within Sri Lanka, predominant and most important are the forest ecosystems. Physiognomically and structurally different forest formations vary from rainforests of lowlands and montane regions, to dry evergreen and thorn forests in the dry zone.

The total forest cover in Sri Lanka, including the closed-canopy forests, sparse forests and mangroves managed by the Forest Department and the forest plantations and wild life reserves managed by the Department of Wild Life Conservation is about 19,150 sq.km. (DCS, 2003a) which is nearly 30% of the land area.

The major forest groupings of the country are listed as follows-

- Montane temperate forest (sub-tropical montane forest)
- Sub-montane forests (mid-country tropical wet evergreen forests)
- Lowland rainforests (tropical wet evergreen forests)
- Moist monsoon forests (tropical semi-evergreen forest or intermediate wet evergreen forests)

Table 26 : Major forest groupings in Sri Lanka

Name	Extent (km^2)	Location (m msl)	Temperature (^oC)	Rainfall (mm)	Canopy Height (meters)
Montane Temperate Forest (Sub-tropical Montane Forest)	31	< 1500	15	< 1500	10 -20
SubMontane Forests (or Mid-country Tropical Wet Evergreen Forests)	690	1000 - 1500	15-20	> 1800	
Lowland Rainforests (Tropical Wet Evergreen forests)	1,415	1000	20	> 2500	20 -30
Moist monsoon forests (Tropical Semi-evergreen Forest or Intermediate Wet Evergreen Forest)	2439	>1000		1800 - 2500	
Dry Monsoon forests (Tropical dry mixed evergreen forest)	10,940	>600		1000 - 1800	10
Dry Zone Riverine Forests	224	> 600		1000 - 1800	

Source: Weerasinghe et al, 2005 (quoting from several sources)

- Dry monsoon forests (tropical dry mixed evergreen forests)
- Dry zone riverine forests (Weerasinghe et al, 2005)

Some forest types are shown in Figure 22. Among the terrestrial natural forest ecosystems in Sri Lanka, tropical lowland wet evergreen forests or lowland rainforests exhibit the highest diversity. Out of the biotic resources, forests are the most outstanding because of their great variety, considerable species richness and remarkably high degree of endemism, watershed value and great economic potential in terms of forest products. Forests are also of great significance in terms of soil conservation, regulating stream flow, ameliorating the climate and providing many other critical ecosystem services. Greller and Balasubramaniam (1980) summarized the various forest classifications of major forest groupings that had been used in Sri Lanka up to that time, and identified major forest types based on the elevation, rainfall and mean annual temperatures. (Table 26) (Source: Batagoda, 2005)

Grasslands

Sri Lanka's ecosystems are enriched with natural grasslands and they are divided into three general categories (Pemadasa, 1984). They are the Patana (or montane), savanna and lowland grasslands. Of these, Patana are the most extensive, with a land cover of about 65,000ha in the south central highlands. The north central, north eastern and south western lowlands on the other hand support a wide variety of climatically, edaphically and phyto-sociologically distinct lowland grasslands or pasture communities, the most noteworthy being the so called Damana, Talawa, and Villu grasslands. The three types of grasslands are ecologically distinct in spite of common features they share. They have also been subjected to different degrees of biotic interferences. (Weerasinghe et al, 2005). The extent of Damana, Talawa, and Villu grasslands is about 10,000 ha (UNEP, 2005).

Inland aquatic ecosystems

Inland aquatic ecosystem comprises fresh water marshes that include villus, rivers, streams, riverine forests, flood plains, and man made reservoirs. Areas under these categories (where data are available) are listed below:

Table 27. Some inland aquatic ecosystems and their extents

Inland wetland ecosystems	
Type	Area
Freshwater marshes	10,000
Streams and rivers	22,435
Reservoirs and ponds	179,790

The flood plains of Sri Lanka's river basins have varying levels of ecological importance. The flood plains of Mahaweli river are the largest, extending to over 50,000 ha. Out of this, about 10,000 ha comprise riverine marshes called "villu". The Mahaweli flood plain is used by people for cattle grazing, fishing (in swampy areas), collecting reeds and cane, cultivation of seasonal crops including rice, and brick making. The floodplain is important as a habitat for large mammals such as elephants, as well as for bird species (CEA/ARCADIS / EUROCONSULT 1999). In the wet zone most of the

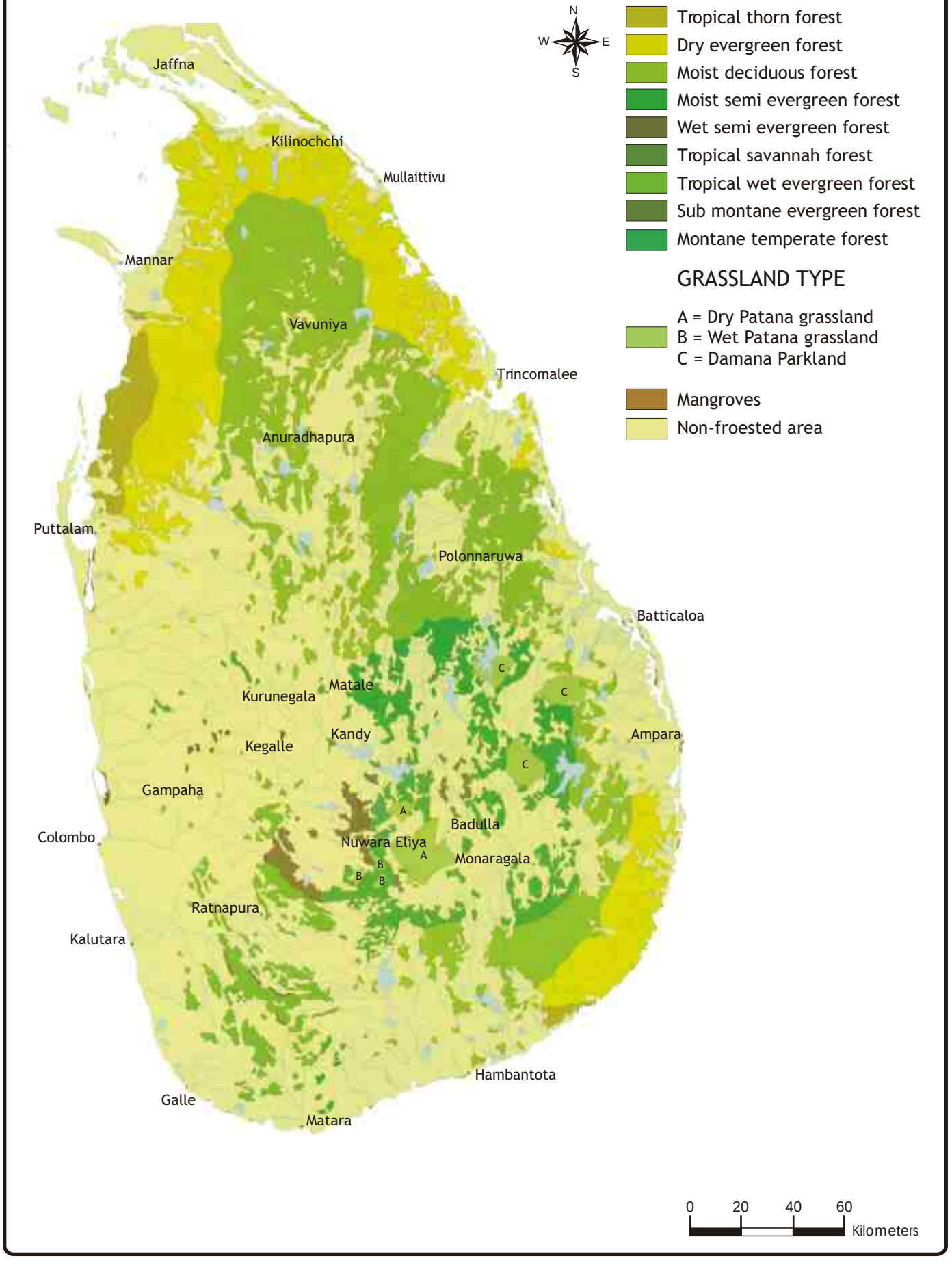


Figure 22. Natural Vegetation of Sri Lanka.
Source: National Atlas of Sri Lanka, Survey Department

Table 28. Some marine and maritime ecosystems and their extents

Type	Area (ha)
Mangrove vegetation	12,189
Salt marshes	23,819
Sand dunes	7,606
Lagoons and basin estuaries	158,017
Sea grass beds	33,573
Sea shores and beaches	11,788
Mud flats	9,754

Source UNEP, 2005. Batagoda 2005, Weerasinghe et al, 2005

flood plains are affected by urbanization and industrialization.

Marine and maritime ecosystems

The Island's marine and maritime biodiversity can be observed in coral reefs, sea grass beds, salt marshes, mangroves, sea shores/beaches, mud flats, lagoons, estuaries and sand dunes (Batagoda, 2005).

There are 94 small coastal watersheds (apart from the 103 rivers) that form a component of coastal ecosystem. Being an island, there are a number of lagoons along the sea coast. All of them are rich in biodiversity to a considerable level. Of the coastal lagoons, 16 are classified as threatened and constitute nearly 50% of the total threatened wetlands (Weerasinghe et al, 2005).

In compliance with the UN Convention on the Law of the Sea, which was ratified by Sri Lanka in July 1994, the country enjoys a total extent of approximately 489,000 square kilometres of maritime waters. The maritime zones consist of internal waters, historic waters and territorial seas, a Contiguous Zone and an Exclusive Economic Zone (EEZ). The major component of this area (437,000 square kilometres) comprise the EEZ. The island on the other hand, has a relatively small land area of 65,000 square kilometres, which gives a land to ocean area ratio of 1 to 7.5. The coastal zone is therefore of strategic significance to its populace due to accessibility to the vast resource base of the marine environment surrounding the island, from any point of its coastline of 1585 km.. However, there are several factors, which could reduce or limit the length of the coastline in terms of unhindered productive access to the ocean (Batagoda, 2005).

Environmental degradation of the coastal zone is a major hazard faced by Sri Lanka. During the last two decades there has been increasing pressure for development in the coastal zone, particularly for tourism and recreational purposes, near shore fisheries, fish farming, industrial development and housing. Communities have exploited natural resources such as sand and coral on a commercial basis. Development pressures have also led to ad hoc reclamation of estuaries, lagoon and marsh waters, and unrestricted disposal of untreated sewage leading to major pollution problems (Batagoda, 2005).

The coastal zone includes both the area of land subject to marine influence and the area of sea subject to land influence. The coastal zone can be defined based on either one, or a combination of geo-physical, ecosystem and human development considerations.

Table 29 Examples of coastal ecosystems

No.	Type	Example
1	Estuaries, especially barrier-built estuaries	Negombo Lagoon
2	Rocky seashore	Tangalla, Beruwela
3	Sea beaches	The sandy beaches along most of Sri Lanka's coastline
4	Inter-tidal mud flats	Associated with estuaries, lagoons and river mouths exposed at low tides
5	Mangrove swamps	Especially fringing mangroves associated with estuaries, lagoons and river mouths
6	Coastal brackish lagoons	Rekawa Lagoon, Mundel Lagoon
7	Saltpans (artificial	Maha Lewaya, Hambantota
8	Shrimp ponds (artificial)	Shrimp ponds in the North Western Province

Source: Weerasinghe et al, 2005

There are 67 coastal administrative units in the country. If the coastal zone is identified landward by these administrative units, and seawards by the narrow continental shelf, the coastal zone includes approximately 24% of the land area and 32% of the population (according to the 1981 census); 65% of the urbanized land area; all principal coastal road and rail transport infrastructure and principal commercial ports; fishery harbours and anchorages; 65% of the industries; 80% of tourism related infrastructure with the majority being located in the western and south-western coastal regions(most of them within close proximity to the shoreline); 80% of fish production; a significant extent of agricultural land; and substantial reserves of valuable minerals (Batagoda, 2005).

Agricultural ecosystems

The land area under agriculture is about 18,604 sq.km. or 28% of the total land area. 740,000 ha or about 40% of the agricultural area is under paddy cultivation (DCS, 2003a). There is a significant level of bio-diversity in the paddy lands, but research carried out in this field is inadequate.

An example of such ecosystem is the Muthurajawela Swamp in the southwest of Sri Lanka. This area was historically used for paddy cultivation, but was abandoned due to salt-water intrusion. At present, it spreads over 2,400 ha, and comprises mangrove swamps, brackish marshes and freshwater marshes (CEA/ARCADIS/EUROCONSULT. 1999).

The paddy fields, especially those in the wet zone, are the habitat of several fish species, which is an important source of protein for the villagers. However, their existence is threatened by high use of fertilizer, diversion of agricultural land for other urban uses etc.

Biodiversity: Threats and protection

Wetlands

In the Asian Wetland Directory, 41 wetland sites of national importance have been described for Sri Lanka (Figure 23). About 34 sites in this list are threatened due to various reasons (Annexe 5). In general, Sri Lanka's wetlands are threatened mainly due to drainage and salt extrusion, aquaculture, fisheries, landfill, coral mining, shell mining and siltation. Many are facing threats owing to conversion into housing, agriculture and salt tanks, while others are affected by fecal pollution.

In the recent times, following the Tsunami disaster of 2004, the damage to coastal ecosystems had been subjected to much discussion. In general terms, over harvesting for firewood, agricultural and aquaculture activities, salt production, and building construction have also contributed to the damage caused to coastal ecosystems. The following specific threats have been observed:

- Increasing populations of green algae Halemeda, and Crown of Thorns starfish causing damage to coral reefs.
- Increase of sea temperature in 1998 resulting in bleaching. Pollution from land-based sources, coral mining, fishing with dynamite, removal of reef organisms, harbour construction and ship anchoring are other causes of damage to coral reefs.
- Prawn farming (especially in the north-western province), mangrove clearing, land filling, infrastructure development and building, and reuse dumping, adversely affect the mangrove vegetation (UNEP, 2005).

In Sri Lanka's diversity of biological resources is high among the flowering plants, which is closely followed by the fungi, bryophytes (mosses and liverworts), fresh water algae and ferns, according to the decreasing order of taxonomic hierarchy. 927 Plant species or 28.3% of flowering plant species are endemic to Sri Lanka. The majority of these endemics are found in the low land wet and sub montane zones of the island. About one sixth of the fern species are endemic to Sri Lanka. There is little information on the

Table 30. Diversity of floral species of Sri Lanka among selected taxonomic groups

Taxonomic Group	Number of Species	Number of Endemic Species
Algae	896*	NA
Fungi	1,920*	NA
Lichens *	110	39
Mosses	575	NA
Liverworts	190	NA
Ferns & Fern Allies	314	57
Gymnosperms	1	0
Angiosperms	3,368+	875

Sources:
+MF&E(1998)
** Ministry of Transport, Environment and Women's Affairs, Sri Lanka.*
*** IUCN (2000)*
Note: NA data not available

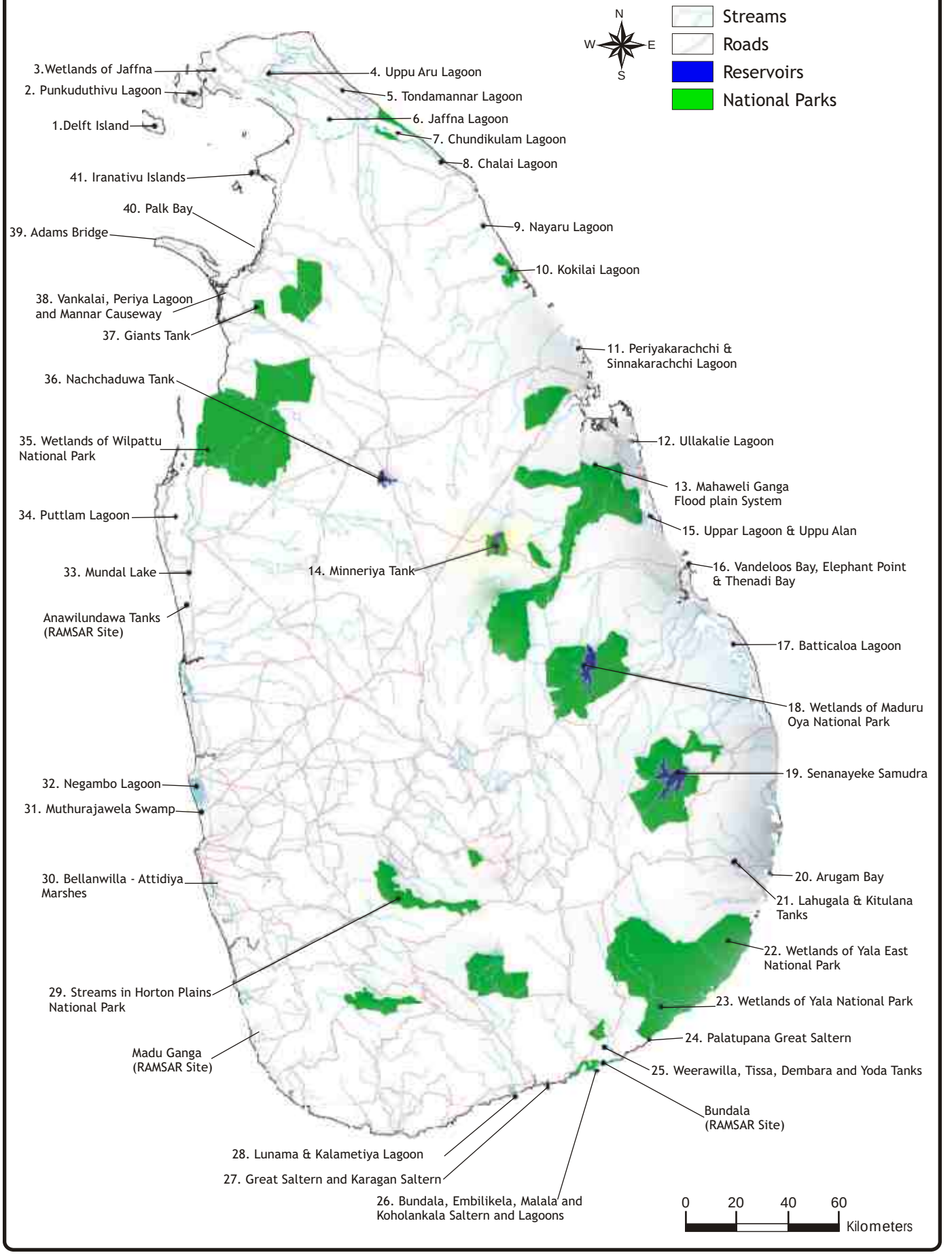


Figure 23. The location of 41 wetland sites of national importance

Prepared by U.R. Ratnayake (CEA/ARCADIS/EUROCONSULT 1999 base data)

endemic species among the mosses, liverworts, fungi, algae and lichens. In one lichen family that has been studied (Thelotremataceae), it was found that 32% of the species are endemic, and is confined to the wet zone rain forests. A large number of species, 480 flowering plants and 90 ferns have been assigned the status "threatened". Wild relatives of agricultural crop plants, like those of rice, are severely threatened due to loss of habitat (Batagoda, 2005).

Forest ecosystems

The tropical dry mixed evergreen forest of the dry zone represents as much as 54% of the natural forest cover, which is approximately 16% of the total land area in the island. The fragmentation of coastal ecosystems and forests, particularly the tropical wet evergreen forests or rain forests of the lowland wet zone, is extremely high. The close canopy forest cover is decreasing gradually, which impacts on biodiversity (Figure 24).

Information on genetic diversity of natural flora and fauna is extremely limited. A few genetic studies have been done on plants. These studies reveal that forest fragmentation and habitat size reduction have resulted in "genetic erosion" of certain endemic species (Batagoda, 2005).

Figure 24 shows the decline of close-canopy forest cover, over the years. The dense natural forest cover in 2002 was 1.46 million ha which is approximately 22.4% of the land area (Fernando 2005, cited in Batagoda, 2005). The rapid decline of forest areas during 1960 to mid 1980s was mainly attributed to the expansion of irrigated agriculture (Handawala, 2002). However, there appears to be a decline in the deforestation since 1980s. The reasons could be the slowing down of agricultural expansion, the enforcement of a moratorium on timber extraction, and the implementation of environmental regulations.

Despite growing awareness of the importance of conserving Sri Lanka's rich biodiversity, there are serious threats to this natural wealth through human activities such as destruction of habitats, selective exploitation of commercially important species, unsustainable collection of biological resources for subsistence needs, and the introduction of alien invasive species. From among the 807 indigenous species (and one naturalized exotic) of flowering plants assessed for threat at the national level, 690 have been identified as Threatened or Highly Threatened in the 1999 List of Nationally Threatened Species of Fauna and Flora of Sri Lanka. Of these, 158 may well be extinct, as 130 have not been recorded since 1900, while a further 28 have not been recorded since 1950. Furthermore, over half of the threatened species are endemics. Among the species that are suspected to be extinct include over 30 species of ferns (Batagoda, 2005) and over 50 species of flowering plants (NARESA 1991) including 13 species of orchids (Weerasinghe et al, 2005).

Animal species

Among the animals, the diversity of vertebrates is relatively well known compared to invertebrates. Among the animal species consisting of different vertebrate groups, the highest proportion of endemic

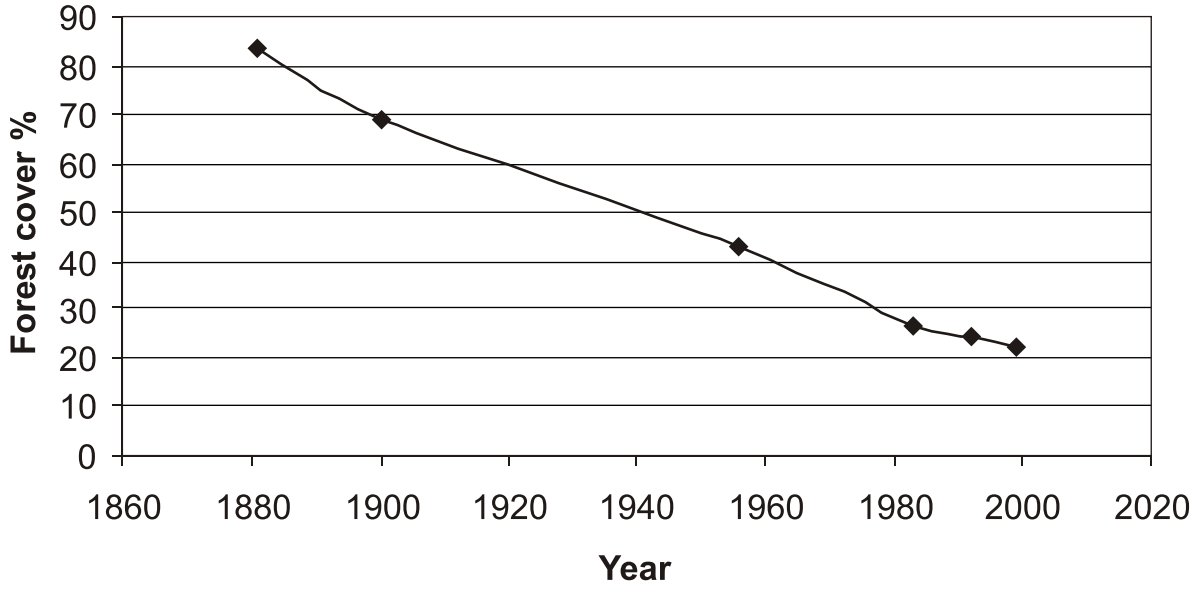


Figure 24. Decline of closed canopy forest cover
Source: ME&NR, 2002, Batagoda, 2005, and UNDP, 2004

species is recorded among the amphibians (65%), reptiles (52%) and fresh water fishes (41%). Among the invertebrate groups studied in depth, the highest proportion of endemics is recorded among fresh water crabs (100%) and land molluscs (76%). Like endemic plant species, most of the endemic fauna too are confined to the wet zone natural ecosystems. Over 75% of the endemic species in each of the vertebrate groups, and over 50-100% of species in the invertebrate groups are under threat. Extinct animals include the Gaur and Comb Duck (Anon 1991quoted in Batagoda, 2005) and possibly 13 species of snakes.

With reference to animal groups, there are 561 species of nationally threatened animals from a total of 1243 species in selected taxonomic groups that were evaluated for threat. According to the IUCN 2000 Red List of Threatened Species, 44 species of terrestrial and freshwater species in Sri Lanka are threatened at the global level. (Weerasinghe et al, 2005).

Threats and driving forces

The main driving force of deforestation is land needs of the increasing population, thus creating increased pressure on forest lands for conversion to non forest uses. Another key factor for reduction of forest cover had been the conversion of forests for planting of agricultural crops such as, coffee, tea and rubber. Inappropriate land use trends, unsuitable forestry practices and the high market price of timber are some other causes for deforestation. Due to the extensive, uncontrolled deforestation and land degradation, the government of Sri Lanka imposed a complete ban on logging in all natural forests in 1989 (Fernando 2005, cited in Batagoda, 2005).

Most of the country's population is in the wet zone, with a high density close to the urban centres. Wet zone is also the area with the highest biological diversity and rich watersheds. Land scarcity coupled with lack of off-farm income opportunities and poverty has led to high exploitation of natural resources for livelihood and human activities thereby significantly affecting the ecosystem balance. In the case of forest ecosystems, the major issues of human interventions include:

- Deforestation, mainly for chena cultivations
- Irrigated agriculture at major development schemes
- Logging and timber extraction,
- Conversion of forest land to pioneer agriculture,
- Over-use of forest bio-resources such as collection of non timber forest products, rattan and bamboo, medicinal plants and food items and Kitul (Caryota urens) tapping,
- Poaching.
- Cattle grazing and deposition of cattle dung (identified as one of the causes of eutrophic conditions in standing water bodies).

Table 31. Species diversity of Sri Lanka among selected taxonomic groups - fauna

Taxonomic Group	Number of species	Number of Endemic Species
Rotifera*	140+	NA
Anthozoa (corals)	180	NA
Annelida *	18	NA
Monogenea (Flatworms)*	23+	NA
Crustacea*	400	NA
Land snails	266	201
Mayflies*	18	18
Mosquitoes	139	NA
Carabid Beetles	525	127
Butterflies**	243	20
Spiders	400	NA
Coastal fish	400	NA
Freshwater fish**	78	32
Amphibians**	54	35
Reptiles**	155	81
Birds (including migrants)	435	23
Mammals	90	14

*Sources:BCAP (1998)*Ministry of Transport, Environment and Women's Affairs, Sri Lanka** IUCN (2000)*

Climate and ecosystems

Climatologically, Sri Lanka has two characteristic eco-zones, which gets divided further by a central mountainous region that reaches up to altitudes of 2,500 meters intercepting the monsoonal winds. This creates an ever-wet southwestern quarter, and a rain shadow in the remaining area where a drier climate prevails during a greater part of the year. The three major agro ecological zones thus created are the wet, intermediate and the dry zone. The far northwest and southeast regions have a climate bordering on arid conditions. Within this broad categorization, each zone is further divided into 23 agro-ecological zones by the Department of Agriculture. Associated with these agro-ecological zones are a number of distinct floristic zones, which contain a rich biological diversity, which has been ranked as the highest per unit area in Asia. Sri Lanka also has very high endemism among both of its fauna and flora, as the island of Sri Lanka had been isolated from the Indian subcontinent approximately 20 million years ago (Weerasinghe *et al*, 2005).

Protection of biodiversity

The extent of land set apart for protection of biodiversity in the country is approximately 951,000 ha, or about 14% island's total land area. This is an increase from 8% in 1950's (NCED, 2005). Of this area, 12.3% is administrated by the Department of Wild Life Conservation (DWLC) and 1.7% by the Forest Department (FD), designated under various categories of reserves under the protected area

network. To a limited extent, a part of the island's biodiversity is under ex-situ conservation. Live collections of selected species and germplasm are maintained in many centres. The Plant Genetic Resource Centre (PGRC) of the Ministry of Agriculture, field gene banks, medicinal plant gardens, as well as the botanical and zoological gardens are the agencies and units that contribute to the preservation of plant and animal species.

As a strategy for the conservation of Sri Lanka's rich biodiversity as well as its watersheds, a number of areas had been declared as National Parks, which come directly under the purview of the Department of Wild Life Conservation. Some key species in the national parks of Sri Lanka and their status are reproduced below from A Guide to National Parks of Sri Lanka, Department of Wildlife Conservation, 2001(Weerasinghe et al 2005).

Despite the increase of total protected area in the country, such land in the wet zone has decreased from 363,854 in 1994 to 346,684 in 2001.

This is due to the population increase and urbanization in the wet zone. As the biodiversity in the wet zone is high, this can be considered as a threat (NCED, 2005).

Information related to important biodiversity reserves in Sri Lanka are summarized in Table 32.

Environmental Impact Assessment

The Environmental Impact Assessment (EIA) in Sri Lanka is a link between environment conservation and development. It is a mechanism available to integrate environment protection measures into development activities at very early stages of planning.

Two important legal instruments created under the NEA were the "Environmental Impact Assessment" (EIA) and "Environment Protection Licence" (EPL). In Sri Lanka the EIA was first introduced through the Coast Conservation Act no. 57 of 1981, which covered projects that came under the purview of the Coast Conservation Department. The National Environmental Act (NEA) of 1988 expanded EIAs to other areas. After the establishment of a Ministry in charge of the Environment in 1990, this Ministry now carries out the policy development functions of the CEA under the NEA.

All prescribed projects listed (by type, magnitude and location) under the NEA, are required to carry out an EIA clearance from the appropriate authority. If the environmental impacts of the project are not very significant then the project proponent will be requested to do an Initial Environmental Examination (IEE). For effectiveness of the procedure, EPL process for industrial and service units was decentralized in 1994 and 1996, where Local Authorities were empowered to issue licences to specified 20 industries. Both these processes, which have been simplified in 2000, enable entrepreneurs to continue with their ventures without administrative impediments when a prescribed list of industries that should adhere to the EPL was gazetted. Under the amendment to the NEA, the Minister has the authority from time to time to prescribe the activities for which an EPL is required. With this provision the CEA now issue licences to 80 types of activities and the Local Authorities for 45 activities for which an EPL is required. The renewal of an EPL had been extended from one year to every three years. These changes can be considered as major milestones in the process of integrating development and environment, so that the outcomes will mutually benefit each other while protecting the ecosystems (Batagoda, 2005).

Policies, programmes and implementation

The setting

Currently about 55% of the total area under natural forest is reserved and administered by either the Forest Department (FD) or the Department. of Wildlife Conservation (DWLC) .Conservation are as

Table 32 Important bio-diversity reserves in Sri Lanka

Reserve Type	Number	Name of Reserve	Area (ha)
Man & Biosphere Reserves (MAB)	04	Hurulu	25,500
		Sinharaja	11,187
		Kanneliya, Dediyagala, Nakiyadeniya	12,050
		Bundala	6,216
National Heritage Wilderness Area	01	Sinharaja	11,187
Ramsar Convention Sites	03	Anawilundawa	1,397
		Bundala	6,210
		Madu Ganga	915

Sources: Weerasinghe et al, 2005, M.P. de Silva (pers. comm.), 2005. http//www.Ramsar.org/ The Annotated Ramsar List: Sri Lanka, http/www.unesco.org/br/brdir/directory biores:asp
Note: In some occasions reserves overlap.

under the Forest Department in 1995 comprised of Forest Reserves, Proposed Forest Reserves, and National Heritage and Wilderness areas. Important biodiversity and watershed areas such as Sinharaja, Knuckles and a further 31 wet zone forests have been classified as Conservation Forests, introducing a new category of Protected Area under the Forest Department. This will also include 20 mangrove sites selected for conservation and the entire 42,000 ha. of forests at elevations above 1,500m. The Protected Area Network (PAN) will thus include all conservation forests and Sri Lanka's only National Heritage and Wilderness Area the Sinharaja forest. The categories of Protected Areas within the jurisdiction of the Department of Wildlife Conservation comprise Strict Natural Reserves, National Parks, Nature Reserves, Jungle Corridors and the Sanctuaries.

Policies There are a number of polices and plans that have a bearing on national planning in relation to biodiversity conservation and sustainable use. Some of them are National Forestry Policy (1995), National Policy on Wild Life Conservation (1990) and National Watershed Policy (2004). Some of the selected important policies are listed in Annex 9.

Forestry and wildlife

In 1997, steps were taken to prepare a plan of action to conserve biodiversity in Sri Lanka. The final document titled Biodiversity Conservation in Sri Lanka: A Framework for Action, which was endorsed by the Government in August 1998, now constitutes national policy document of the Government on Biodiversity Conservation and Sustainable Use.

The National Forest Policy, formulated by the Ministry of Forestry and Environment was approved by the government in 1995 (Batagoda, 2005). This policy emphasizes the importance of retaining the present natural forest cover, and increasing the overall tree cover. A large part of the natural forests are to be completely protected for the conservation of biodiversity, soil and water resources. Multiple use forestry is to be promoted and the natural forests outside the protected areas system are to be managed in a sustainable manner for forest products and services. This National Forest Policy (1995) recognises the main areas identified in Agenda 21, such as multiple roles and functions of forests, protection and sustainable management and conservation of forests, reforestation and forest rehabilitation, efficient utilization of forest products etc. The main objectives of the National Forest Policy (1995) have been put forth as,

- To conserve forest for posterity with particular regards to biodiversity, soils, water and historical, cultural, religious and aesthetic values.
- To increase the tree cover and productivity of the forests to meet the needs of present and future generations for forest products and services.
- To enhance the contribution of forestry to the welfare of the rural population and strengthen the national economy with special attention paid to equity in economic development.

Recognising that the state agencies alone cannot protect and manage the forests effectively, the national forest policy promotes people's participation in forestry development and conservation and therefore emphasizes the need to develop partnerships with local communities, NGOs, and other stakeholder groups outside the state sector.

A National Wildlife Policy was formulated by the Department of Wildlife Conservation in the year 2000, to emphasise the commitment of the Government to conserve wildlife resources for the benefit of present and future generations while assuring the sustainable use of the resource for education, recreation and research in a transparent and equitable manner. The policy emphasizes the need for effective protected area management with the participation of local communities.

Watershed and coastal zone management

The Government of Sri Lanka has adopted a National Watershed Management Policy (ME&NR, 2004a) with the objective of making the optimum utilization of natural resources in a sustainable manner. In addition, National Wetland Policy was adopted with the objective of managing wetlands in the country sustainably (ME&NR, 2004b). Wetland management regulations have already been drafted under the National Environment Act No. 47 of 1980. The wetland policy and the regulations are intended to provide a strong regulatory framework for the management of wetlands in the country.

The National Conservation Review of Sri Lanka implemented by the Ministry of Agriculture, Land and Forests constituted a systematic assessment of biodiversity in natural forests of the country. Its overriding objective was to define a national system of protected areas with forest biodiversity fully represented. The outcomes of this review have led to the setting up of a database on forest biodiversity, and the creation of new categories on protected areas for the conservation of forests.

Implementation arrangements

Some of the important implementation arrangements in environmental management are as follows:

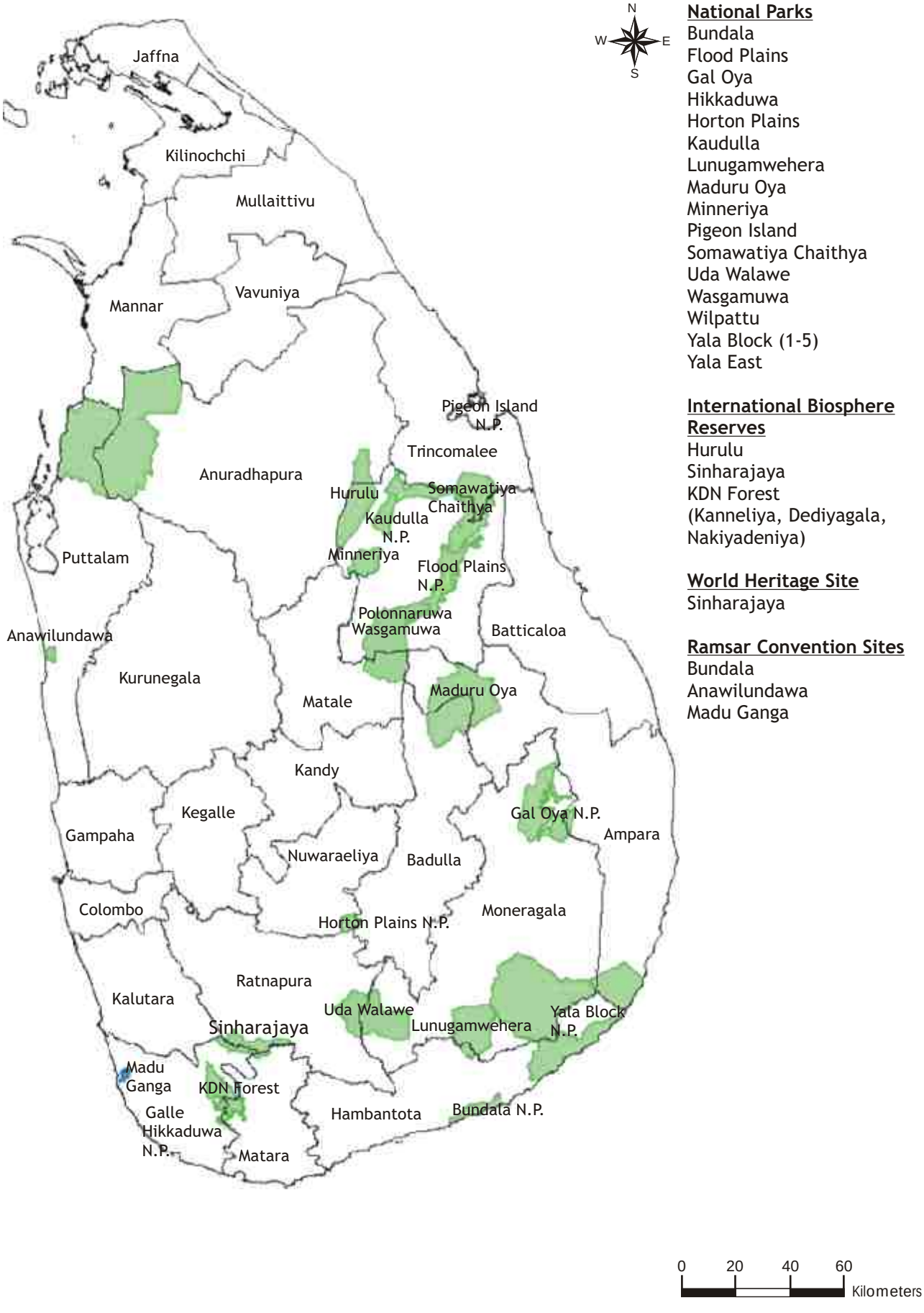


Figure 25. National Parks and ecosystems of international importance

Prepared by Forest Department, GIS Unit

- Biodiversity Conservation Action Plan (1999)
- Coastal Conservation Action Plan (2000)
- Clean Air Action Plan (1995)
- Forestry Sector Master Plan (1995)
- National Conservation Strategy (1988)
- National Environmental Action Plans starting from 1992

Under the provisions of the Coast Conservation Act a comprehensive Coastal Zone Management Plan was prepared and the approval of the Cabinet of Ministers was obtained in 1990 (Batagoda, 2005). The CZMP focuses its attention on coastal erosion management, conservation of natural coastal habitats and conservation of cultural, religious and historic sites, and areas of scenic and recreational value. The objectives of the Coastal Zone Management Plan includes the identification of coastal problems that need to be addressed with a clear indication of reasons for the importance of such problems; presentation of the management programme to address these problems; identification of the measures for the Government, non-government organizations and the general public to reduce the scope and magnitude of coastal problems, the identification of research to enhance the management of coastal resources. The Cabinet of Ministers approved the "National Coastal 2000 Action Plan - Recommendations for a Resource Management Strategy for Sri Lanka's Coastal Region" in 1994, as the follow-up action of Coastal Zone Management Plan (CZMP) to more holistically address coastal zone management.

The Forestry Sector Master Plan was developed in 1995 to implement the National Forest Policy included the main activities identified in Agenda 21 (Batagoda, 2005). The Forestry Sector Master Plan places special emphasis on the conservation of biological diversity both in the forest and wildlife sub sectors. It also makes a policy direction for forest management through the adoption of traditional community participatory management approaches.

The National Policy on Wildlife Conservation was approved in 1990 and again reviewed in 2000 to conserve wildlife resources for the benefit of present and future generations, while assuring the sustainable use of this resource for education, recreation and research in a transparent and equitable manner.

The government in1998 adopted a framework action plan for conservation of biodiversity in Sri Lanka. This addresses most of the policy issues in biodiversity conservation. Currently a study is underway to identify gaps as well as other thematic and cross-cutting areas for which additional recommendations are being framed.

Physical infrastructure development in the coastal zone has been given due consideration by identifying setback-guidelines based on coastal erosion rates, beach dynamics, shoreline ecology and related activities (Batagoda, 2005).The Coast Conservation Department has decentralized several of its functions to the Divisional Secretaries under the terms of Public Administration circular No. 21/92 dated 21st May 1992 (Section 5 of the Coast Conservation Act No. 57 of 1981) which enables the delegation of authority to improve the efficiency of coastal management. A permit system is adopted for restricted sand mining and for construction of small buildings. Ensuring the compliance with conditions stipulated in permits is through a monitoring system which includes periodic site visits, direct supervision, nomination of state authority, and compliance surveys. In the case of larger development projects which could have significant impacts on the environment it is necessary for the developer to prepare and submit an Environmental Impact Assessment (EIA) report prior to obtaining approval for the implementation of the project.

A committee system called the Committees on Environment Policy Management (CEPOMs) has been established for the purpose of coordinating environment related policy matters among the sectors such as those with respect to transport, agriculture, fisheries, urban development ministries etc., and related line agencies (Batagoda, 2005). The CEPOM Biodiversity, and the national level Committee Integrating Environment and Development Policy (CIEDP) have functioned for biodiversity related policy co-ordination and integration of biodiversity concerns into the national planning process through sector-based plans, and in connection with energy generation and supply, transport, irrigation, urban development etc. The national inventory of flora in Sri Lanka is completed, and 14 volumes of Flora of Ceylon have already been published (Batagoda, 2005). The national herbarium under the Ministry of Agriculture is functioning satisfactorily, updating continuously the information on national flora. The National Zoological Survey which was established in 1990 to take inventory of the national fauna has failed to reach expectations. The IUCN in Sri Lanka and national universities initiated action to inventorise the populations and other parameters associated with fauna and flora in the National Red Data Book of Sri Lanka in 2000.

Legislation and institutions

At present there are 20 directly relevant legal instruments and more than 80 others which indirectly enforce the control, regulation and management of biological resources in Sri Lanka. Due to the cross-sec

toral nature of Biodiversity there are 20 institutes engaged to implement the above legal instruments (Batagoda, 2005). Some of the important legislation in environment includes:

- National Environmental Act of 1980 amended in 1998
- Soil Conservation Act of 1951 amended in 1996
- Coast Conservation Act of 1988
- Mines and Minerals Act of 1992
- Forest Ordnance, revised in 1998
- Fisheries and Aquatic Resources Act of 1996

Many of the legislation were amended recently to incorporate concerns arising from recent issues in environmental management.

In 1993, the Fauna and Flora Protection Ordinance was amended to include buffer zones. Many of the forest areas in view of their importance in terms of water and biodiversity have been declared as conservation forests under the amendments made to the Forest Ordinance. Similarly, the Forest Ordinance of 1907 has been amended several times to include community and participatory management concepts. The ordinance is presently being further amended to include forestry concepts such as zoning of forests as per management type, multiple-use forestry managed by communities living around forests, move from more participatory approaches in forest management and law enforcement rather then command and control approaches, and private sector participation in forestry activities etc (Batagoda, 2005).

The Government also introduced the Coast Conservation Act No. 57 of 1981, which came into operation in October 1983. The Coast Conservation (Amendment) Act No: 64 of 1988 prohibits engaging in mining, collecting, possessing, processing, storing, burning and transporting in any form whatsoever of coral within the coastal zone. In effect, removal of coral other than for research purposes is prohibited. The Government in 2000 decided to restrict the usage of coral based lime in the construction work of the government sector and now it is implemented through the construction agencies in the country (Ministry of Forestry and Environment 2000).

Sand mining has been controlled to a satisfactory degree by the Coast Conservation Department and this activity is allowed only in selected areas of the coastal zone. More recently, the Ministries of Environment and natural Resources and Irrigation and Water Management (2003-2004) took action to control river sand mining.

Provision is made in the Constitution of Sri Lanka (Chapter IV, Article 27(14)) for the protection of the environment by stating that the state shall protect, preserve and improve the environment for the benefit of the community. The Chapter IV, Article 28(f) of the constitution emphasises the duty and obligation on the people by stating that it is the duty of every person to protect nature and preserve its riches. Section 8 of the National Environment Act (NEA) No. 47 of 1980 states that the powers, functions and duties of the Central Environmental Authority (CEA) shall be to recommend national environmental policy and associated criteria to the Minister. Such as those for the protection of the environment and to be protected with respect to the uses and values whether tangible or intangible, the quality to be maintained, the extent to which the discharge of wastes may be permitted without any detriment to the quality of the environment, long-range development uses, planning and any other factors relating to the protection and management of the environment. The NEA which was amended in 1998 is an umbrella statute on environment and natural resources management, which empowers the CEA to recommend basic policy on the management and conservation of the country's natural resources in order to optimise benefits, and to preserve the environment for the future (Batagoda, 2005). A more detailed list of policies, strategies and legislation appears in Annex 9.

Indicators

Indicator	2000	2004	2005
Man and biosphere reserves	2 (36,687 ha)	3 (48,737 ha)	4 (54,953 ha)
Ramsar wetland sites	1 (6,210 ha)	3 (8,522 ha)	3 (8,522 ha)
Number of wetland sites of national and regional importance			41
Number of threatened wetland sites			34
Protected area (reference-bio diversity)	15%		
Total Forest cover		30%	
Close canopy forest cover		22.4%	

UN-Water/WWAP/2006/11

Chapter 05

Water and Human Settlements

The majority of Sri Lankan people live in rural areas. Like in many developing countries, the urban population of Sri Lanka is growing. Urban areas have increasingly become the focus of human settlements and economic activities, and they present distinctive challenges to water managers. At the same time, the importance of well designed rural settlements can not be overlooked. This chapter discusses the issues associated with both types of human settlements and role of water in addressing the key issues.

Urban and rural settlements in the context of Sri Lanka

Municipal Councils, Urban Councils and Town councils were treated as urban areas during the period of 1953 to 1981 census. But from 1992 the local government institutions were reorganized as Municipal Councils, Urban Councils and Pradeshiya Sabhas, and only the Municipal Council and Urban Council areas are considered as urban areas in 2001 census (DCS, 2003a). As such, some of the areas that were under Town Councils are now treated as rural areas. As a result there is no urban population in Moneragala, Polonnaruwa, Kilinochchi, Mullaitivu and Mannar districts. Some changes in sector-wise population is observed due to this definition change which has no relation to the migration patterns (Nimal Rohana, 2005).

Both urban settlements and rural settlements are not new phenomena to Sri Lanka. History tells that Anuradhapura and Polonnaruwa, which were the ancient Sinhala capitals until the 12th century, were highly populated urbanized settlements. Rural settlements may have preceded the urban settlements in ancient times. But while the rural settlements evolved continuously, the evolution of the urban settlements were disturbed from time to time.

Panabokke et al (2002) theorize that villages in Sri Lanka grew up as small settlements around village tanks. Some of these villages have been in existence for more than 2000 years. The construction and the management of these small tanks was the responsibility of the village community. As such, the village was not vulnerable to the political disturbances in the central government. The village administration system also evolved around the management practices associated with the village tank.

Urban and rural population

As shown in Figure 26, the population of Sri Lanka increased rapidly from the middle of the 20th century. The population in 2001 was around 18.7 million according to the census carried out in that year.

Figure 26 shows the increases of both rural and urban populations. However, it may be noted that a comparison of rural and urban population increases could be distorted due to the definition changes described above. According to official estimates the urban population was about 21.5% in 1981 (DCS,2003a). As the information from several Districts in the North and East were

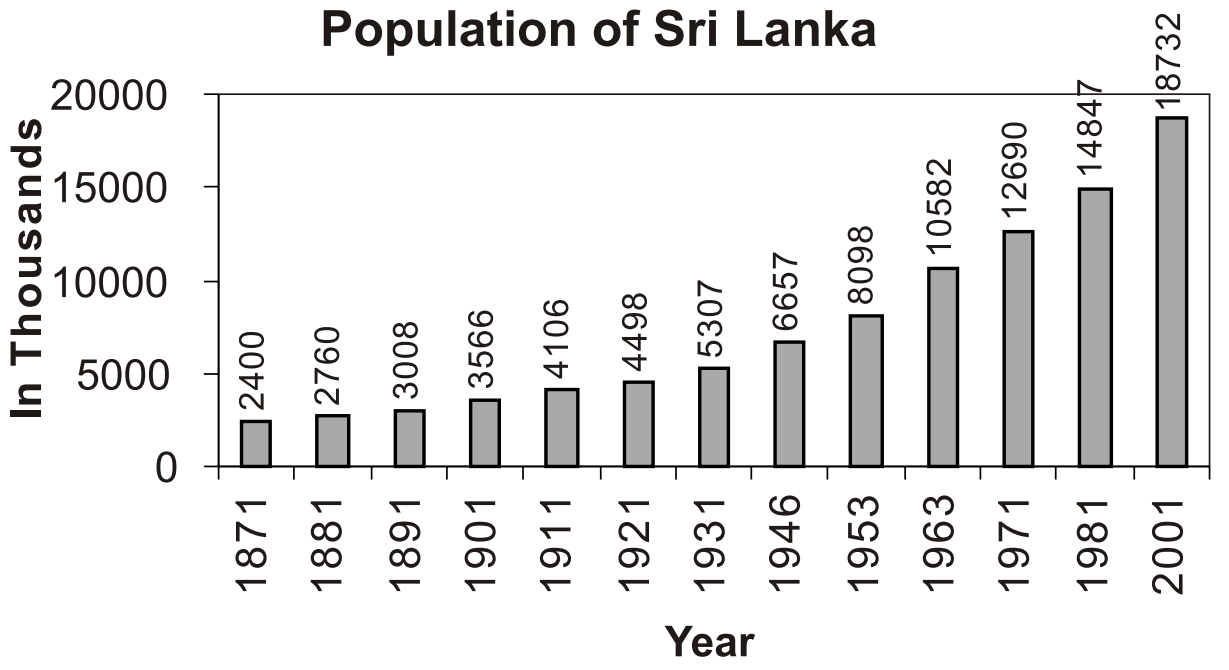


Figure 26. Trends of population increase in Sri Lanka
Source: Department of Census & Statistics. 2004. Statistical Abstract 2003 Vol1/2004, Department of Census & Statistics

not available in 2001, a realistic estimate for the present cannot be made with the available data.

It has been noted that there are peripheral areas around officially designated urban areas, which show urban characteristics. Inclusive of such areas as well, the share of urban population has been estimated as approximately 30% in 2000. This is projected to increase and 45% by 2015 and to 65% by 2030 (Somaweera. 2002).

Poverty

An attempt has been made by the Census and Statistics Department to establish an official poverty line for the country acceptable to all parties concerned. Households whose consumption expenditure falls below this level are considered poor.

Some rural and urban poverty characteristics are compared Table 33.

Water has differential impacts on the rural and urban poverty. It can be seen that the increase of wet spells in the wet zone and decrease of that in the dry zone can have negative impacts on the livelihoods of both rural and urban poor.

Urban poverty characteristics

Income and earning capacity are the most important dimensions of poverty, as identified by the communities. However, the water-related problems such as lack of private access to toilets, private access to water supply and land drainage too are among the major problems faced by the communities. The water for domestic use is given the highest priority (43%)

Table33. Poverty indicators for different sectors

	Head-count-poverty ratio-national poverty rate (2002)	Poverty gap index (2002)	Per-capita income (SLRs.)
Rural	24.7	5.6	2835
Urban	7.9	1.7	4997
Estate	30.0	6.0	1663

Note: National poverty rate is the percentage of population living below the national poverty line D C S , 2004a). Poverty Gap Index is the mean proportionate poverty gap in the population, identifying the requirement to uplift the poor above the poverty line (Nimal Rohana, 2005).

among the services required, other priorities being sanitation and sewerage (27%), electricity (24%) and rainwater drainage (6%) (Gunetilleke et al, 2004).

Despite disadvantages such as having to pay bills, the communities consider having private water connections and private toilets as a priority. According to a survey carried out in the city of Colombo, the private access to water supply varies from 50% of the population to 100%. Similarly, the private access to toilets varies from 51% to 100% (Gunetilleke et al, 2004).

Access to improved water supply in urban and rural settlements

Vision, Policies and strategies

Wickramage (2002) describes the vision of the water supply and sanitation sector as follows:

"To improve the standard of living, promote economic prosperity and preserve the environment by providing access to safe drinking water and adequate sanitation for the people of Sri Lanka."

The objective of the national policy on water supply is to ensure that all residents have access to safe drinking water by 2025. The intermediate target for 2010 is 85% (Wickramage, 2002). The sources of safe drinking water include protected wells, tube wells and pipe-borne water.

Presently (2000) the national water supply coverage can be described as follows:

Pipe borne water supply	23.4 %
Hand Pump / Tube wells	4.8 %
Protected dug wells	47.2 %
Total	75.4 %

(Source: DCS, 2002a)

(*Note:* Ministry of Urban Development and Water Supply quoted a lesser value of 71.4% for the population with access to safe drinking water, according to an official communication in 2005).

Achieving national standards in service level and quality of water in both urban and rural areas is one of the water supply sector targets (George, 2005).

The available information (Table 34) shows that accessibility to safe drinking water varies across the sectors, with Colombo metropolitan area having a high level of access.

Rural water supply

The NWSDB operated 266 water supply schemes in 2000 and 121 of them were in rural areas. The average duration of water availability in areas outside municipalities is about 14 hours/day (CBSL, 2001). It has been observed that the quality of service to rural areas is different from the urban areas.

There are several projects and programmes undertaken to provide good quality water supply to rural communities. They include ADB assisted Third Water Supply and Sanitation Project which plans to improve water supply and sanitation and educate people in hygienic matters in six rural districts. Both NWSDB (CBSL, 2001) and Water Resources Board carry out programmes to provide tube wells for the rural communities. According to Panabokke and Perera (2005) about 30,560 tube wells have been constructed by the two agencies.

Until 1970 the rural population depended mostly on dug wells for their drinking water supply. However, with the initiation of pipe-borne rural water supply schemes and ground water development for domestic purposes since 1970s, rural water supply is obtained from multiple sources (Jayasekara, 2002). Considering the poor chemical quality of ground water in the dry zone (Dissanayake and Weerasooriya, 1985), the dependability of dug wells, as a source of safe drinking water is doubtful.

The efforts of Government, NGOs, Community Based Organizations (CBOs) and private sector have resulted in significant increase of safe drinking water availability to the rural population. Noteworthy changes have been observed between 1992 and 2001 in

Table 34: Availability of Safe Water Across Sectors

Sector	Source of supply	Sample size	Percentage of Households
All Sectors	Safe sources	6160	75.4 %
	Unsafe sources	2009	24.6%
Colombo metro	Safe sources	891	99.3%
	Unsafe sources	6	0.7%
Other urban	Safe sources	575	95.7%
	Unsafe sources	26	4.3%
Rural	Safe sources	4551	74.6%
	Unsafe sources	1536	25.4%
Estate	Safe sources	145	24.8%
	Unsafe sources	439	75.2%

Source: DCS, 2002a

Hambantota District, where the coverage increased from 52% to 88%. Similar increases are observed in Puttalam (64% to 86%) and Polonnaruwa (40% to75%) in the same period (Jayasekara, 2002).

Unlike in the case of urban water supply, a number of Government agencies and NGOs provide drinking water for the rural settlements. This has resulted in different levels of quality of the service (Jayasekara, 2002).

Urban water supply

Urban water supply is defined as water supply within Greater Colombo, within all urban and municipal council administrations, urban areas specially designated by the Urban Development Authority, and within towns and Pradeshiya Sabhas (lowest level of elected local authority) where the population is more than 6,000. However it has been noted that there is considerable population in peripheral areas of urban centres where water supply and sanitation facilities are generally poor. There are concentrated towns within rural areas, having a population less than 6,000 but which have urban characteristics. These two types of human settlements though having urban characteristics are still categorized as rural areas (Nimal Rohana, 2005).

At present, about 75% of the urban population are served with pipe-borne water. The NWSDB plans to increase the coverage to 100% in 2010 (George, 2005). The sources of drinking water and safe drinking water sources for urban sector are as follows:

In 2000, the average duration of water supply in the Colombo Municipal area was 21 hours/day and 20 hours in other municipalities.

Water supply for urban poor

Settlement characteristics: Sri Lanka has a long history of providing infrastructure and services to urban poor living in under-served settlements. The government initiated several short and long-term programmes to provide shelter and basic amenities for such population. The growth of urban population, especially in the capital city of Colombo and the suburbs, has made this activity very important. At present, the population density in the Colombo District is very high, 3,300 persons per sq.km compared to the national average of about 300 persons/sq.km. The Colombo Municipal Area supports approximately 131,000 households with a population of about 642,000 persons in an area of about 37.4 sq.kms (DCS, 2003a) and a large migratory population who daily visit the city for livelihood purposes. It is estimated that this "floating population" into the city of Colombo is about 700, 000 (UNEP, 2005).

Urban poverty is less visible when the national or district level indicators are studied; the urban sector having 14% of households below the higher poverty line, while the rural sector has 31%. (DCS, 2004a). However, there are a significant number of poor people living in the cities, especially in Colombo who live in under-served settlements, which are characterized by poor services and infrastructure. A survey made in 2002 identified 1614 settlements in the city of Colombo (Gunetilleke et al, 2004) where the population density is extremely high, approximately about 820 persons/ha (82,000 persons/sq.km.). The average size of a housing block is about 1.5 perches (1 perch= 25 sq.m).

Institutional arrangements The community-based organizations include Community Development Councils (CDC), women's societies, funeral aid societies and religious societies. They provide or assist in providing the services such as drainage, sanitation, credit, health services, employment and funeral services.

The CDCs were established in many underserved settlements in Colombo under the Urban Basic Services Improvement Programme of the UNICEF. They focus on improving housing, and implement projects to provide services and infrastructure. The CDCs organize and mobilize communities in decision-making and implementation activities.

Programmes There had been several programmes to uplift the living conditions of the people in such settlements implemented by the government as well as NGOs. One such activity (funded by GTZ) is the Participatory Improvement of Under-served Settlements in Colombo (PRIMUSS), which focuses on the provision of services, particularly sanitation and drainage (Gunetilleke et al, 2004)

Table 35. Sources of drinking water for the urban sector

Region	Protected well	Pipe-borne	Tube well	Unprotected wells/other
Colombo metropolitan region	15.6	82.1	1.6	0.7
Other urban areas	22.7	66.5	6.2	4.4

(Source: DCS, 2002a)

The Sustainable Cities Programme, a global programme of UN Habitat, which has been implemented in Sri Lanka since 1999, was able to introduce number of best practices including Sustainable Cities Programme (SCP). This programme presently covers 18 municipalities in Sri Lanka. Some of these local authorities have taken keen interest in internalising the SCP process into their city administration (Somaweera, pers. Comm.).

Some of the main public institutions that provide services to urban settlements in Colombo include:

- Colombo Municipal Council
- National Housing Development Authority
- Urban Development Authority
- National Water Supply and Drainage Board
- Common Amenities Board
- Department of Health

The main provider of the drinking water to urban settlements is the National Water Supply and Drainage Board. Flood protection in the city of Colombo from the adjacent Kelani River is the responsibility of Irrigation Department, which maintains several infrastructure facilities for this purpose.

Water loss due to leakages

Water loss to leakages and other factors in infrastructure is termed as Unaccounted for Water (UFW). In Sri Lanka UFW is estimated at 35 % within the Greater Colombo and 50% within the City of Colombo. (Nimal Rohana, 2005) A water audit for CMC area is described in Table 36.

Sanitation services in urban and rural settlements

The type of sanitation facilities varies according to the type of access and type of the facility for each sector of society. The available data shows that the estate sector has poor access to sanitation, in both aspects.

The targets identified in 2003 for the provision of sanitation by the NWSDB are as shown in the Corporate Plan of 2003 2007 (Table 38).

Table 36. A water audit for Colombo Municipal Council (CMC) system (1985)

Parameter	Average Daily % Supply
1. Gross Water Input to the CMC system	100.0
2. Adjustment for errors in bulk meter	0
3. Net input to CMC	100.0
4. Consumption for 37735 domestic connections	37.4
5. Consumption for 4681 stand-posts /bathrooms	17.1
6. Unauthorised use	0.4
7. Commercial and non-domestic	24.1
8. Total (4+5+6+7)	79.0
9. Leakage in the whole System	21.0

Source: Nimal Rohana, 2005

Table 37. Access to sanitation by type of access

Type of access/ sector	Exclusively for household	Shared with other household	Community/ public faclity	Total with latrines
Colombo metro	74.0	11.7	14.0	99.8
Other urban	84.0	8.2	3.0	95.2
Rural	86.5	8.3	0.2	95.0
Estate	45.5	17.4	9.4	72.3
Sri Lanka	81.8	9.3	2.6	93.9

Table 38. Access sanitation by type of latrine

Type of latrine/ sector	Water seal	Pour-flush	Pit	Other	None
Colombo metro	87.3	10.2	1.8	0.4	0.2
Other urban	86.5	4.8	3.3	0.5	4.8
Rural	72.6	6.2	16	0.1	5.0
Estate	35.5	30	6.3	0.5	27.7
Sri Lanka	72.6	8.2	12.8	0.3	6.1

Contamination from wastewater discharges

Some of the causes of raw water pollution in Sri Lanka are as follows:

Discharging sewage water to surface water bodies

Solid and liquid waste produced by industries being discharged to surface drainage networks, eg chromium is discharged into the Kelani Ganga by the canneries located in the proximity of the river (Nimal Rohana, 2005).

Agricultural practices

Pollutants are mainly sediments, pesticides and nutrients (Nimal Rohana, 2005).

The industrial effluents are required to meet the quality the Central Environmental Authority stipulates requirements (Reference: Tolerance Limits for Industrial Effluents Discharged into Inland Surface Waters"(SLS No. 652: 1994). The implementation of the quality regulations is carried out through the Divisional Secretaries and the Environmental Officers attached to the Divisional Secretaries Offices.

In the early 1990s, a World Bank study carried out on industrial pollution found that 80% of the polluting industries are located in the North and South of Colombo in the areas of Ekala, Ja-Ela and Ratmalana. A project was formulated to collect wastewater from the industries, and dispose it after treatment (Nimal Rohana, 2005).

Discharge load by sector

The discharge loads of effluents by sectors are not readily available. The studies that have been carried out provide only occasional and location specific information. Continuous monitoring of water quality at vulnerable locations has been identified as a priority.

The per capita waste loads that have been used in the design of schemes under the study that was carried out in 1990 are given in Table 40.

Table 39. Provision of pipe borne sewerage facilities to high density urban areas

	Area Coverage %				
	2003	2004	2005	2006	2007
CMC	75	78	80	83	85
Dehiwala	22	24	27	28	30
Kolonnawa	53.5	54	56	58	60
Ratmalana & Moratuwa		10	20	35	50
Ja Ela/ Ekala		10	25	30	40
Kandy City Limits			5	9	11
Nuwara Eliya Town			5	15	23
Galle			5	10	25
Negombo			10	25	30
Kotte				10	20
Jaffna					10
Kurunegala					10

Source: Corporate Plan 2003-2007, National Water Supply and Drainage Board

Table 40: Per capita waste generation in grams/capita/day

Constituent	Residential areas	Commercial employees	Industrial employees
Flow l/capita/day	135	50	50
BOD5	55	25	25
Suspended solids	55	25	25
Nutrients			
Amonia Nitrogen	20	10	10
Organic Nitrogen	55	25	25
Total Kjeldahl Nitrogen	75	35	35
Organic Phosperous	10	5	5
Inorganic Phosperous	20	10	10
Total Phosperous	30	15	15

Source:Associated Engineering/Surath Wickremasinghe Associates, September 1994.

Effect of water-related natural disasters (floods, storms, droughts)

Effect of water-related natural disasters

Urbanization and natural disasters

It is reported that western region around Colombo and the southeastern region are the least affected from the rainfall changes. However, floods are reported in and around Colombo area are mainly caused by land use changes, that is, the increase of the built up areas causing a reduction in infiltration and retention areas (Ratnayake and Herath, 2005).

Contingency plans

Sri Lanka is a densely populated country with an average of approximately 300 persons per sq. km. Nearly half the population is living in the wet zone districts, showing the influence of water resources on internal migration. Colombo District is the most populated district with approximately ten times the national population density. The inward migration to the Colombo District has been attributed to the high concentration of economic activities and opportunities, better infrastructure, education and health facilities. It has also been noted that the rate of such migration into urban areas had been contained since 1980s mainly due to the high land prices and housing rents, inadequacy of housing and facilities and high cost of living in urban areas (CBSL, 1998).

It is interesting to note that while Colombo has experienced a net inward internal migration, while the other urbanized districts in the wet zone have experienced a net outward internal migration. Mainly rural districts such as Anuradhapura and Polonnaruwa in the dry zone, where substantial investments in water resources development have been made, indicate significant levels of inward migration (DCS, 2003). Therefore, it can be argued that investment in water resources development, especially for agriculture, is a contributing factor to contain rural to urban migration.

Cities' impact on ecology

Pollution of land, water and coastal resources in urban areas and degradation of aesthetic value due to poor waste management and unsanitary disposal of liquid and solid waste, are the main problems. Air and noise pollution and loss of biodiversity are also present in several big cities in Sri Lanka. Lack of institutional, technical and law enforcement capacity in local authorities in arresting degradation of urban environment and natural resources base, are identified as the main constraints in containing these problems. (Nimal Rohana, 2005; Somaweera, 2002).

When garbage disposal services are not provided by the local authorities, under-served settlements sometimes dispose their garbage to canals and water bodies (Gunetilleke et al, 2004). While this situation underlines the low priority given to solid waste disposal among the services, this practice results in considerable ecological damage. The blockage of the drains facilitate mosquito breeding and increases local flooding. The encroachment of underserved settlements onto the Colombo flood protection bunds increases the vulnerability of both the people as well as flood protection infrastructure to the floods (Official correspondence with Irrigation Department).

The instability of the livelihoods of the urban population shows little relation to water availability. In fact rains disrupt the livelihoods such as street hawking, construction industry and other daily paid occupations. This is a different situation compared to rural livelihoods.

Urban development and water management

Water demand management

Following demand management strategies are under consideration by the government as recommended by several studies.

- Per capita consumption to be reduced from 145 lpcd to 120 or 100 lpcd by tariff system
- Promotion of alternative water uses- recycling of wastewater from industrial sector and use of separate system for gardening etc.
- Rain water harvesting for urban areas.
- Creation of awareness among users (Nimal Rohana, 2005).
- Public Participation

The programmes in water supply sector include Urban Settlements Improvement Programme (USIP), "Gemidiyawara" programme which aims at providing water for the rural people, and the Community Water Supply and Sanitation Project (CWSSP).

The projects focus on under-served communities in urban areas and village communities. They are implemented in partnership with CBOs, NGOs and local government institutions. Costs of the activities are met by contributions from donors, community, and local government institutions. The major part of the community contribution has been in the form of labour, and other forms have been cash and building materials.

The activities of USIP include provision of piped water supply and private latrines. The USIP facilitates the development of sustainable community based environmental infrastructure service in the under-served settlements on a participatory and partnership basis. Several different sub-projects are implemented under the framework of USIP, including the pilot project to formulate a development strategy and a scheme for water supply and sanitation development for underserved households focussing on Colombo metropolitan area. Both the "Gemidiyawara" and CWSSP focus on village communities.

Pricing policies

The pricing of drinking water is a very sensitive issue in the country's socio-political context and therefore only a part of the cost is passed on to the consumer while the state absorbs capital costs, debt services and depreciation involved. Current pricing policy is based on the recovery of the operational costs of the NWSDB, which consists of:

- Direct production costs (cost of chemicals, electricity and fuel)
- Storage costs
- Distribution costs
- Billing and collection costs
- Administration costs of the operational staff

Price revisions are made from time to time after evaluating the financial situation of the NWSDB.

Other problems in urban and rural settlements

The government structure in Sri Lanka consists of three tiers. Since 1987, the Provincial Council became the second tier, and the local authorities being the third tier became weaker. This situation was further aggravated as a result of abolishing the Local Government Service, a specialized service for local administration.

Major deficiencies of integrating the urban planning perspective with its sectoral resource allocation at national, provincial and local level causes problems to settlements. Shortage of serviced land, incompatible use of urban land, disregarding zoning and land use regulations, delayed response of the tenure system to changes from non-urban to urban uses are some of the common issues prevalent in the urban areas. With regards to urban housing, the critical issues are inadequacies and inconsistencies in planning and zoning regulations, unsustainability of public sector housing programmes, low investment in rental housing and an absence of safety nets for vulnerable groups. Inadequacy and inequitable distribution of resources for urban basic services, incompatibility in service provisions against the development trends and associated institutional problems are seen as main issues (Nimal Rohana, 2005).

Indicators

- Availability of safe drinking water = 75%
- Pipe borne water supply for urban population = 75%
- Total pipe-borne water supply = 23.4%
- Availability of sanitation (whole island) = 87%
- Public participation in water decisions: = moderately satisfactory

Chapter 06

Water and Food

Enhancing food security, particularly of the poor and vulnerable, through the more efficient mobilization and use of water, and the more equitable allocation of water for food production is one of the biggest challenges facing humanity. Since independence in 1948, successive governments in Sri Lanka invested heavily in irrigated agriculture.These investments resulted in substantial gains in food security and nutrition standards. This chapter focuses on the current status and critical issues related to water and food.

Cultivated area

The total cultivated area in Sri Lanka had been estimated as 1.86 million ha (DCS, 2003) of which about 632,000 ha are irrigated (Meegastenne, 2005). Crop production systems in Sri Lanka are commonly categorised into three major groups namely, major[1], minor and rain-fed based on the water availability and usage. The area under irrigation had been increasing steadily during the last century, especially after 1950 though the rate of increase had reduced after completion of the Mahaweli Development Project in mid 1980s. The current trends indicate a slower growth rate of the total area under irrigation. However, the current emphasis on restoration, augmentation and rehabilitation of existing irrigation systems and better water management is expected to result in an increased and more stable cropping intensity. The total extent of asweddumized[2] lands available for rice cultivation was about 742,000 hectares in 2003. Out of this, 45%, 24% and 31% of the total extent were under major and minor irrigation schemes, and rain-fed respectively (Table 41).

Major & minor irrigation systems and role of irrigation

The Irrigation Department (ID), established in 1900 has played a major role in Sri Lanka's irrigation development. The government policy of substantial investments in irrigated agriculture since the early 1950s has contributed to achieve near self-sufficiency in rice production, and indirectly improved the general well being of the rural population. Since mid 1980s, the focus of national policy shifted from large-scale water resources development to better water management. In 1984, an Irrigation Management Division (IMD) was formed in the Ministry of Lands and Land Development (under which the irrigation sector was placed) for the creation of farmer institutions and promoting participatory irrigation management. Although inadequate attention on

1 Irrigation schemes with more than 80 ha. command areas are considered major irrigation systems.
2 Asweddumized land refers to total cultivable land available in the country for rice cultivation.

Table 41. Asweddumized rice extent in Sri Lanka - (1979 and 2003)

Method of water supply	1980/81		2003	
	Extent (ha)	%	Extent (ha)	%
Major	245,550	36	335,026	45
Minor	171,066	26	177,433	24
Rain-fed	253,078	38	229,257	31
Total	669,693	100	741,716	100

Source : Department of Census & Statistics, 2003

water resources development in the last 20 years has often been the subject of much criticism, the fact that greater importance had been paid for better water management is generally accepted.

Irrigation systems with command areas more than 80 ha are administratively classified as major irrigation systems and are state managed. The major irrigation systems are spread over approximately 350,000 ha. Out of these, the ID manages 292 irrigation schemes with a command area of about 255,000 ha. The IMD implements farmer institution building programs in 40 systems. The Mahaweli Authority of Sri Lanka (MASL) manages about 95,000 ha. In addition, ID provides protection against floods and salt-water intrusion to about 32,900 ha which are mainly rain-fed (Meegastenne, 2005).

The minor (village) irrigation systems are usually associated with a village and are managed by the local community. Department of Agrarian Development and Provincial Councils play a major role in providing the necessary services to the farmers. According to DCS (2004), the paddy area under minor irrigation systems is about 177,000 ha. The Department of Agrarian Development (DAD) cites a substantially higher area of about 245,000 ha as being under minor irrigation. While major irrigation schemes are normally production systems, the minor systems can be considered as social, economic and cultural systems as well.

Rice is the main crop cultivated under major irrigation systems in the dry and intermediate zones. The paddy area under irrigation increased from 296,000 ha. In the 1950s to about 575,000 in 1990s. The annual paddy production from irrigated agriculture amounts to 82% of the total domestic production (DCS, 2004c). In Yala, the somewhat drier season, the contribution from irrigation is more pronounced, highlighting the positive impact that irrigation has on food security and livelihoods.

The predominant irrigation type in Sri Lanka is surface irrigation. Although there were attempts to promote micro-irrigation, especially drip irrigation and micro-sprinklers, the progress is slow due to the lack of a national programme and inadequate policies.

Water use

Water requirements

Out of the irrigated lands in Sri Lanka about 90% is cultivated with paddy.

The typical water use values are as listed in Table 42. Several programs have been implemented by the major irrigation agencies in the recent past to improve water use efficiency. These programs have resulted in reducing water use in several selected irrigation schemes and had contributed to improve water productivity. Water use for crop growth is by and large constant, the major part of the interventions has been concentrated at reducing the land preparation period of paddy. Other interventions include the cultivation of short-term paddy varieties, improved irrigation scheduling, promoting participatory management, rehabilitation and modernization of irrigation systems.

The actual water use is highly variable. Irrigation water use (duty) is as high as 4.5 m in Yala season, which has been recorded in Kaltota scheme in the Ratnapura district. These values include the land preparation requirement. However, many major irrigation schemes have carried out water management programs in the recent past and water use efficiency has been substantially improved. Figure 27 below indicates some of the current values in few selected major irrigation schemes based on the data for 2000 to 2005.

Figure 28 describes the water productivity variation among selected irrigation schemes. The values relate to paddy production and irrigation releases from the sluice. Therefore, the values shown here are heavily dependent on rainfall. Until recently, only a few irrigation systems had system level data on production and yield, with most of these data being collected at administrative district level. Therefore, water productivity could be measured at only a few schemes. However, the situation is improving with crop-cut surveys being undertaken in several irrigation schemes.

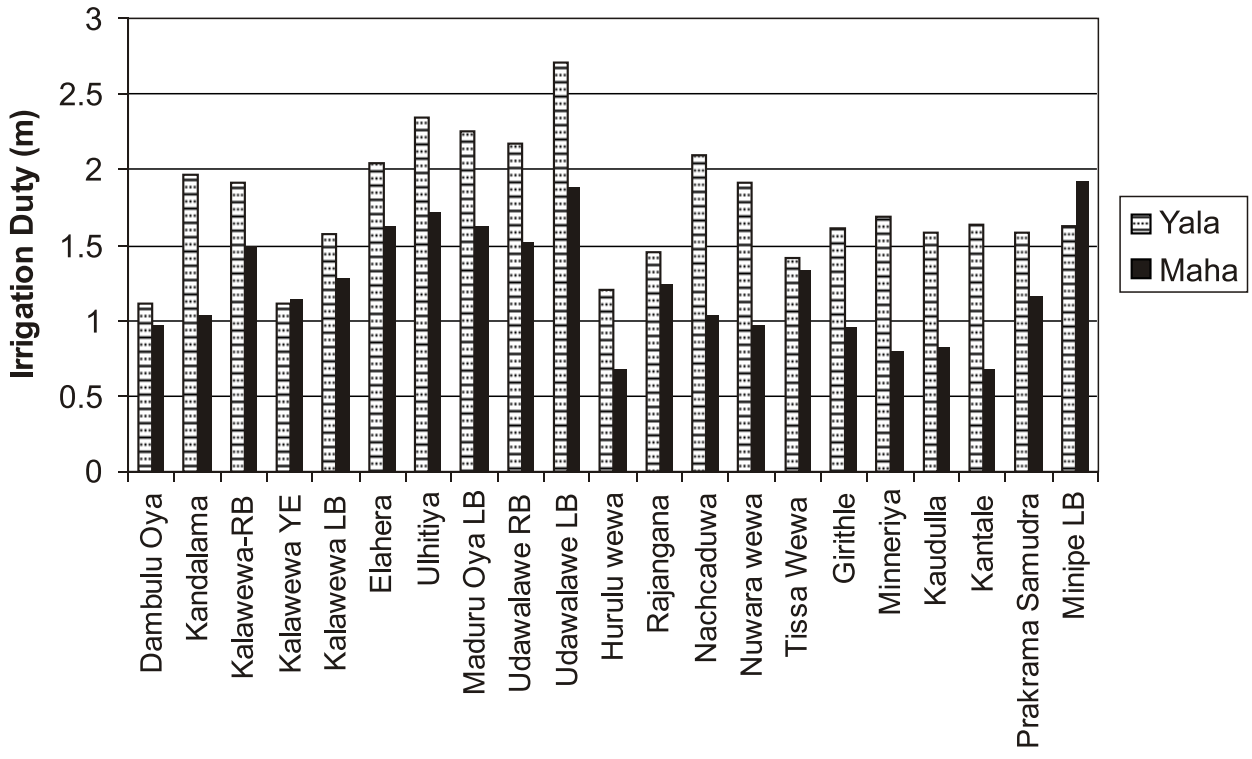


Figure 27. Irrigation duty in selected major irrigation schemes

Sources of data: Meegastenne, 2005; Irrigation Department and Water Management Secretariat/MASL

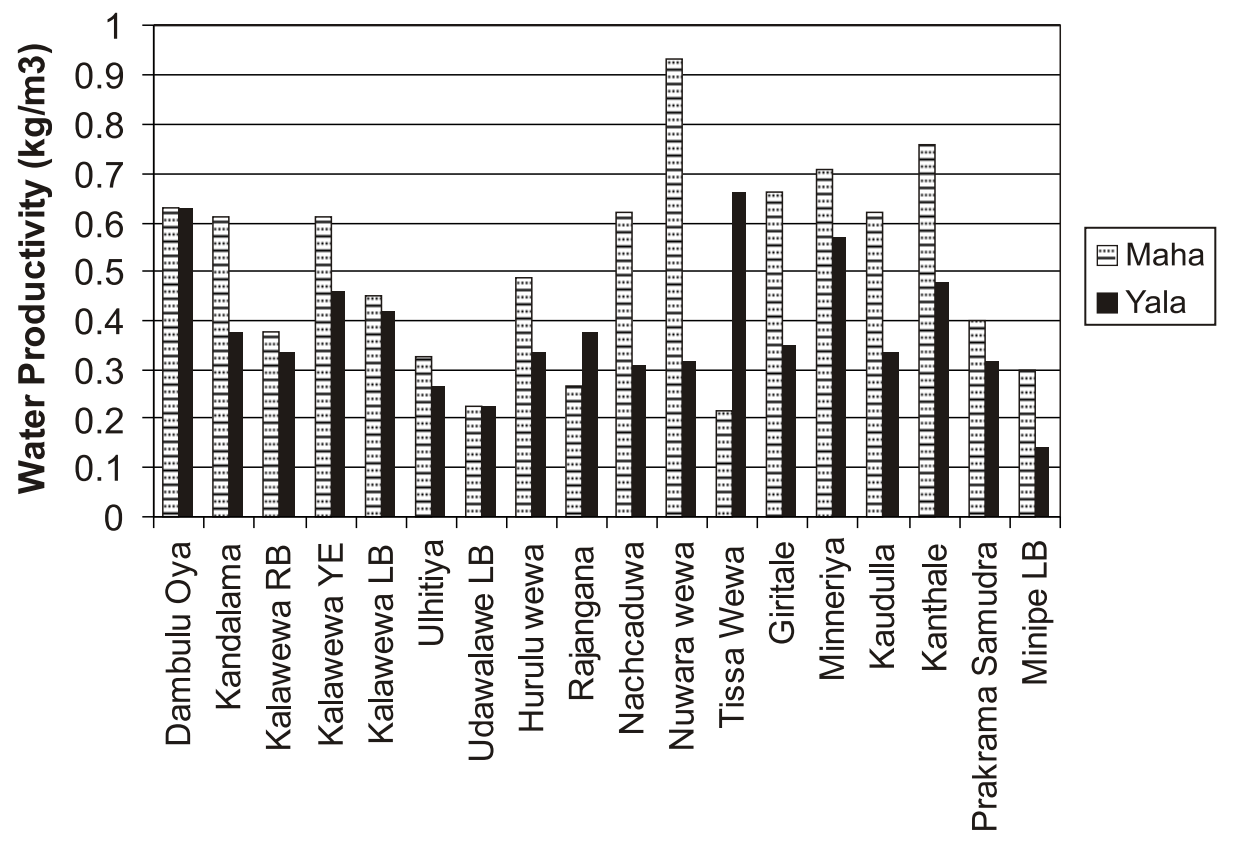


Figure 28. Water productivity in selected irrigation schemes

Sources of data: Meegastenne, 2005; Irrigation Department and Water Management Secretariat/MASL

Table 42. Crop water requirements of selected food crops

Crop	Crop Duration (days)	Water Requirements (mm)	
		Yala	Maha
Paddy			
Low land	105	910	470
Up land	105	-	430
Coarse grains			
Maize	115	825	460
Sorghum	110	1075	610
Pulses			
Soybean	105	710	390
Mung bean	75	460	245
Cowpea	90	770	370
Groundnut	110	735	395

Source: Field Crop Research & Development Institute, Maha Illuppalama, 2003

Paddy yields

The average paddy yield increased from about 1.5 tons/ha in 1950 (CBSL, 1998) to about 4.0 tons/ha in 2001 (DCS, 2004c). The Figure 29 shows the pattern of paddy yield changes from 1950 to the present. It can be observed that the Yala yield has been generally lower than the Maha yield until 1994. However, there is a clear increasing trend of Yala yields since 1994, overtaking the Maha yields from 1998. While agricultural extension and locally developed high-yielding paddy varieties have made the biggest contribution to yield increases, improved water management may have contributed to the yield increases in the dry season.

In the recent years, the yields of paddy had been recorded as 4.23 tons/ha for major irrigation, 3.45 tons/ha for minor irrigation and 3.02 tons/ha for rain-fed paddy. Though there is an increasing trend of paddy yields, especially in irrigated agriculture, the present levels remain below the potential yield value of the improved paddy varieties introduced by the Department of Agriculture (Emitiyagoda, pers. comm.). The yield potential of presently cultivated varieties vary from 7-12mt/ha under optimum conditions (Weerasena et al, 2005). However, the average yield is about 4.0 tons per ha. The low productivity and profitability of agriculture is a concern for the policy makers and these factors contribute to the low investment by farmers in agriculture.

The Department of Agriculture (DOA) introduced locally bred high-yielding rice varieties in late 1950s. By late 1960s, the percentage of area cultivated with these varieties increased to more than 60% (CBSL, 1998). It increased further to 93-95% during the period 1993-97, and to 98-99% during the period 1998-2002 (DCS, 2004c). During the past two decades 28 improved rice varieties have been developed and released for cultivation in Sri Lanka by the DOA. At present, these improved varieties cover over 98% of the total extent cultivated.

Cropping intensity

While the area under irrigation has substantially increased over the last 50 years, the cropping intensity has not shown a corresponding increase. Based on the statistics available with the ID, the annual cropping intensities of major irrigation schemes vary from about 200% to less than 100%. During the period 1994-2003, the major irrigation schemes in Polonnaruwa and Ampara districts recorded cropping intensities of 191% and 183%, indicating a positive contribution from water resources development. In contrast, the cropping intensity in Anuradhapura District was 138%, indicating that there is scope for improvement of production with water supply provision. In fact, the major irrigation schemes such as Mahakanadarawa and Huruluwewa in the Anuradhapura District are plagued with chronic water scarcity.

Figure 30 explains the variation of cropping intensity in the areas developed for paddy, including rain-fed and irrigated areas. Typically low cropping intensities in rain-fed and minor irrigation areas have generally contributed to the low national values. The rainfall pattern has influenced the year to year variation.

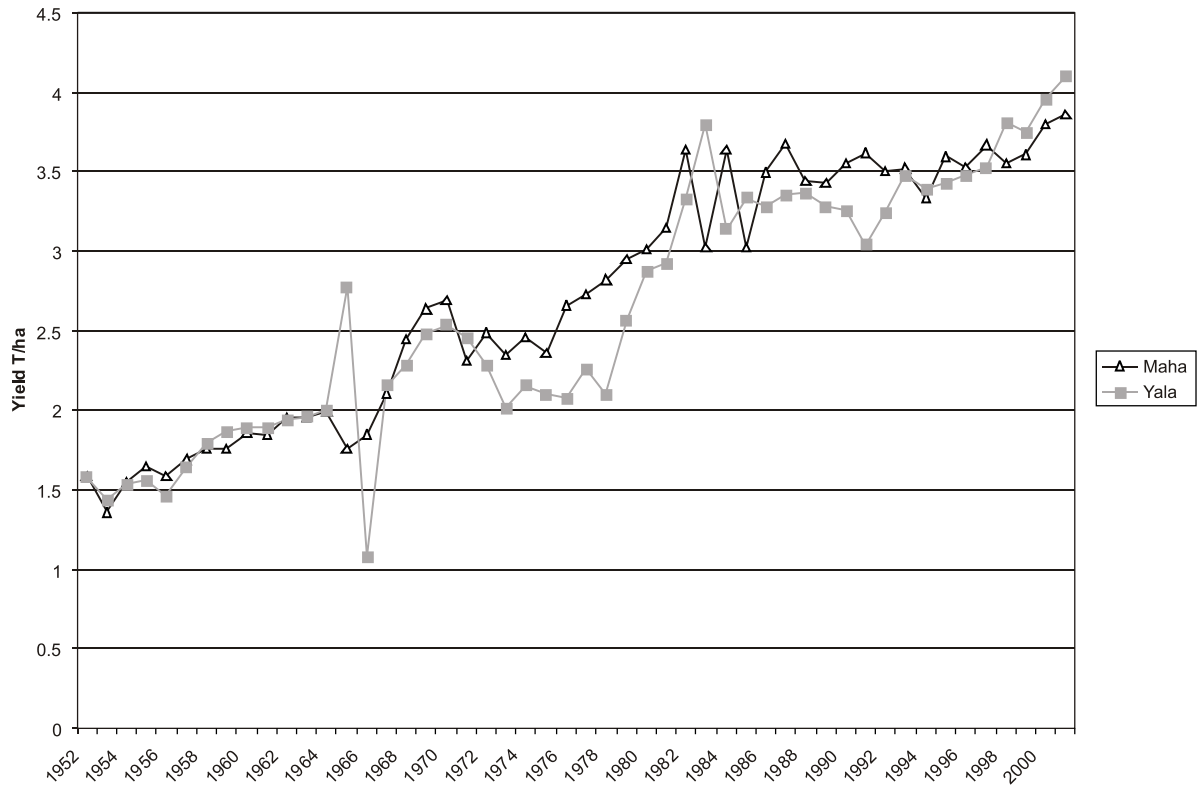


Figure 29. Variation of paddy yield

Source: Imbulana and Neupane (2005)

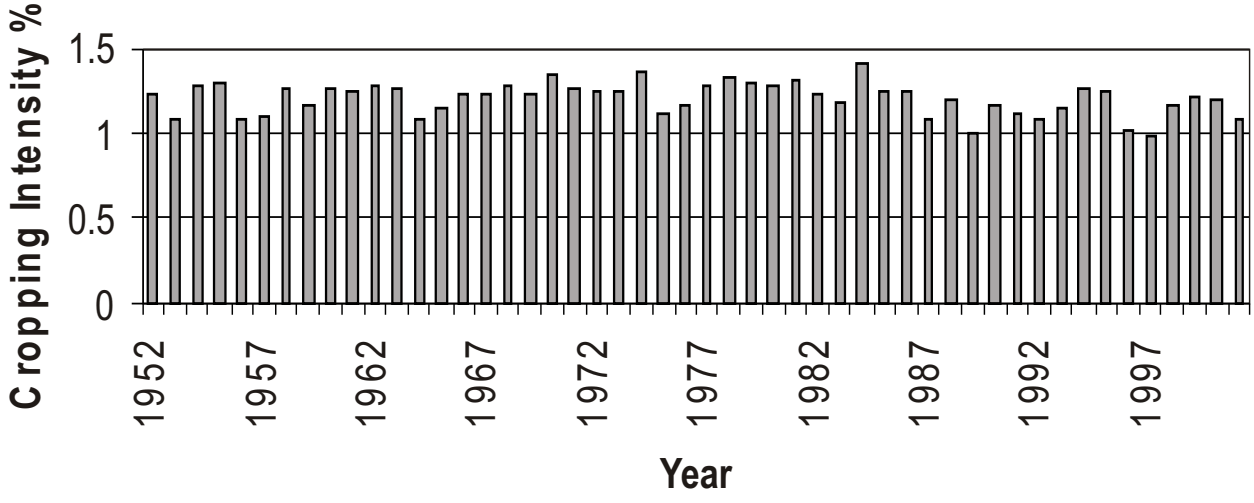


Figure 30. Variation of cropping intensity under paddy cultivation

Sources: Aluwihare & Kikuchi, 1990; DCS, 1998; DCS, 2004c

Other food crops

The major food crops under rain-fed cultivation include rice, chilli, vegetables, maize, millet and fruit crops.Vegetable production in Sri Lanka is dominated by about 40 different species including root and tubers cultivated under different agro-ecological zones. In the year 2003, major vegetable cultivation was undertaken in a total extent of 74,267 ha, with a production of 552,380 metric tonnes. The extent, production and average yield of vegetables, roots and tubers had been almost stagnant during the last decade. Per capita availability of vegetables has been estimated to be around 42.24 kg/year, and the corresponding value for root and tubers, (excluding potato), is around 14.5 kg/year. (Weerasena et al, 2005).

A domestic per capita consumption of about 200 grams/day of vegetables is envisaged for the future and it becomes explicitly important to increase the vegetable production in this country. It has been identified that this could be achieved with an increase of the cropping intensity and productivity of vegetables by cultivating high yielding varieties. Approximately forty tropical, subtropical and temperate fruit species are grown in the country. The average extent cultivated with fruit crops is about 140,000 ha. Annual production is about 640,000 metric tonnes of which 58% is locally consumed, 30-40% constitute post-harvest losses and about 2% is exported (Weerasena et al, 2005).

Although there was an attempt to promote crop diversification with low water use as one of the objectives, the statistics do not indicate much success in this direction.

Livestock, fisheries and aquaculture

Livestock

Dairy and poultry are the two main industries within the livestock sector. The national milk and egg production during the 1993 to 2003 period is shown in Figure 31. The current local production of milk is adequate to meet only about 15 percent of the national requirement. The balance is imported mostly in the form of milk powder. During the year 2003, 67,941 metric tons of milk and milk-based products had been imported. During the year 2003 the producer price of milk had been SL Rs. 15.00 per litre. Poultry meat production has increased by 2689.5 mt (3.6 percent) in 2003. The per capita availability of chicken meat has increased from 1kg in 1992 to 4.3 kg. in 2002. High cost of animal feed and limited infrastructure facilities such as cold rooms, have been identified as problems faced by the poultry producers (Kodituwakku, 2002).

High cost of animal feed has been identified as one of the biggest drawbacks in the development of livestock industry. At present, animal feed millers use expensive imported raw materials. Therefore encouraging use of locally available raw material in the provender industry, the production of which will require more land and water, can minimize animal feed cost. The water use in livestock production has not been well studied. However, milk-based products such as curd form a major source of income for many dry zone formers. Therefore, water resources development imparts a positive impact on livestock population, and thereby on the rural incomes. The percentage of rural households owning livestock is highest in the northeastern provinces (33.7%), followed by north-western (29.4), and north central (26.9%) (World Bank, 2003). As the major part of these provinces lie in the dry zone, water resources development will have positive impacts on livestock production as well as on the rural economy.

Fishery

Seventy eight per cent of the total fish requirement is met by local catch, and this had been approximately 284,960 metric tons in 2003. The balance is met by imports as dried and salted fish, canned fish and a small quantity of fresh fish. The contribution from marine sector is 89 % (254,680 metric tons) of the total. The inland and aquaculture fish supply variation over the years is shown in Figure 32. (CBSL, 2004).

In early 1980's, the government of Sri Lanka adopted a policy decision to stop supporting inland fisheries development on religious grounds (1990 - 1994 National Development Plan). Production and revenue declined significantly and this sub-sector deteriorated. Subsequently, this decision was reversed (Five year fisheries development programme 1995 - 2000) and development activities were being pushed towards a revival of the fisheries in this sub-sector (Maldeniya, 1997). The development of fisheries sector is very significant in terms of providing animal protein through ample cheap fish to the lower income groups. There is much potential to increase the productivity and sustainability of the different fish production systems in the country. These objectives can be achieved through integration of appropriate technologies, supportive government policies and development of infrastructure facilities.

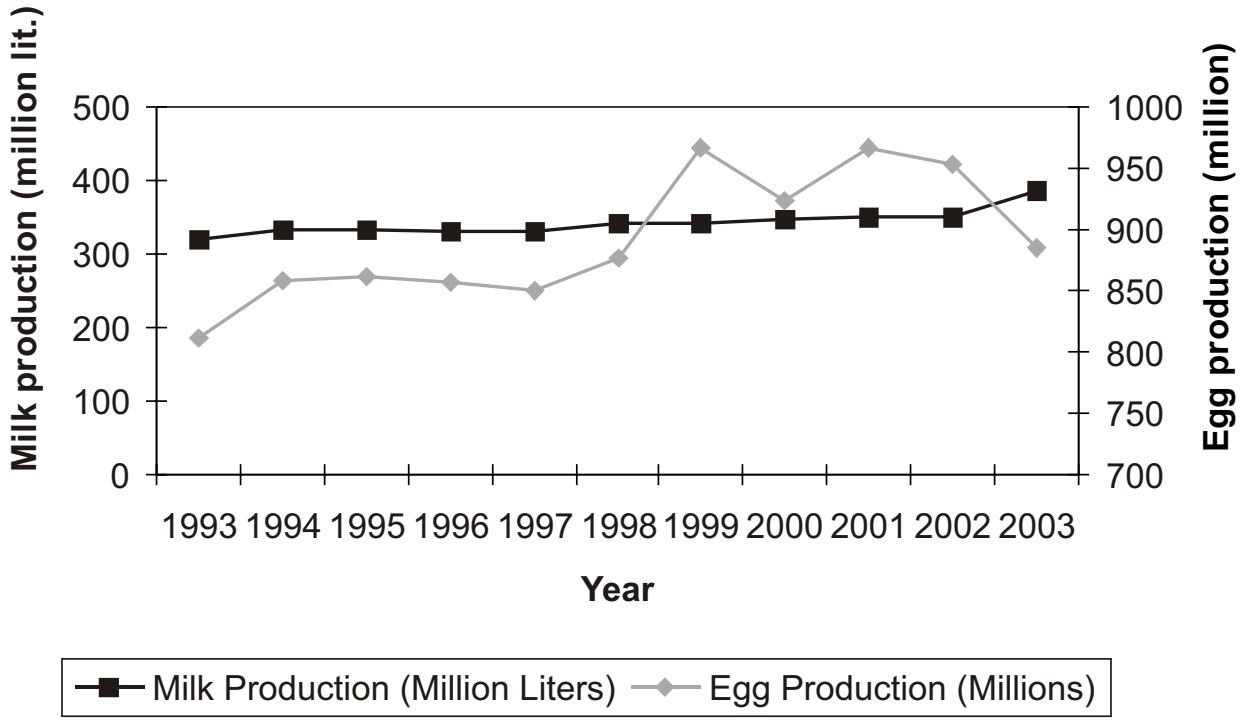


Figure 31: Milk and egg production in Sri Lanka (1993-2003)
Source: Department of Census and Statistics, 2003

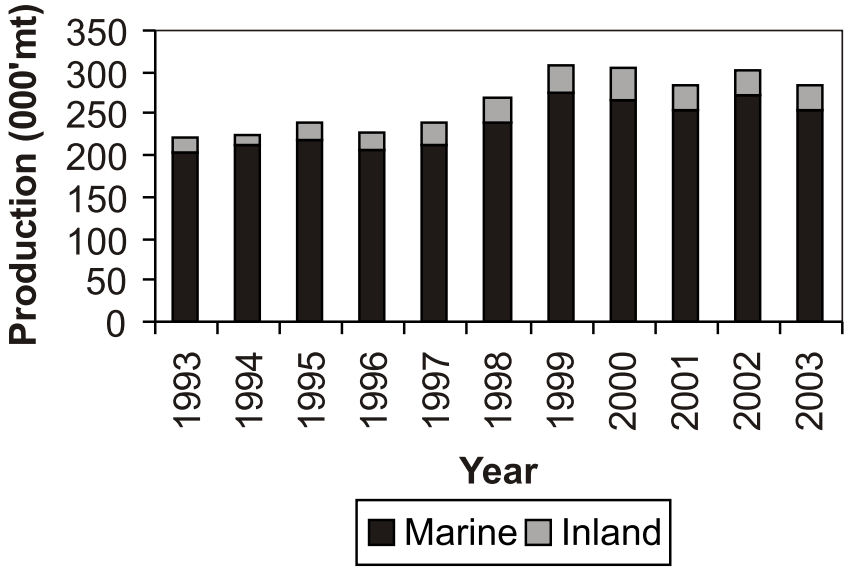


Figure 32. Fish Supply in Sri Lanka (1993 2003
Source: Central Bank of Sri Lanka Annual Reports

Food trade and virtual water

Food imports

Food imports to Sri Lanka in 2003 included quantities of maize (136,697 mt), lentils (90,681 mt), soybean (1,451 mt), mung bean (8,181 mt), black gram (7,597 mt) and potatoes (45,518 mt), imported to meet the requirements for food, as well as for animal feed industry. The crops of these food items require relatively less water compared to rice, and could be successfully cultivated with limited irrigation water. Demand for these commodities within the country is expected to increase further, with the increase in human population and rapidly growing poultry industry. The extent and production of OFCs from 1993 to 2003 are presented in Figure 33, which shows a gradual decrease in both parameters (Weerasena et al. 2005).

The present production levels in crop, livestock and fishery sectors indicate that the country depends on large quantities of imports of food commodities such as lentils, potato, fruits, maize, milk powder and fish products to improve food security (Figure33) There is a need to increase the domestic production of these food products in a sustainable manner to meet the requirements of the growing population and the agro-industries (Weerasinghe et al, 2005).

Goals and programmes

Per capita food consumption

Rice is the staple food of most Sri Lankans. It constitutes the major source of energy. The per capita consumption of fruits in Sri Lanka is about 9.01 kg/year, whereas the Medical Research Institute recommendation indicates a quantity of 25-40kg /year/person of the edible portion of fruits, to be included in the balance diet. In Sri Lanka fruit crops are generally rain-fed, and reported as having a low productivity level. The productivity levels could be improved through irrigated farming and /or by using high yielding varieties.

The Food Balance Sheet data of 2002 indicates a national level per capita availability of 2,363 calories and 59.2 grams of protein per day (DCS, 2004b), which indicates a fairly satisfactory position with regards to national level food security. However, it appears that there are disparities among different sections of the society. The average monthly household income of urban and rural sectors has been estimated as Rs. 22,420.00 and Rs. 11,712.00 respectively in 2002 (DCS, 2004d). According to 1995/96 values, the poor households consume 18% less calories than non-poor households. Therefore these average figures appear to be ambiguous, in view of the fact that the

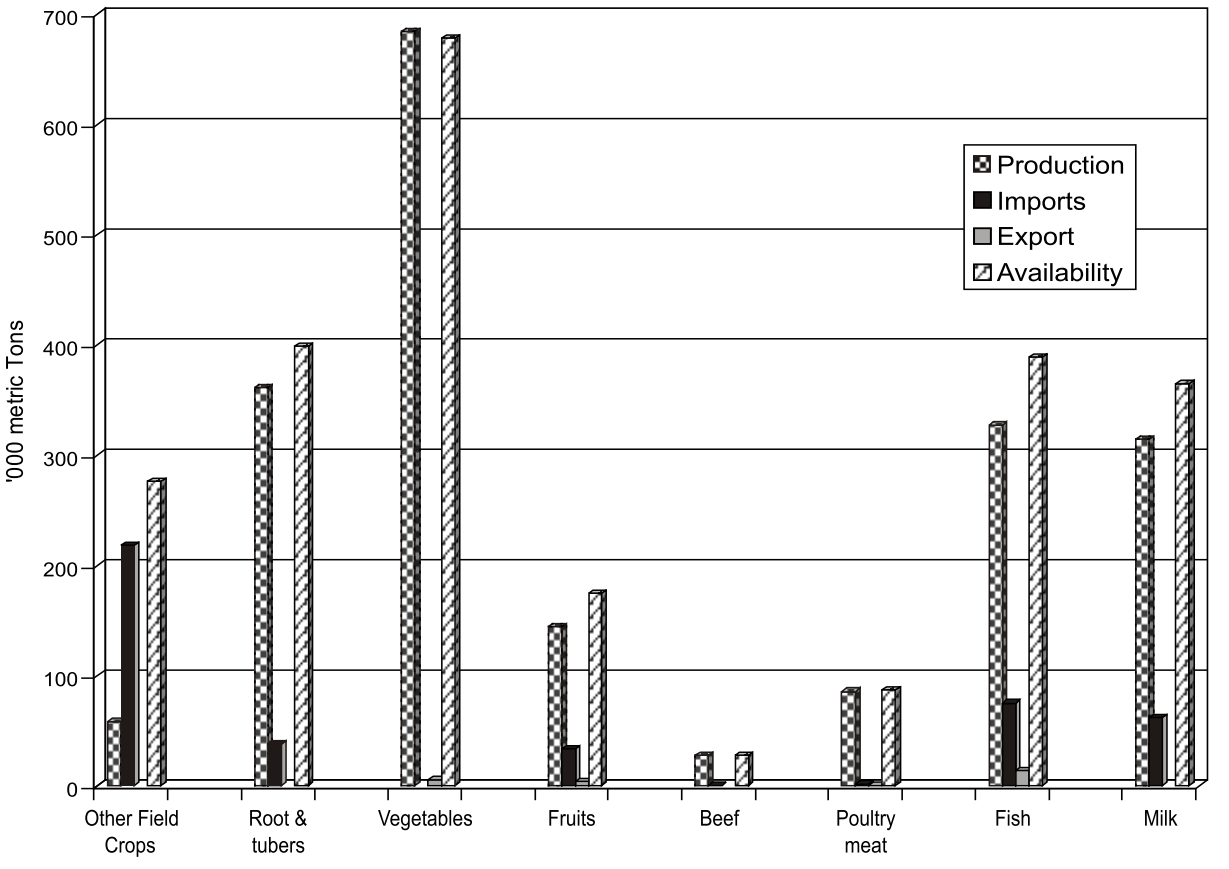


Figure 33. Production and availability of selected agricultural commodities

Table 43: Per capita availability of food commodities 2002

Commodity	Per Capita Availability				
	Kg Per year	gms Per day	Calories Per day	Prot. gms Per day	Fat gms Per day
Rice	98.09	268.75	929.86	17.74	1.21
Wheat Flour	34.88	95.55	332.53	10.51	0.86
Other Cereals	4.66	12.74	45.95	1.2	0.5
Root and tubers	15.34	42.01	55.47	0.45	0.07
Sugar	31.41	86.06	344.13	00	00
Pulses and Nuts	7.61	20.84	73.97	5.27	0.92
Vegetables	42.24	115.71	54.53	2.39	0.32
Fruits	9.76	26.75	29.33	0.5	0.44
Meat	6.0	16.45	22.42	3.94	0.74
Egg	2.79	7.65	13.24	1.02	1.02
Fish	12.34	33.82	57.16	10.03	1.7
Milk	16.08	44.05	75.55	3.62	4.37
Oils and Fats	35.69	97.77	338.6	2.94	31.8

Source: Food Balance Sheet DCS, 2002 cited in Weerasena et al, 2005

family incomes of the rural poor have not been sufficient to sustain the required levels of nutrition and household food security, compared to the urban residents.

The Food Insecurity Map produced by the World Food Programme in 2003 clearly indicates that food insecurity is more prevalent in the Uva and northeastern provinces compared to other provinces. It also shows that irrigation development has helped to improve food security in areas such as the North Central Province.

The Food Insecurity Map (Figure 34) indicates that districts such as Polonnaruwa where heavy investments in water resources development has been made, records better levels of food security compared to other rural areas such as Moneragala. Therefore, it is necessary to enhance food production in the country as well so as to improve the accessibility of the poor and vulnerable population to food at household level, through efficient mobilization and equitable allocation of land and water for food production.

Major programmes

One of the major programmes implemented in 2004 was the Dahasak Wew (Ten thousand tanks) Programme, aimed at effecting necessary repairs to 10,000 small reservoirs and diversion structures within a period of 4 years. The funds for this programme are mainly obtained from local funds and donations from the interested institutions. The benefits include increased production, groundwater recharge and enhancing water supply for domestic purposes, livestock, fisheries and recreation (Official correspondence of Ministry of Agriculture, Livestock, Lands and Irrigation, 2004). It is expected that cropping intensity of the agricultural areas under these tanks will increase from current 75% to 125%, thereby benefiting about 64,000 families (MALL&I, 2005).

The Ministries of Agriculture and Irrigation also initiated a programme titled "Granary Area Programme" in 2003 to improve the productivity of paddy cultivation in selected major irrigation areas. The selection was based on the potential for growth; measured in terms of potential for yield increase, better water availability and existence of farmer institutions. It was hypothesized that increased productivity will contribute to better incomes and thereby higher investment in agriculture by farmers, resulting in a sustainable irrigated agricultural system. The programme plans to improve the average paddy yields to 6.5 tons/ha from a level of 4.5 tons/ha in 2003 (MAL&MI&WM, 2003) through mainly agricultural and irrigation management interventions. However, the impact of this programme is too early to be measured, because the implementation was delayed.

The five-year Fisheries Development Plan (1995-2000) of the Ministry of Fisheries and Aquatic Resources accords high priority to the management of coastal fisheries and development of offshore, inland fisheries and aquaculture.

Some of the food security relational Millennium Development Goals, and Sri Lankan achievements are given below:

Table 44. Millennium development goal 1 - eradicate extreme poverty and hunger

Goals and Targets	Sri Lanka Score Card
Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than one US dollar a day. **Target 2:** Halve, between 1990 and 2015, the proportion of people who suffer from hunger.	The proportion of the population living on less tha n one US dollar per day in Sri Lanka was 4 percent in 1990 and 6.6 in 1995 Based on the Household Income and Expenditure Survey of 2002, the percentage of poor population in Sri Lanka was 28.1 percent in 2002. The high prevalence of underweight children (below 5 years) is a matter for concern, although it decreased from 38% in 1993 to 29% in 2000.

Source: Central Bank of Sri Lanka Annual Report 2003

The improvements in the nutrition status are seen as significant, due to provision of better health facilities and improved food security. Studies in the 1940s revealed that the main reason for high rate of neo-natal mortality was maternal anaemia resulting from an inadequate diet. The per capita calorie availability increased from 1990 kcal in 1952 (CBSL, 1998) to 2,360 in 2003 (DCS, 2004b). The maternal mortality rate (per 1000 live births) dropped from 8.3 in 1948 to 0.2 in 1995. Correspondingly, infant mortality rate reduced from 92 to 17 in the same period. Some of the relevant indicators are listed in Table 45

Agricultural policy directions

Agricultural policies implemented since independence in 1948 generally aimed at achieving self-sufficiency in food crops. In the case of rice, the target has been 100% self-sufficiency. The current programs aims at ensuring the economic security of the people engaged in irrigated agriculture by increasing agricultural production, while ensuring sustainability of related ecosystems.

The Government of Sri Lanka considers agriculture as central to all strategies for planning rural economic development of the country. It has been recognized that the growth of agriculture is essential not only to achieve self-reliance at national level, but also for household food security, equitable distribution of income and wealth, and thereby ensure reduction of poverty. The broad objectives of the current policy (MALL&I, 2005) includes:

- Achievement of basic food self-sufficiency
- Improvement of nutritional status
- Increasing employment opportunities through promoting agri-business
- Boosting rural incomes through creating income generating activities
- Expanding agricultural exports
- Strengthen demand driven research
- Farmer centred extension and technology transfer system
- Conservation and development of soil and water resources

Among challenges to achieve policy objectives, a water shortage emanating from deficiencies in the country's rainwater capturing and storage capacity and the poor use of available water has been identified as the major one. Among the strategies to achieve

Table:45 Nutrition related indicators: 1950-2000

Indicator	1950	1975	1996	5-year Average (1995-2000)
Maternal mortality rate (per 10,000 live births)	55.5	10.2	2.3	Not available
Infant Mortality Rate (per 1000 live births)	82.3	45.1	17.3	13.6
Neo-natal Mortality rate (per 1000 live births)	49.2	27.0	12.9	8.3

Sources: WHO, 2002 (for 1950-1996) and DCS, 2002a (for 5-year average from 1995-2000)

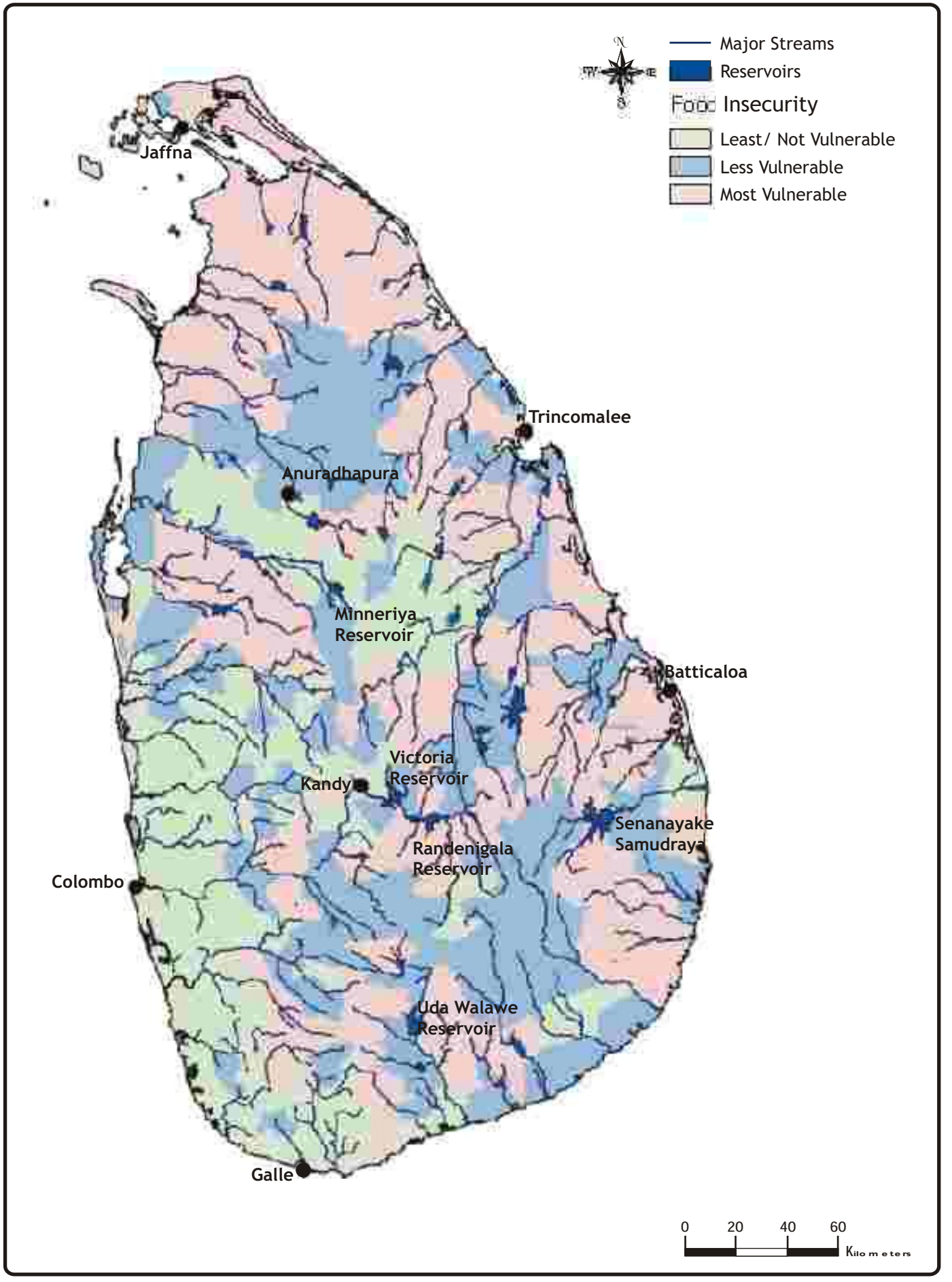


Figure 34. Food insecurity in Sri Lanka

Prepared by U.R. Ratnayake (World Food Programme and Department of Census and Statistics - Dr. Amara Satarasinghe base data)

the objectives are making rational use of water, enabling optimum utilization of water through renovation and rehabilitation of irrigation systems and promoting conjunctive use of surface and groundwater (MALL&I, 2005).

Since independence in 1948, the Government of Sri Lanka has initiated a series of policies and programmes to improve food security and nutritional levels in the country. Self-sufficiency in rice to ensure food security and to generate rural employment was considered as priority by successive governments. In 2003 the country almost achieved self-sufficiency in rice, producing 3.0 million metric tonnes of paddy. It has been noted that rice production has increased mainly through the introduction of "green revolution" technologies such as improved varieties, use of fertilizer and proper pest management practices. The expansion of irrigation facilities, fertilizer subsidy scheme, agricultural credit facilities, price support schemes and import restrictions were the past government policies that have contributed towards increasing rice production.

The promotion of the cultivation of other field crops (OFCs) was initiated in mid 1960's with the introduction of government sponsored "Food Production Drive" programmes. Local production of these crops was encouraged during the period 1970-77 through the protective policies. From the 1980s onwards, the government through various projects encouraged domestic production of OFCs. However, the efforts made by the agricultural extension staff to persuade the farmers to diversify their crops did not materialize as anticipated, as the farmers were not enthusiastic due to various constraints such as low productivity and unfavourable trade policies resulting in low prices for their produce.

Marketing and trade

The direct intervention of the Government of Sri Lanka towards marketing of agricultural products was activated during different time periods in order to afford a certain degree of protection to local farmers engaged in producing rice and OFCs. The Paddy Marketing Board (PMB) was established as a state organization in the early sixties mainly to purchase and process paddy grown by local farmers. The PMB catered to only about 10% of the production but controlled the entire grain market. However, the activities of these establishments were gradually withdrawn with the adoption of open economic policies in the late eighties. As a result, the PMB was closed down in 1996 with the idea of creating a competitive environment for grain marketing. The government has initiated several measures to protect the local producer as well as the consumer since the open economic policies were introduced 1977. It also introduced a producer price system for rice and selected OFCs in August 1997.

The Co-operative Wholesale Establishment (CWE) was entrusted with the responsibility of purchasing selected commodities whenever the producer prices drop below the recommended prices. The activities of CWE were privatised in 2003. The Multi-Purposes Cooperative Societies (MPCS) were also encouraged to get engaged in developing an appropriate marketing system for agricultural produce. They received government patronage in the early 1990s, while the MPCS's operational activities are now completely independent. They purchase local produce during the harvesting season at open competitive market prices. In year 2003, the Government established a number of Dedicated Economic Centres (DECs) in major agricultural producing regions to improve facilities for private sector marketing. These Centres provide a trading floor for the farmers to sell their products directly to retailers and wholesalers.

The Central Bank of Sri Lanka introduced a Forward Sales Contract System (FSC) in 1999 to promote the trade of agricultural products at a pre-determined price and an assured quality. Feed and food producers who use locally grown raw materials such as paddy, maize and essential commodities purchase the portion of their requirement under this system. Financial assistance is provided by the Central Bank through Commercial Banks as short-term soft loans. This Forward Sales Contract Systems help to stabilize the producer price scheme as well as to assist in the maintenance of the quality of the product specified by the industrialists.

Sri Lanka has introduced major trade policy reforms such as tariff concessions to the trade, by removing a great deal of non-tariff measures (NTMs) during the last two decades. Sri Lanka has also increasingly simplified and liberalized its trade policy during the 1990s. Though the Government of Sri Lanka revised its import tariff structure several times, import duties on agricultural products have been kept outside the reach of the standard tariff structure. This policy was intended to provide the sector with more time to adjust itself to lower tariff rates. In order to provide some additional assistance to agriculture, the import of several agricultural inputs and equipment were liberalized in 1997. Import of fertilizer and agro-chemicals; cleaning, sorting and grading machines for seeds, grain, and dried leguminous vegetables, and seed-packing machines were exempted from duty in 1997. Other items exempted from duty in 1997 included greenhouses, poly tunnels, sprinklers, drip-irrigation systems, and some types of packing materials (Weerasena et al, 2005).

Agricultural tariffs in Sri Lanka had often been subjected to unpredictable and frequent changes. For example, in January 2002, the ad-valorem taxes for some key agricultural imports were converted into a specific duty. Instead of 35% ad-valorem tax, the import duty for rice became Rs. 7/kg, a tariff equivalent to 36% of the unit import value in 2000. It was once again increased to Rs. 9/kg in 2003. Similar changes were made in tariff of most food commodities. These changes are often made to protect domestic production. The domestic production of most food items was not competitive with world market prices due to high cost of production. These ad hoc tariff changes have adversely affected the food crop sector, mainly its production, processing and trade environments (Weerasena et al, 2005).

Participatory management

Participatory management in irrigated agriculture is accepted as the Government policy, and several programmes have been implemented for more than two decades to encourage and facilitate better participation of farmers in the management process. The programmes carried out so far have had mixed results. While there is a clear improvement of the farmer-officer relationships and communication, it can be seen that the State's responsibility of supporting irrigated agriculture cannot be totally overlooked.

The current policy emphasizes that irrigated agriculture will be supported financially by the State, while farmers actively participate in decision-making. It is also envisaged to mobilize and empower farmers in such a way that they are economically independent and sustainable. The Ministry of Agriculture, Livestock, Lands and Irrigation has embarked on a programme to establish "Yaya" Farmer Production Societies at the field level. The societies will be provided with a small initial capital for establishing a revolving fund. They will be injected with technical expertise to undertake marketing, agro-processing, and provision of extension services. It is planned to establish 10,000 such societies in 2005 (MALL&I, 2005).

Research and extension policies

Research and extension services were the main strategies employed to achieve the present productivity levels of food crops. Crop research has looked at two basic components viz. variety improvement and the development of production protection technology.

Environment specific improved farming technologies have been continuously developed by the Department of Agriculture for the advancement of the food crop sector in the county. These research programmes focus on development of new varieties and improved technologies with regard to land preparation, water management, plant establishment, pest and disease control including weed control, fertilizer application, soil fertility improvement, harvesting and threshing. These technologies have been introduced to farmers to maximise yield and quality in a cost-effective manner. However, the investment made in research and development of food production has been indicated as quite inadequate considering the importance of the food security concerns. It is shown hat the percentage of GDP invested on agricultural research is only 0.2% and this has to be increased to at least 1% to make agricultural research a viable proposition. Sri Lanka Council for Agricultural Research Policy (CARP), Institute of Post Harvest Technology, Bathalagoda Rice Research Institute, Hector Kobbekaduwa Agrarian Research and Training Institute and Galgamuwa Irrigation Training Institute are some of the important institutions in the irrigated agriculture sector contributing to the research effort (Weeraseena *et al,* 2005).

Role of irrigation in poverty alleviation & food security

Irrigation has played a major role in alleviating rural poverty. Recent national surveys (excluding North and East) on household income indicate that income from agriculture forms a high proportion of family income in the North Central, Uva, Northwestern and Southern Provinces. On an average, agricultural activities contributed 7.8% of the average monthly household income at national level. In the rural districts, the contribution from agriculture was highest in Moneragala District (27.3%), followed by Polonnaruwa (21.5%) and Hambantota (18.7%) (DCS, 2004d).

Out of the agricultural crops, paddy occupies a place of importance due to several reasons. Rice is the staple food of the majority of Sri Lankans, and producing it at an affordable price and in adequate quantities is economically and politically important. Paddy cultivation has important associations with the country's history and culture, and therefore it has a social and cultural significance surpassing mere economic value. At present, more than 90% of the national rice requirement is produced in the country, compared to about 40% in 1950.

Vidyaratne and Tilakaratne (2003) define a food poverty line measured in terms of amount of money spent monthly on food required for a person to achieve basic nutritional requirement for good health. This line is the highest in highly commercial western province (Rs. 627.00) and the lowest in the north central province (Rs. 577.00), where 24% of the

irrigated agricultural areas are located. Food poverty, measured in terms of percent of people living below food poverty line, is again lowest in the NCP, while the highest values are recorded in the plantation areas where the poor are mostly paid labourers.

The food poverty line for Sri Lanka, estimated according to a survey in 1995/96 was Rs. 591.00. The corresponding value projected to 2002 using Colombo Consumer Price Index was Rs. 1,094.00. In 1995/96, 32.7% of the population lived below the food poverty line. The corresponding values for Western and North Central Provinces were 22% and 33%, while in Uva Province where the estate sector employees are predominantly present, a value of 48% was recorded (Vidyaratne and Tilakaratne 2003).

Rice production in Sri Lanka achieved its highest level in 2003 (Figure 35). The annual extent cultivated and production in 2003 was 982,610 ha. and 3,071,206 mt. respectively. The use of high yielding varieties, increased use of fertilizers, improved pest management practices, improvement of irrigation infrastructure facilities and favourable weather conditions were among the major factors which contributed to increased rice production (CBSL, 2004). Assuming that the present per capita consumption level of 100kg/year remains unchanged the estimated annual requirement for 2005 is 3.2 million metric tons.

Roles of men and women in agriculture

The proportion of economically active women in Sri Lanka has shown a rapid growth over the years and is relatively high when compared with the neighbouring countries. But still the economic activity rate is very much lower for women than for men. This is mainly attributed to the cultural practice where the household responsibilities are taken up by female members of a family making it difficult for females to participate in income earning occupations away from home. In Sri Lanka, 40% of agricultural workers are women, mostly within the age groups of 24-25 yrs. More than 70% of the female agricultural workers render their services without receiving a pay or profit, whereas only 29% of male workers are found to be in this category (DCS, 1997). Women involved in agriculture commonly perform the tasks of weeding, transplanting, harvesting and post harvest activities.

One fourth of the women agricultural workers have ventured to set up self-employment projects with much preference towards livestock rearing, poultry farming and fish breeding. In contrast nearly two thirds of the male agricultural workers are occupied in profit making ventures related to crop cultivation, livestock and poultry farming and fish breeding. A number of recent studies have revealed that new agricultural technologies have had a

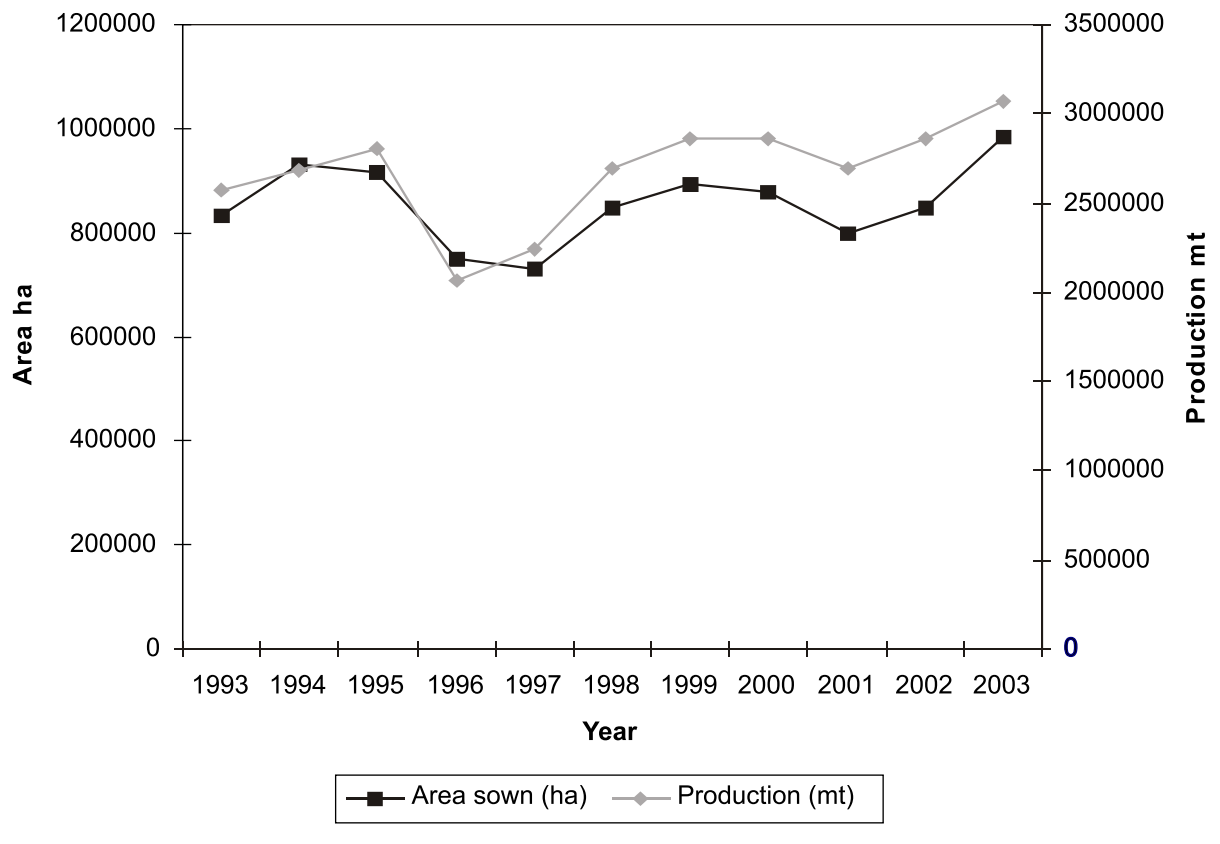


Figure 35. Area planted and production of rice (1993-2003)
Source: DCS, 2004

negative or even adverse impact on women (Amarasuriya, 1995). In some areas where mechanization was introduced, men have taken over the activities of women. The use of agro chemicals in cultivations has had a negative effect, where it tended to eliminate women from weeding activities. Empowering low-income women has been identified as a critical ingredient in food security, increasing agricultural productivity, reducing poverty, reducing malnutrition and the means of looking to the future by investing in the next generation (Sugathadasa, 1995). Some key findings from International Food Policy Research Institute's (IFPRI) gender research studies reveal that household agricultural output can be increased up to as much as 20% by reallocating inputs from men's to women's field plots, and increasing women's human capital is a key element for poverty reduction.

Issues and constraints

The World Bank (2003) lists the following as hindrances to the agricultural growth:

- Unpredictable trade policies
- Restrictive quarantine regulations
- Delays in passing seed-related regulations
- Commodity price interventions
- Restrictive land policies
- Poorly functioning water delivery systems

Many of these issues have an impact on water use allocation for agriculture. At present, Irrigation Department, Mahaweli Authority, Provincial Councils and Department of Agrarian Services are all carrying out programmes to improve the water delivery systems. There is a need to improve the operation and maintenance of irrigation systems in parallel, through increased and effective investment of resources, so that improvements to the delivery systems are sustained. Another major issue is the inadequacy of coordination among the large number of agriculture and irrigation agencies.

Indicators

Indicator	1950	1970	2004
Per capita calorie consumption/day	1,990 kcal	2,264 kcal	2,360 kcal
Self sufficiency in rice		65%	
Area under irrigation	296,000 ha		632,000 ha
% area under irrigation	4.5%		9.6%
Water productivity (reference irrigation water releases)			0.15-0.9 kg/m^3
National Food poverty line			Rs. 1,094 (in 2002)
% population under food poverty line			32.7% (1995/96
Cropping Intensity in paddy lands (1997-2001)			113%
Cropping Intensity in irrigated lands (1997-2001)			123.5%
Paddy yield in major irrigated lands (1997-2001)			4.23 tons/ha

Sources: 1950 values- CBSL, 1998; other values-various sources

UN-Water/WWAP/2006/11

Chapter 07

Water and Industry

Industries are vital to human societies and are one of the main users of water. However, industry should assume their responsibility to protect water quality and ecosystems while taking into account of the needs of competing sectors.

The present distribution of industries in the country is uneven. There is a high concentration of industries in certain districts (Gampaha, Colombo and Kurunegala districts), while it is low in some other districts, especially in the Northern areas. The distribution of industries in different districts in the country is given in Table 46.

According to the Department of Industries, the heavy industries are mostly located in Colombo and Gampaha districts (Table 46 - Senaratne, 2005).

Industrial water demand

A comprehensive assessment of water requirements for industries is not available at present with any responsible organization. The National Census of Industries (or the annual sample surveys on industries) carried out every 10 years by the Department of Census and Statistics is an important source of information on industrial activities. However, aspects such as the availability of water sources, presently used quantity, whether the source is surface water or ground water, future requirements, the production and disposal of wastewater are not systematically collected at present (Senaratne, 2005). This has been identified as a constraint for rational planning of the water supply and drainage needs and for ensuring adequate regulatory measures for pollution control.

In the manufacturing industries, though the quantity of water usage differs widely depending on the products and the magnitude of their operations, the industries that commonly fall within food products, beverages, textiles, tanneries and leather, paper, industrial chemicals, petroleum, rubber products, iron and steel could be classified as water consuming. The sources of water for industries vary depending on the purpose of usage, required quantity and desired quality. This could be from pipe borne water supply of NWSDB or a local authority, extractions from private dug wells and deep wells, or from rivers (Senaratne, 2005).

The NWSDB maintains data regarding the consumption of water by industries that obtain water from their water supply schemes. The details of the industries that had been obtaining water from NWSDB during the past few years are presented in Tables 47 and 48, which indicates a relatively low prominence and the slow growth of the industrial sector within the consumer base in the NWSDB schemes.

Table 46 Distribution of Industries

No	District	No. of Establishments	Persons Engaged
	Western Province		
1	Colombo	14,094	203,743
2	Gampaha	17,315	254,042
3	Kalutara	7,055	68,177
	Central Province		
4	Kandy	8,729	56,245
5	Matale	3,516	19,008
6	Nuwara-Eliya	1,980	23,012
	Southern Province		
7	Galle	6,127	48,591
8	Matara	5,306	28,870
9	Hambantota	3,976	19,985
	Nothern Province		
10	Jaffna	2,787	9,157
11	Mannar	432	1,414
12	Vavunia	604	2,616
13	Mullativu	527	2,083
14	Kilinochchi	463	1,912
	Eastern Province		
15	Batticaloa	2,027	7,810
16	Ampara	3,910	14,116
17	Trincomalee	1,524	6,251
	North Western Province		
18	Kurunegala	17,820	86,360
19	Puttalam	6,670	42,041
	North Central Province		
20	Anuradhapura	4,780	22,275
21	Polonnaruwa	2,712	16,189
	Uva Province		
22	Badulla	3,342	17,244
23	Moneragala	2,320	9,853
	Sabaragamuwa Province		
24	Ratnapura	6,453	42,319
25	Kegalle	6,929	30,982
	Total	**131,398**	**1,034,295**

Source: Senaratne, 2005

Industries and degradation of water quality

The pollution of water sources by industries is a grave concern in certain areas. Improper disposal of wastewater and solid waste are causing the pollution of both surface water and ground water in some areas. The severity of the problem differs from place to place depending on the particular industry, the nature of waste and the location.

A study conducted by the Central Environmental Authority (CEA) in the Kelani River, which is the main source of drinking water to Colombo, reveals that there are industries polluting the river with an added possibility of groundwater pollution as well. It has recommended that all toxic material should be removed from effluents at the source, and that monitoring effluent standards should be effectively maintained.

In another study conducted in Mount Lavinia/Ratmalana a mixed residential and industrial area, the occurrence of coloured water in the drains, and pollution of water in the wells due to industrial effluent discharge is highlighted among other things. The study recommends the limiting of industrial expansion in certain areas. There are other instances where the tanneries, which existed close to residential areas, were relocated in remote areas due public complaints regarding pollution (Senaratne, 2005).

The National Environmental Action Plan (1998-2001) states that strong environmental laws and institutions are in place to ensure that industries do not harm the environment or the natural resources. However, it notes that industrial effluent continues to pollute surface and ground water especially in the Colombo and Gampaha Districts. The tanneries, paper industry (MF&E, 1998), textile dying and bleaching, food processing, metal finishing, agro produce, sugar, distilleries, breweries and mineral products (UNEP, 2005) are reported as causing severe pollution. The Kelani River, Negombo lagoon (north of Colombo), Lunawa lagoon and Bolgoda Lake (south of Colombo) are among the affected surface water resources. In addition, the effluent from distilleries in the Kalutara District has polluted the groundwater resources in the area (MF&E, 1998).

Policy guidelines, regulations and incentives

The Government of Sri Lanka has recognised the industries as a sector to be considered for water allocations in the draft policies on water. Generally, the industrial water requirements together with commercial requirements have been low, and are below the water requirements for drinking water and sanitation, food security and irrigation, ecology and environment and hydropower generation. The NWSDB has a higher tariff for industrial and commercial consumers than for domestic consumers, the ratio being 1:6. In terms of the draft National Policy on Drinking Water Supply and Sanitation prepared by the NWSDB, "the cross subsidy from commercial/industrial consumers to domestic consumers shall be reduced to a reasonable level". However, neither the "reasonable level" nor the time frame for this provision is well defined (Senaratne, 2005). Demand management is recognized as an important aspect for economic utilization of water resources.

Small industrial water requirements, in areas where the NWSDB is the provider, the allocations are governed by the normal NWSDB policies and procedures.

The preparation of plans for provision of infrastructure for industries within designated industrial areas is the responsibility of the Regional Industry Services Commission. Such plans are

Table 47. Industries Obtaining Water from NWSDB Schemes

Province	Parameter	No. of Consumers			
		1999	2000	2001	2002
Western	No. of industries	831	996	1,115	1,179
	% from total connections	2.98%	3.52%	3.05%	3.50%
Southern	No. of industries	-	-	153	165
	% from total connections	0.00%	0.00%	0.16%	0.16%
Sabaragamuwa	No. of industries	30	34	-	67
	% from total connections	0.15%	0.15%	0.00%	0.16%
Central	No. of industries	-	-	-	136
	% from total connections	0.00%	0.00%	0.00%	0.18%
Uva	No. of industries	30	35	41	44
	% from total connections	0.15%	0.16%	0.18%	0.16%
Eastern	No. of industries	-	-	-	-
	% from total connections	0.00%	0.00%	0.00%	0.00%
North Western	No. of industries	168	114	91	93
	% from total connections	0.48%	0.46%	0.53%	0.50%
North Central	No. of industries	-	46	39	39
	% from total connections	0.00%	0.22%	0.18%	0.16%
Northern	No. of industries	-	-	-	-
	% from total connections	0.00%	0.00%	0.00%	0.00%
Total	No. of industries	1,059	1,225	1,439	1,723
	% from total connections	0.21%	0.22%	0.22%	0.24%

Source Economic and Social Statistics of Sri Lanka 2003, Central Bank and National Water Supply & Drainage Board

Table 48. Industrial consumption of water from NWSDB schemes

Province	Parameter	Water Usage			
		1999	2000	2001	2002
Western	Consumption (MCM)	3.1	3.1	3.44	3.36
	% from total	2.49%	2.55%	2.34%	2.24%
Southern	Consumption (MCM)	0	0	0.13	0.17
	% from total	0.00%	0.00%	0.63%	0.71%
Sabaragamuwa	Consumption (MCM)	0.01	0.03	0.01	0.02
	% from total	0.17%	0.53%	0.13%	0.23%
Central	Consumption (MCM)	0	0	0	0.02
	% from total	0.00%	0.00%	0.00%	0.12%
Uva	Consumption (MCM)	0.04	0.03	0.06	0.05
	% from total	0.65%	0.50%	0.86%	0.71%
Eastern	Consumption (MCM)	0	0	0	0.21
	% from total	0.00%	0.00%	0.00%	2.50%
North Western	Consumption (MCM)	0.06	0.11	0.06	0.04
	% from total	0.43%	1.15%	0.88%	0.68%
North Central	Consumption (MCM)	0.01	0.03	0.02	0.01
	% from total	0.14%	0.43%	0.27%	0.14%
Northern	Consumption (MCM)	0	0	0	0
	% from total	0.00%	0.00%	0.00%	0.00%
Total	Consumption (MCM)	3.22	3.3	3.72	3.38
	% from total	1.59%	1.70%	1.69%	1.48%

Source : Economic and Social Statistics of Sri Lanka 2003, Central Bank and NWSDB, quoted in Senaratne, 2005

submitted to the Industrialization Commission, on whose recommendations the plans are gazetted by the Minister. The implementation of approved plans is the responsibility of the Regional Industry Services Commission.

The regulations controlling industrial pollution include; National Environmental Act No 47 of 1980, NEA amended Act of 1988, Environmental Impact Assessment Regulations of 1993 and Gazette Extraordinary no. 859/14 of 1995, Provincial Councils Act of 1987, Municipal Councils Ordnance of 1980 and Urban Councils Ordnance and Pradeshiya Sabha Act no. 15 of 1987. According to these regulations, development of any waste disposal facility with a capacity exceeding 100 tons per day is a proscribed project. Such a developer should obtain an environmental clearance, and conduct an Environmental Impact Assessment (EIA) or an Initial Environmental Examination (IEE). The local authorities have the power to make by-laws for the control and regulation of industrial waste (UNEP, 2005).

The Central Environmental Authority (CEA), which is the national authority for ensuring environmental protection, has the responsibility and authority to carry out environmental planning and regulation, issuing licenses to carry out prescribed activities that are likely to cause pollution of environment. These activities need to comply with standards and prescribed criteria of the CEA. For some industry types, the CEA assigns the authority to the local authorities for the issue of licenses. In such instances, ensuring environmental protection is the responsibility of the local authority. There are environmental officers attached to the local authorities such as Municipal Councils and Urban Councils, and to the Divisional Secretary offices in the case of Pradesiya Sabhas.

The industrial parks set up by the Government are another method to control industrial pollution. They provide for the use of clean technology for central water treatment facilities. The export processing zones at Katunayake and Biyagama also provide central effluent disposal facilities (MF&E, 1998a)

The monitoring of the environmental pollution is the responsibility of the CEA and local authorities. Their activities are affected by inadequate manpower and other resources (Senaratne, 2005). Several reasons have been enumerated for the inadequate implementation and enforcement of regulations. These include:

i. Lack of proper waste disposal facilities for the local authorities compels them to dump waste in environmentally harmful manner.

ii. Poor levels of income of the local authorities

iii. Lack of proper land-zoning for industries and residential areas (UNEP, 2005a)

iv. Lack of incentives for compliance

v. Difficulties on obtaining technical assistance for pollution minimization (MF&E, 1998)

In an effort to change unsustainable consumption and production in industrial development and in view of maintaining strict quality standards of export of products, conformity to variety of standards focused on environmental and social welfare aspects are promoted by the government. These include product standards such as ISO 9000, 14000 and 18000 series for food and beverage items, and standards for garment and textile industry. Concept of "Cleaner production" has been identified as a key element in achieving this, and a National Cleaner Production Unit has been set up in the Ministry of Industry, Tourism and Investment Promotion foe this purpose.

There are several effluent standards related to the industries, established by the Sri Lanka Standards Institution for the prevention of water pollution by industries. These are mainly the tolerance limits of industrial effluents at receiving water bodies, such as inland water bodies, marine water bodies and also those for land irrigation. Tolerance limits are also for specific types of industries. A list of such standards available is presented in Annex 5.

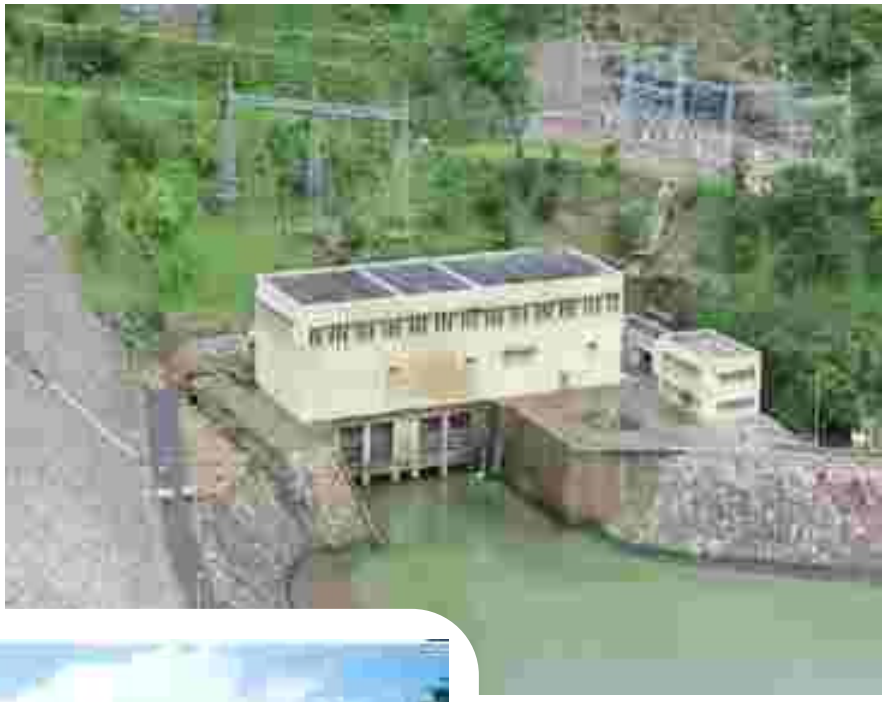
There are also Sri Lanka Standards for environmental management systems, based on the ISO standard 14000 series. These are supposed to be guidelines for industrialists, to be adopted by them on their own, in order to improve their environmental quality. These standards intend to provide organizations with elements for an effective environmental management system (Senaratne, 2005)

Indicators

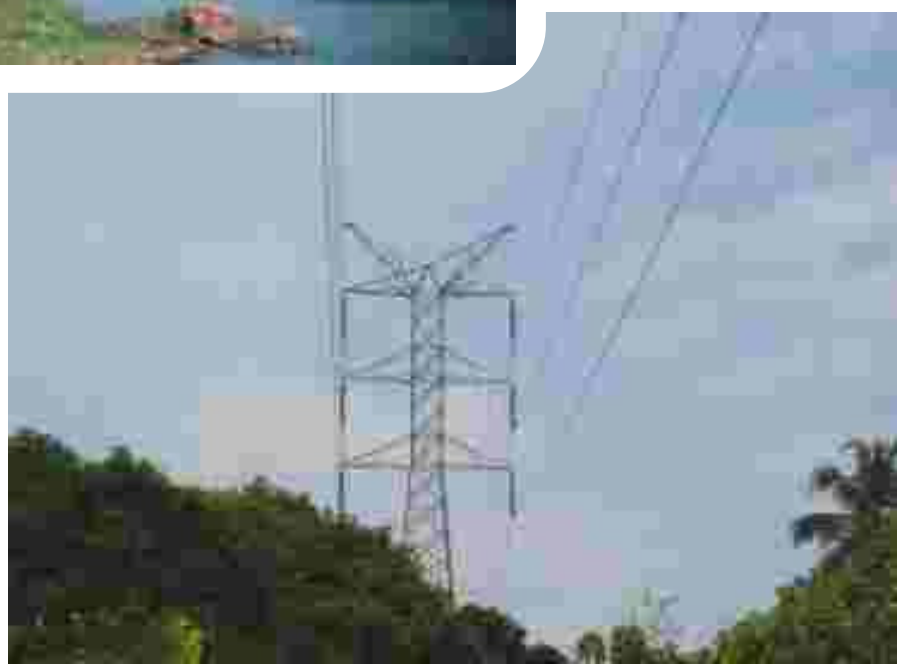
Availability of laws and guidelines to control industrial pollution can be considered as moderately satisfactory while implementation of laws and guidelines to control industrial pollution range from unsatisfactory to moderately satisfactory.

UN-Water/WWAP/2006/11

Chapter 08



Water and Energy



Water is vital for all forms of energy production. There is a need to ensure that energy requirements are met in a sustainable manner while minimizing the environmental impacts. Sri Lanka used to be heavily dependent on hydropower generation in the early 1990s. The situation is changing now due to climatic variations in the recent times making hydropower production unreliable. Social and environmental concerns constrain the full utilisation of hydropower potential. However, alternative sources such as coal and petroleum give rise to environmental concerns as well. This chapter examines the current status of energy production and use with an emphasis on hydropower generation, and discusses the major issues.

Energy production and future projections

The major primary energy sources of Sri Lanka are hydropower, petroleum and fuel wood. The share of each primary energy source for the year 2001 is petroleum 41%, hydropower 9%, and biomass 50% (Seneviratne and Handagama, 2005). The Ceylon Electricity Board (CEB), established in 1969 by an Act of Parliament, is the statutory body in Sri Lanka with responsibility for generation, transmission and distribution of electrical energy. By the end of November 2004, six Independent Power Producers (IPP) were connected to the main utility for long-term power generation (which is presently treated as a period between 10 to 15 years). All such long-term thermal connections, range from 20 MW to 163.5 MW of individual capacities, and comprise a total of 434 MW.

In August 1995, the Ministry of Power and Energy attempted to form a national energy policy for Sri Lanka, for which a committee was appointed. This committee drafted ten national policies and six general strategies to achieve an optimum energy mix for the future. At present a macro-level energy plan for the country is being addressed by Ministry of Power and Energy (Seneviratne and Handagama, 2005). The existing hydroelectric plants of CEB are given in the Table 49.

Energy need

Like in most other developing countries, Sri Lanka's energy consumption in the household sector is primarily for cooking, with a small but important component for lighting. Factors such as fuel mix, cost of supply, energy conservation and availability, influence the household energy consumption. In 2001

Table 49: Installed Capacity of Power Plants

Station Name and Capacity (Mw)		Commissioning
Laxapana Hydro power Complex (CEB)		
Old Laxapana	3 × 8.33 = 25	December 1950
	2 × 12.5 = 25	December 1958
Wimalasurendra	2 × 25 = 50	January 1965
Polpitiya	2 × 37.5 = 75	April 1969
New Laxapana	2 × 50 = 100	February-March 1974
Canyon	2 × 30 = 60	March 1983,Mar 1988
Mahaweli Hydro power Complex (CEB)		
Victoria	3 × 70 = 210	1984 - 86
Kotmale	3 × 67 = 201	1985 - 88
Randenigala	2 × 61 = 122	July 1986
Ukuwela	2 × 19 = 38	1976
Botawenna	1 × 40 = 40	1981
Rantembe	2 × 24.5 = 49	1990
Other CEB Hydro power systems		
Small hydro systems	11+ 6 + 3 = 20	1963 - 88
Samanalawewa	2 × 60 = 120	October 1992
Kukule	2 × 35 = 70	July 2003

Source: Seneviratne and Handagama, 2005

the sectoral energy consumption of the households and the commercial sectors was 53%, while the transport sector was 28% and the industrial sector 19%.

Electrical energy in Sri Lanka is produced mainly from petroleum and hydro sources, and delivered to different consumer sectors. Users from all these sectors look for low cost and reliable electrical energy to reduce costs in a competitive market environment. Therefore the cost of electricity generation, and the cost of unserved energy would be vital parameters in achieving a proper mix of economic policies. In Sri Lanka, as in most developing countries, the electricity generation and distribution, is owned or heavily controlled by the government, the reason being the involvement of a huge investment to produce low cost electrical energy in the long-term.

According to the electricity consumption data for 2002, the main consumer is the domestic sector (49%), closely followed by the industrial and commercial sector (48%). Other users include street lighting (2%), and religious establishments (1%) (Seneviratne and Handagama, 2005). CEB prepares load forecasts (taking into account low, medium and high growth rates of demand), using econometric techniques. To capture different consumption patterns of various consumer categories, a sector-wise forecast is prepared separately. This sector-wise forecast is considered to be derived from the total system demand forecast. The analyses carried out using the load forecast is considered as the base case, and sensitivity analysis are carried out for various input parameters.

In long term planning to meet the demand, hydropower, fossil fuel based thermal power, and other renewable energy sources are the primary energy options considered. (Nuclear power is not considered due to technical non-feasibility). Plant selection is based on economic evaluation, and the network expansion and modification is planned according to demand growth and plant locations (Seneviratne and Handagama, 2005).

Households with access to electricity

At the beginning of the year 2002, only 65% of the population had access to electricity from the national grid, which is planned to be increased to 77% by end of 2006 (Seneviratne and Handagama, 2005). The electricity demand is growing at a rate of 7-8% annually. The growth of electricity clearly follows the country's economic growth (Seneviratne and Handagama, 2005).

Table 50: Major Hydropower Facilities and their Characteristics

River Basin	Hydropower Station/reservoir	Storage Capacity (MCM)	Generation capacity MW	Volume of Water/Unit Energy (MCM/GWh)
Kelani	Wimalasurendra/Castlereigh	44.0	50	1.983
Kelani	Old Laxapana/Norton	0.39	50	0.935
Kelani	New Laxapana/Canyon Pond	0.92	100	0.822
Kelani	Canyon/Mousakele	125.0	60	2.246
Kelani	Polpitiya/Laxapana Pond	0.2	75	1.643
Mahaweli	Kotmale	173.5	201	1.882
Mahaweli	Victoria	723.0	210	2.001
Mahaweli	Randenigala	864.0	122	6.293
Mahaweli	Rantambe	7.0	49	12.425
Mahaweli	Ukuwela	4.11	38	5.388
Mahaweli	Bowatenna	56.0	40	8.262
Walawe	Samanalawewa	278.0	120	1.305
Kaluganga	Kukule	5.67	70	2.188

Source: Seneviratne and Handagama, 2005

Hydropower

Number and capacity of dams

The major hydropower facilities and their characteristics are listed in Table 50.

At present 35 small-scale hydropower projects contributing 74 MW are in operation, while 38 projects with 91 MW are under agreement (Standard Power Purchase Agreement-SPPA), and 65 projects with 130 MW have been given Letters of Intent (LOI) from CEB, to proceed with the development of small-scale (mini) hydropower generation facilities.

Proportion of hydropower in overall energy production

Electricity generation from 1989 2003 is shown in Table 51. It shows that the share of hydro in meeting electrical demand has decreased to 40 % during the recent past when compared to 90% and above during the early nineties. In terms of electricity generating capacity, hydropower contributes 1,247 MW out of a total installed capacity of 2,223 MW (CBSL, 2004). This is mainly due to the addition of thermal power plants to meet the increasing demand experienced after the completion of the Accelerated Mahaweli project (Seneviratne and Handagama, 2005).

At the beginning of year 2002 only 65% of the population had access to electricity from the national grid, which is planned to be increased to 77% by the end of 2006. The electricity demand is growing at the rate of 7.8% annually. The growth of electricity clearly follows country's economic growth (Seneviratne and Handagama, 2005). Rural electrification progress contributed to the increase of electricity consumption as well as improved living conditions in rural areas. There were 12,857 rural electrification schemes completed in 1995, which increased to 15,529 in 2001. (Statistical Unit of CEB, 2001).

Table 51 Generation Summary (1989-2003)

Year	Hydro		Thermal		Total
	GWh	%	GWh	%	GWh
1989	2801	98	57	2	2858
1990	3144	99.8	5	0.2	3149
1991	3116	92.3	260	7.7	3376
1992	2900	81.9	640	18.1	3540
1993	3796	95.4	183	4.6	3979
1994	4089	93.2	275	6.3	4386
1995	4514	94	269	5.6	4800
1996	3249	71.8	1126	24.9	4527
1997	3448	67	1463	28.4	5146
1998	3915	68.9	1654	29.1	5683
1999	4175	67.6	1901	30.8	6173
2000	3197	46.7	3486	50.9	6841
2001	3113	46.9	3407	51.4	6625
2002	2696	38.8	4114	59.2	6946
2003	3190	41.9	4421	58	7611

Source : Seneviratne and Handagama, 2005

Village hydropower

The government promoted the generation of electricity off the main grid for poor rural areas. This system was initiated around 1992, and there had been a steady growth. Two projects have been carried out by the Energy Services Delivery Project initiated in 1997, and the Renewable Energy for Rural Economic Development Project initiated in 2002. The latter projects were providing technical support, an instalment basis grant, and partial cover of the project development cost. At present, the installed capacity of such schemes is about 41,491 KW (UNEP, 2005). The important features of these schemes are as follows:

- The projects are selected based on the proposals submitted by Community Based Organizations
- Hydropower projects planned in well-managed stream catchments have better likelihood of approval

- As a result, the appreciation of the local community for environmental conservation has been enhanced.
- Electricity Consumer Societies have been established to oversee the daily operations (UNEP, 2005).

Alternative forms of energy

The government has taken a policy decision to encourage the private sector to develop renewable energy generating systems of less than 10 MW capacities. These may include projects such as mini hydro and wind, as well as the use of municipal solid waste, paddy husk, saw dust, sugar cane waste, dendro etc. All hydro plants exceeding 10 MW of generating capacity are to be developed by the government in the foreseeable future. Renewable energy plants less than 10 MW are classified into three categories according to the mode of operation. These are, Grid-connected (deliver of electricity exclusively to the grid), Self-generating (these while delivering electricity to the grid, a part is consumed by the developer), and Off-Grid (operate in isolation).

The government promotes the public-private partnership in power generation. A Standard Power Purchase Agreement (SPPA) is signed between the developer and CEB to procure energy at a pre determined price. The main features of SPPA are as follows:

- CEB will purchase all energy produced by the facility.
- Power plant is not subject to centered dispatch

Tariff is based on avoided cost to CEB, which is announced annually. The principle of avoided cost imply that the CEB is willing to pay the cost that it avoids in its own system, as a result of SPPAs being available, and delivering energy to the CEB grid.

The cost of the transmission inter connection has to be borne by the developer.

In 1999 CEB implemented a 3 MW wind power plant as a pilot project. Most of the renewable energy developed is in the area of mini hydro generation (Seneviratne and Handagama, 2005). The quantity of energy produced from wind power plants is 3 GWh per annum.

Energy production, environment and climate change

Biomass was the major source of energy in 1950s, fuel wood being the most important component. The share of biomass in the total energy use was 70% in 1972, but this has reduced to 57% in 1995 (CBSL, 1998). At present the contribution of biomass for energy production is about 48% (CBSL, 2005). The reduction of fuel wood as a source of energy appears to be related to the increase in electricity consumption. The impacts of this change are discussed below.

Sri Lanka has forty-one wetlands of national importance. In about 12 of them the collection of fuel wood is cited as unsustainable. Fuel wood collection is also a threat to the conservation of the natural forest cover of Sri Lanka. Availability of electricity at an affordable price would help less-affluent people to reduce their consumption of fuel wood, and thereby conserve the environment. Thus the critical link between hydropower generation and the sustainability of water resources is clearly seen.

Although there are negative impacts due to clearing of forests etc, storage of water for hydropower generation has helped the environmental health of the rivers in several areas. During drought periods hydropower generation and the resultant release of water downstream helps to reduce the salinity intrusion (Such instances are further discussed in Chapter 10- Sharing Water).

While these impacts are on the positive side, some negative impacts of the construction of reservoirs too have been discussed in the chapter on ecosystems. The Upper-Kotmale hydropower project, of which the technical and economic feasibility was completed in 1987, could not be initiated until 2005 due to objections relating to environmental and social issues. The project was finally inaugurated with substantial reduction in power generating capacity to ensure allocation of water for sustenance of waterfalls affected by the proposed reservoir and a comprehensive resettlement plan.

Goals and strategies for future energy demand

The Figure 36 shows the variation of electrical energy demand in a typical week day, and the contribution by different power plants (including thermal plants) to meet the demand.

The long-term generation expansion plan of CEB has identified several prospective hydro projects, namely, Gin-Ganga, Broadslands, Uma Oya and Moragolla. The possibilities identified by the CEB to expand the capabilities of existing hydro plants are as in the Table 52.

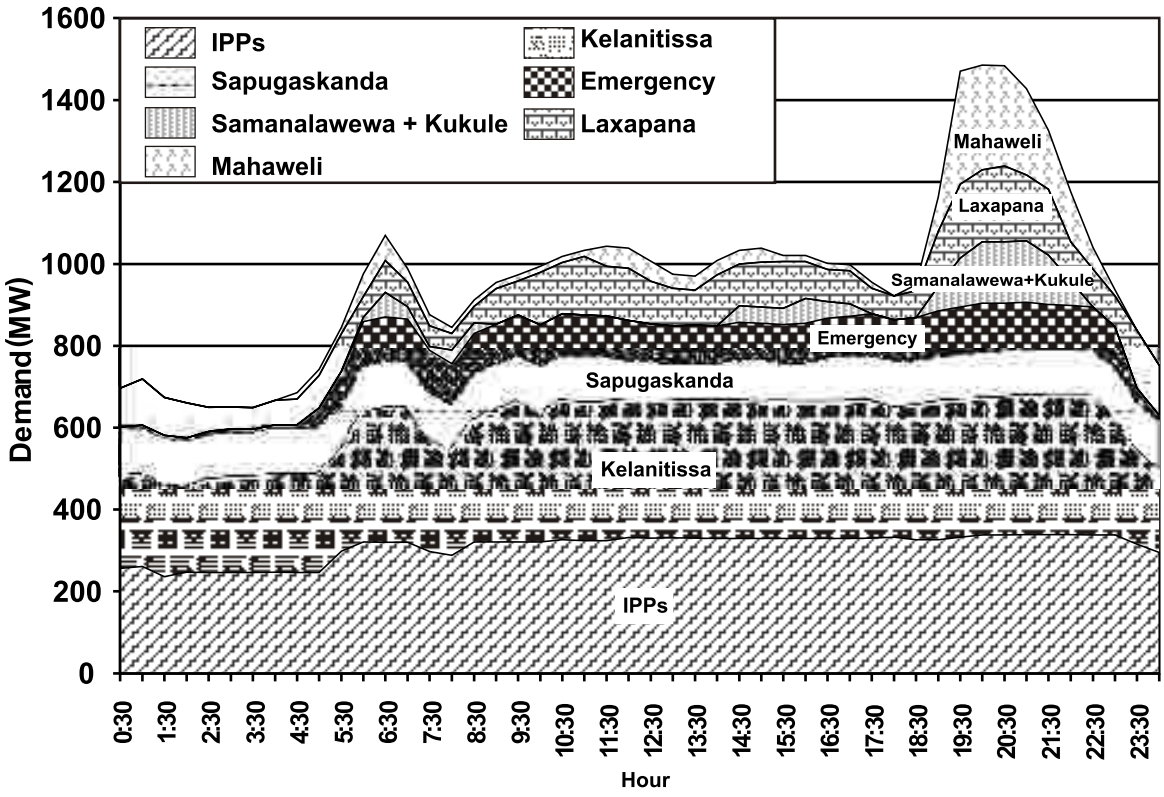


Figure 36. Energy demand variation in a week day and contribution from different plants

Source: Seneviratne and Handagama, 2005

Table 52. Expansion Proposals for Existing Hydropower Systems

Additional plants at Samanalawewa (2*60 MW) for peaking.
Additional plant for Polpitiya (37.5 MW)
New Laxapana (50 MW) power stations.
Raising the dam crest level by 20% and harnessing more energy at Kotmale
Additional tunnel At Victoria and a capacity increase by 210 MW.
Diversion of Upper Kalu Ganga into Moussakelle reservoir for increased energy production.
Modificationof Maduru Oya irrigation tank to incorporate a power plant to generate electricity

Source - CEB-Generation Plan-2003 cited in Seneviratne and Handagama, 2005

Indicators

- Percent of hydropower contribution to electricity
  - In terms of power generated = 40%
  - In terms of installed capacity (2003) = 56%
- Percent population with electricity from national grid = 65%
- Installed capacity of community managed hydropower schemes = 41.5 MW

Chapter 09

Managing Risks

It is of great importance to ensure that human beings and ecosystems are secured from floods, droughts, pollution and other water-related hazards. Management of water related risks contribute to the sustainability of development. Sri Lanka experienced several natural disasters in the recent past, the Asian Tsunami of 2004 being the worst in recorded history. This chapter discusses the extent of the disaster risk, current measures to control and mitigate such events and the critical issues.

Types of water-related natural disasters

Floods, landslides and droughts are the most destructive types of water related natural disasters that are encountered in Sri Lanka. A summary of such events is listed in Table 53.

Table 53: Natural Disasters in Sri Lanka from 1957 to 2003

	Number of Events	Deaths	Persons Injured	Home-less	Affected	Total Affected	Damage US$ (000's)
Drought	10	0	0	0	8,613,000	8,613,000	
average per event		0	0	0	861,300	861,300	
Flood	36	935	1,000	2,747,601	6,274,127	9,022,728	367,444
average per event		26	28	76,322	174,281	250,631	10,207
Slides	3	119	0	0	130	130	
average per event		40	0	0	43	43	
Wind Storm	5	1,151	5,000	100,000	1,913,000	2,018,000	137,300
average per event		230	1,000	20,000	382,600	403,600	27,460

Source: http://www.em-dat.net/disasters/profiles.php cited in Ariyabandu, 2005

Droughts

The dry zone is frequently subjected to droughts. However, drought situations are occasionally encountered in the wet zone as well. It has been identified that on an average droughts of a serious nature occur every 3-4 years, while severe droughts occur every 10 years (ADPC, 2003).

Severe droughts have occurred during the periods 1935-1937, 1947-1949, 1953-1956, 1965, 1974-1977, 1981-1983 and 1988-1989. In more recent times droughts have occurred in the years 1995-1996, 2001, 2002 and 2004. Successive droughts in years 2001, 2002, 2004, have resulted in colossal losses to the economy and livelihoods. In 2001 it was estimated that 1,000,000 people in Sri Lanka were affected, while in 2002 the figure had reached 557,000. In 2004, an estimated 52, 651 ha of crops were damaged in 7 districts (Ariyabandu, 2005).

Floods

Floods are usually associated with monsoon rainfall. It is reported that on an average, about 200,000 people are affected due to floods. Major floods have occurred in 1913, 1940, 1947, 1957, 1967, 1967, 1968, 1978, 1989, 1992, 2002 and 2003. The 1978, the floods which followed a cyclone, affected one million people, killed 915 people and submerged 28% of the land area, mainly in the dry zone. The highest ever recorded rainfall of 805 mm within 24 hours was in 1987 at Kanukken. The City of Colombo received 494 mm of rain within 24 hours in 1992, and this resulted in one of the worst urban floods. The most recent floods in 2003 resulted in 235 deaths and affected 137,221 families (ADPC, 2003).

The Kalu, Kelani, Nilwala, Gin and Mahaweli rivers originating from the wet zone are the major flood prone rivers in Sri Lanka. When considering all river basins in Sri Lanka, Kalu Ganga located in the South-west has the highest annual discharge to the sea. The main cause of flooding of Kalu Ganga at Ratnapura town, the provincial capital of Sabaragamuwa, is the very high annual rainfall falling in the upper catchment areas and the steep slopes of upper reaches. While the river gradient above Ratnapura is steep, the gradient from Ratnapura to the sea outlet is very gentle, and hence inadequate to create velocities to discharge the floods. The steep gradient upstream makes it difficult to give advance flood warnings to this city, and in addition the river constricts at approximately 32 km downstream of Ratnapura town and detains the flood water for several days.

Floods in Kelani Ganga are mainly due to excessively heavy and lengthy rainfall, particularly in the upper catchment of the river, and the mild gradients encountered in the lower parts of the river. The low lying area sof the river are located in the heavily populated and developed Colombo metropolitan region, which increases the cost of damage from floods.

Floods in Nilwala Ganga are mainly due to heavy and long duration rainfall along with the mild gradients seen in the lower parts of the river. The tributaries of this river often encounter flash floods. The low lying area of the river is located in the Matara District in the South, which is a highly urbanized area. The catchment area of the Gin Ganga lies entirely within the wet zone in South-western Sri Lanka, while the upper catchment is within the Sinharaja rainforest area. Floods are mainly due to the heavy and long duration rainfall, and the mild gradient in the lower parts of the river. The low lying area of the river is located in the Galle District, and the outlet of the river is located in Galle, the capital city of the Southern Province.

Floods in Mahaweli Ganga which is the largest river in Sri Lanka occur mainly due to heavy rainfall particularly in the upper catchment of the river and the mild gradient in the lower parts of the river (Dias, 2005). The districts Ratnapura and Kegalle in Sabaragamuwa Province, and districts of Kalutara and Galle in the Southern Province, Batticoloa and Trincomalee districts in the Eastern Province are identified as the most flood prone districts in the island in terms of frequency of flooding. (Ariyabandu, 2005).

Landslides

Most of the landslides that occurred in Sri Lanka during north-east monsoons, south-west monsoons and the second inter-monsoon have been in three distinctively separate areas. Scientific studies at the National Building Research Organisation (NBRO) have shown that the reasons for the increase in the frequency of landslides, are unplanned intensive cultivation, non-engineered construction activities, deforestation, neglect of land and increase of human interventions. The threat continues in the guise of population pressure and the consequent demand for infrastructure, and political interference in decision-making (Ratnayake and Herath 2005).

Landslides have been identified as having direct implications on flooding. The large quantities of soil brought down by the slides get deposited in the reservoirs reducing their capacity. The Rantambe Reservoir, a hydroelectric reservoir in the Mahaweli cascade, commissioned in the early 1980s, was silted over 60% by the end of a decade.

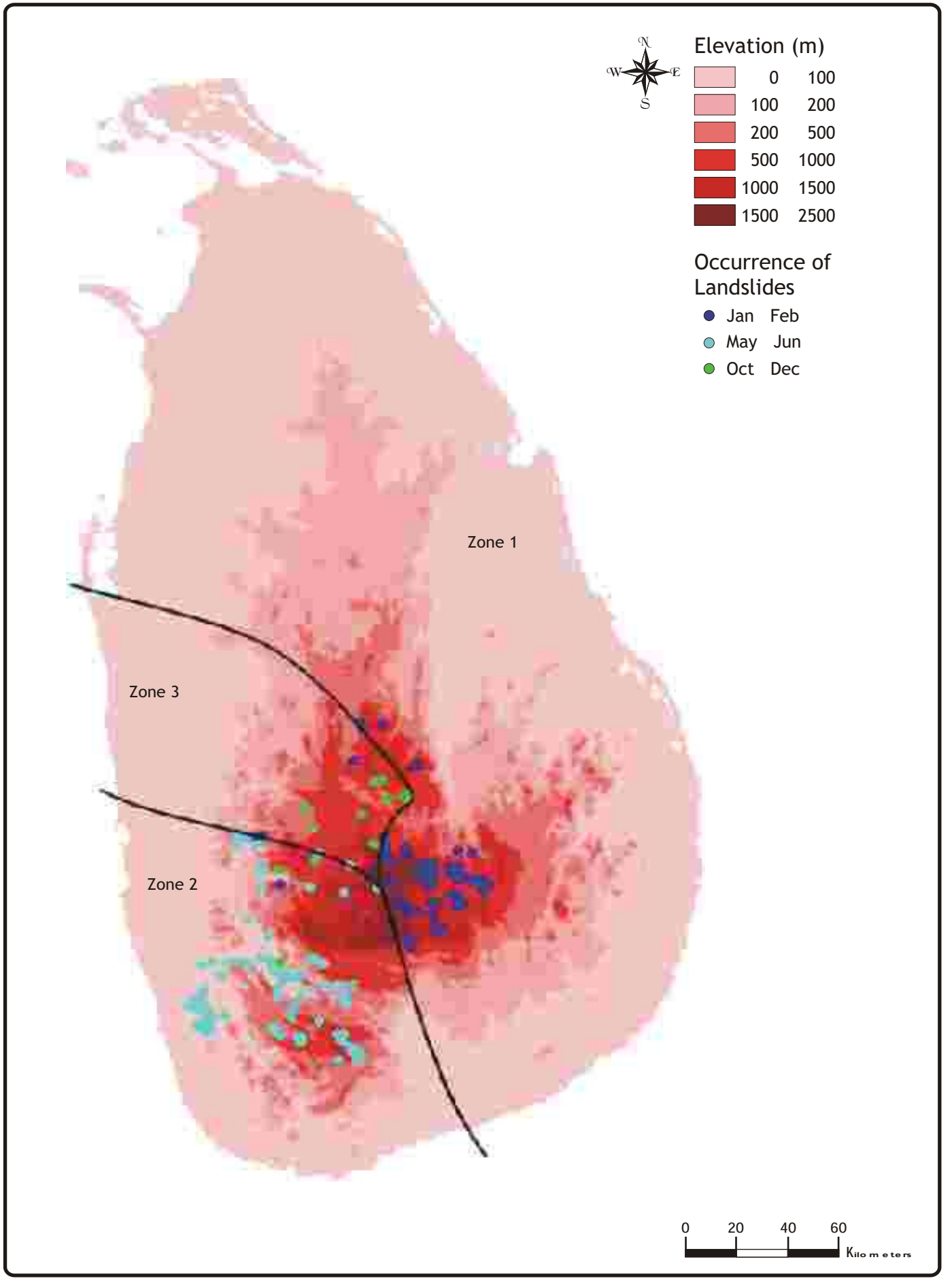


Figure 37. **Temporal clustering of landslides**
Source: Ratnayake and Herath, 2005

Three major danger zones based on annual timing of landslide hazards have been identified (Figure 37), thus providing a guide to the public about the time of the year during which they have to be more vigilant. (Ratnayake and Herath 2005).

Tsunamis

Tsunamis are not of frequent occurrences in Sri Lanka. Prior to 2004, Sri Lanka's recorded history of about 2,500 years mentions only about two such incidents. However, the Asian tsunami that hit the eastern, north-eastern and southern coasts of Sri Lanka is the worst known natural disaster in Sri Lanka's history. About 1000 km or two-thirds of the coastline was affected (UNEP, 2005a). It is estimated that between 38,000 and 40,000 people died, and the damage to infrastructure and the economy have been estimated at approximately US$ 1 billion (MF&P, 2005).

The damages to infrastructure include roads, bridges, railways, harbours, fishing vessels, schools, tourist hotels, telecommunication systems, water supplies and dwellings (MF&P, 2005). The heaviest damage was experienced by the fisheries sector, with about 80% of the active fishermen being affected, and 75% of the fishing fleet being destroyed. Ten out of the 12 fishing harbours were damaged. Other damaged areas include fishing gear, ice plants, landing ports, breakwaters, ice plants and houses of the fishing community (CBSL, 2005). In some areas in the east, the affected population was as high as 80%. Other affected sectors included agriculture and drinking water, due to incursion of saline waters and marine sediment. It is estimated that 62,000 dug-wells were affected in this manner. 44 health institutions were completely destroyed together with medical personnel (UNEP, 2005a), and this may have added to the human suffering.

However, as in all other cases of disasters, the cost of human suffering remains less noticed and unaccounted for in cost estimates. It is estimated that more than 900 children were orphaned or separated from parents. Similarly, there are many parents who lost all their children. Women and children remained the most affected categories during the disaster as well as in the aftermath. Providing for their security remains a grave national responsibility.

The current ongoing research reveals that environmental damage to coastal ecosystems such as coral reefs and mangroves reduced the capacity of such natural barriers to mitigate the tsunami force, and thus intensified the destruction. It was observed that in the reaches where coral mining was rampant, the damage to the coast was severe, but where vegetated coastal sand dunes existed tsunami waves were effectively barricaded as observed in Yala and Bundala National Parks, and where damage occurred only at places where the dune line was interrupted by river outlets. Similarly, deep stands of mangrove forest also appear to have afforded a significant protection against the waves (UNEP, 2005a). Therefore, the government and NGOs are planning to restore these natural barriers wherever possible and preserve the ecosystems with the participation of the community.

Other forms of natural disasters

In Sri Lanka, cyclonic storms and gale-force winds are also bound with monsoon activity, or as a result of severe weather changes in the Bay of Bengal. Cyclonic storms occur mainly during the north-east monsoon. Sri Lanka's definition of cyclones refers to wind speeds of over 118 km per hour, while a cyclonic storm qualifies to be called so when the wind speeds are 62-117 km/h.

During the period of 1881-2001 eleven cyclonic storms and five cyclones crossed the Sri Lankan coasts. A majority of these, or approximately 85%, occurred during the month of December, and reached the country via the eastern sea board. Cyclonic activities that had been recorded off Sri Lanka's east coast by the Meteorology Department were in March 1907, November 1922, December 1964, November 1978 and December 2000 (Ariyabandu, 2005). Although satellite weather forecasting and radar stations off the east coast have made it easier to predict the development of a cyclone structure over the Bay of Bengal, it is still not possible to predict accurately the movement and direction of cyclonic winds. Though Sri Lanka is outside the cyclone belt, the few cyclones experienced were the causes for extreme rainfall events. There were eleven cyclones and two storms recorded between 1845 and 1958 but there were several since then (MF&E, 2000).

Climatic variations and long-term projections

Several indicators have been used by researchers to assess the climatic variations in Sri Lanka. Such indicators include the following:

Change of the rainfall pattern during different rainfall seasons

Jayatillake et al (2005) studied the changes of the rainfall pattern during the monsoon and inter-monsoon periods described elsewhere in this document. A comparison of the Mean Seasonal Rainfall during these two seasons over the 30 - year reference periods of 1931-60 and 1961-90, together with their associated Coefficients of Variation are summarized in Table 54.

Table 54. Change & Variability of Mean Rainfall during Different Rainfall Seasons Periods 1931-60 & 1961-90

Rainfall Season	1931 - 1960		1961 - 1990		Change	
	Rainf fall mm	CV %	Rainf fall mm	CV %	mm	%
First Inter Monsoon (Mar - Apr)	299.7	23%	268.3	27%	-31.5	-10.5%
South-West Monsoon (May - Sep)	547.0	21%	556.2	16%	+9.2	+1.7%
Second Inter Monsoon (Oct-Nov)	566.9	22%	558.1	23%	-6.7	-1.1%
North-East Monsoon (Dec - Feb)	591.5	31%	478.5	42%	-113.0	-19.1%
Annual (Jan - Dec)	2005.1	12%	1861	14%	-144.1	-7.1%

Source Jayatillake et al, 2005

Comparison of rainfall data during these two periods, show an overall decrease of 7% in the average annual rainfall, but it is important to note that there is a wide disparity in the magnitude of changes that have taken place when the different rainfall seasons are separately considered.

Wet and dry spells and amount of rainfall

An analysis of inter-annual as well as intra-annual rainfall trends of the central region Sri Lanka has shown that there is a decrease in the annual rainfall in this region. The March - April inter-monsoon period showed the highest decrease in rainfall, where almost all the rain gauges have recorded a decreasing rainfall trend. Other major observation is the reducing numbers of rainy days giving rise to an increasing trend in intensity of rain and prolonged dry spells. Hearth and Ratnayake (2004), mention that the intensity-frequency relations had indicated a decrease of inter-monsoon rainfall, while the intensities and return period of extreme events appeared to become shorter.

Ratnayake and Herath (2005) studied the characteristics of wet and dry spells in Sri Lanka using data from 1960-2001 (Figure 38). The characteristics used for the analysis were total rainfall, length of wet spells, length of dry spells, amount of rainfall per spell and amount of rainfall per rainy day. A visual scrutiny of the cumulative rainfall series plotted against time for long-term trends indicated to the researchers that a change had occurred in the late seventies. Therefore the characteristics mentioned in the above paragraph were compared before and after 1978. Figure 38 illustrates the results where the legend indicates the ratio of values of the characteristic before and after 1978.

North-eastern and western regions experience increasing rainfalls while rest of the country experiences a decreasing trend. It is also seen that the amount of rainfall received per spell has both increasing and decreasing trends. The lengths of wet spells are decreasing and the dry spells are increasing in most parts of the country. Comparison of the results given in Figure 38 shows that though the lengths of wet spells decreased, the average rain received in a spell increased significantly. The study also showed that intensity of rainfall, measured as the amount of rainfall per rainy day is also increasing (Ratnayake and Herath, 2005). The daily rainfall intensities and the lengths of dry spell are increasing all over Sri Lanka, while the lengths of wet spells are decreasing. (Ratnayake and Herath, 2005).

Change of rainfall patterns and natural disasters

Natural disasters in Sri Lanka are increasing in intensity and frequency due to human intervention and climate changes. Almost all river basins are flood prone in the wet zone. The increased frequency of the floods in recent years is attributed to climate, deforestation, and increased sediment runoff and silting of rivers. Landslides are the other major forms of disaster. They generally follow intense and continuous rainfall exceeding a threshold between 350 to 400 mm within two days. Though Sri Lanka is outside the cyclone belt, the few cyclones it experienced were the reasons for extreme rainfall events. (Ratnayake and Herath, 2005). Therefore the increase of natural disasters is mostly as a result of the changes in climate.

Padmakumara (2004) has identified that almost all the past landslides had very high rainfall as their triggering cause, and that if more than 15% of the annual rainfall is received within 14 consecutive days,

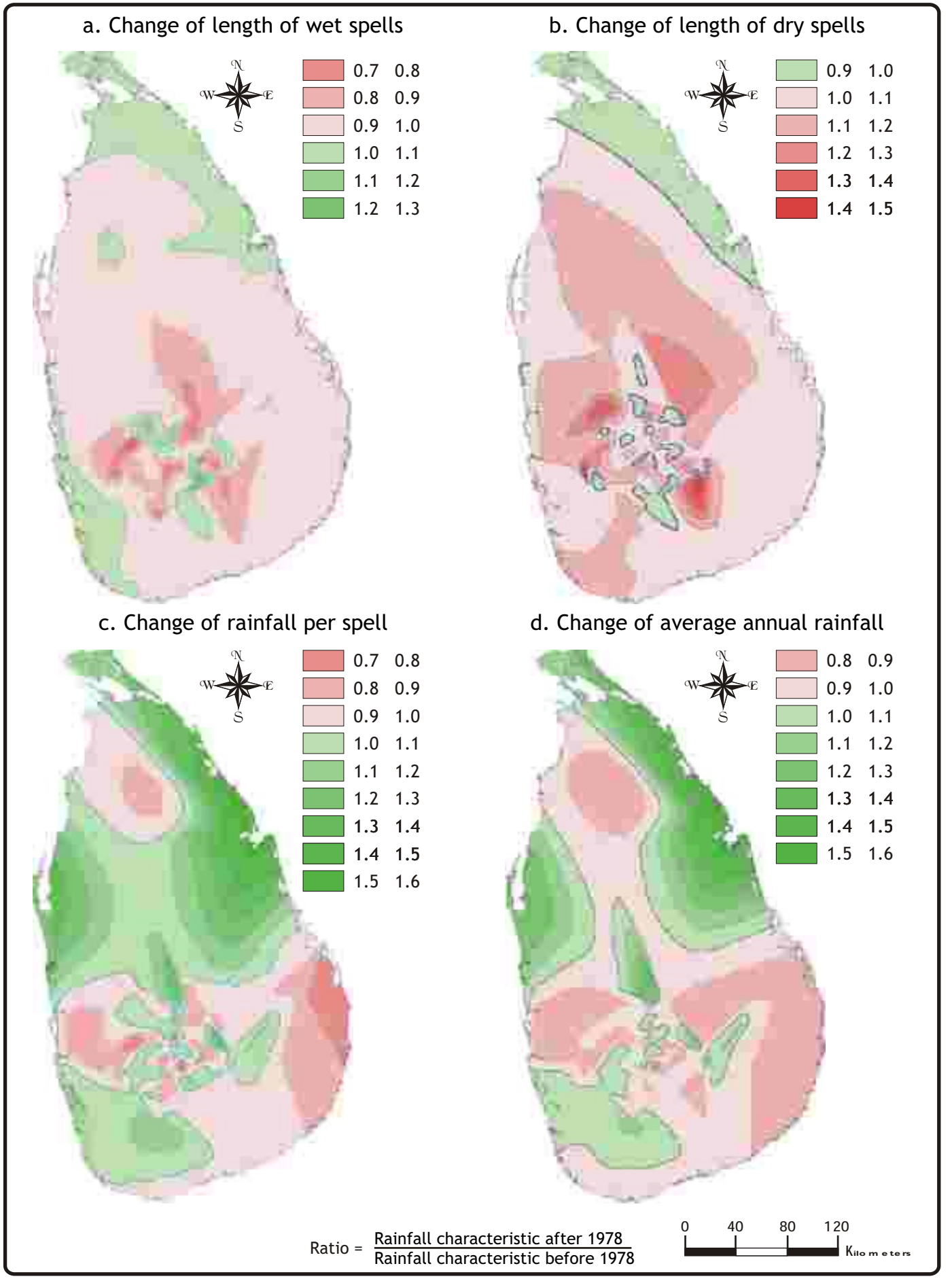


Figure 38: **Changes in the characteristics of wet and dry spells before and after 1978**

Source: Ratnayake and Herath, 2005

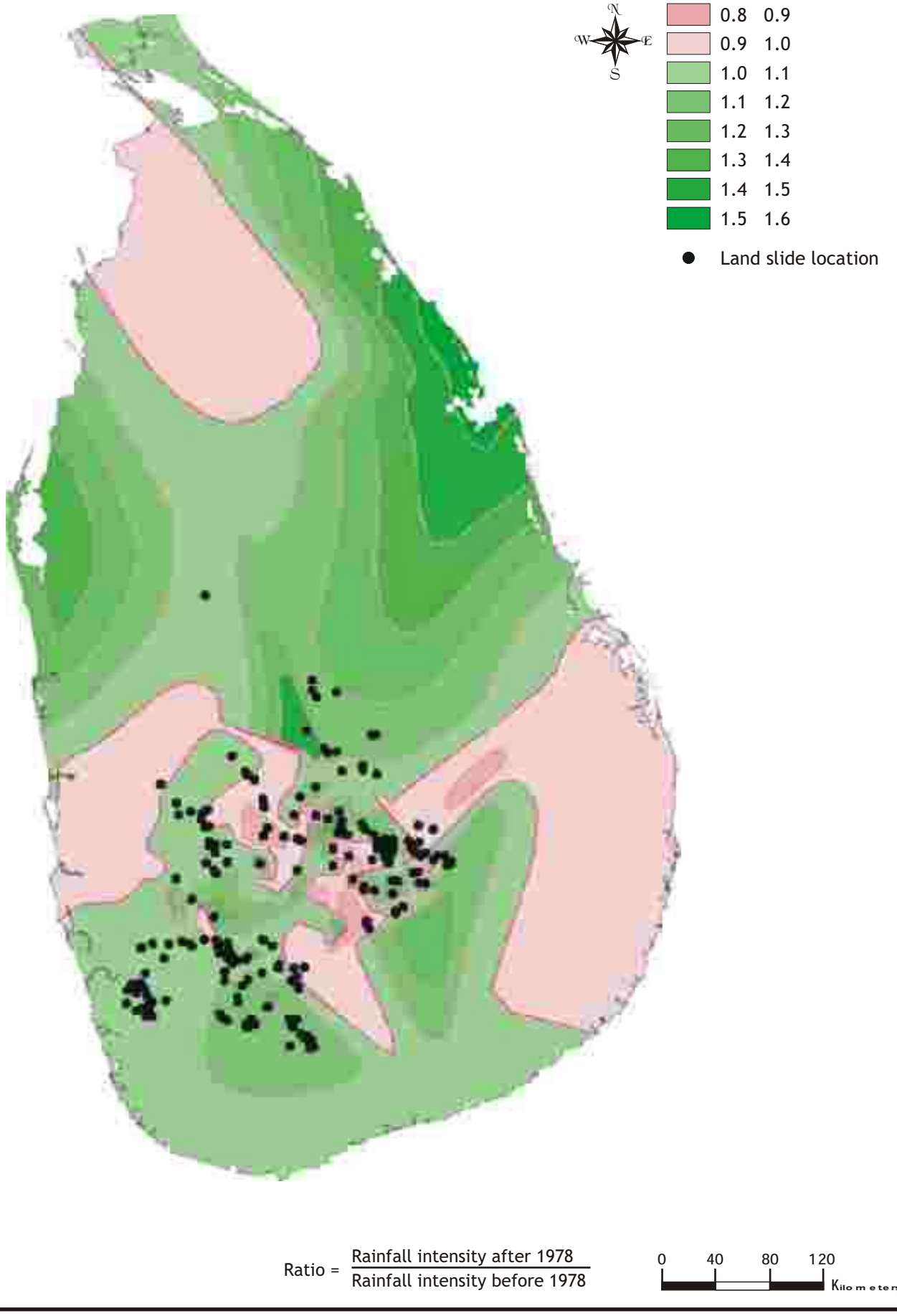


Figure 39: **Rainfall intensity changes and occurrence of land slides**
Source: Ratnayake and Herath, (2005)

it could destabilize the slopes. It has also been identified from the past data that only already initiated landslides can move due to lower rainfall. Therefore, the landslide hazard increases with the increasing rainfall received during a 14-day period.

Increasing rainfall intensity is known to trigger landslides and very high correlation is seen between the locations of the past landslides and the areas of increasing rainfall intensities as seen in Figure 39. Few landslide events occurred in the areas of decreasing intensities.

However, these landslides were in the regions where rainfall received per wet spell showed an increase. As there is an increase in landslides, the zoning of such danger areas and public awareness coupled with resettlement programs should be carried out to mitigate the risks. It will finally add up to increase of flood occurrences (Ratnayake and Herath, 2005).

The number of districts affected by floods has increased tremendously after the late seventies. However, according to the results of a study carried out for WWAP in Sri Lanka (Ratnayake and Herath, 2005), the western region around Colombo and the south-eastern region are the least affected from the rainfall changes. Floods that are reported in and around Colombo area are mainly caused by land use changes. The land use changes that are contributing to the increase of floods are the increase of built up areas causing a reduction in the infiltration and retention areas.

Water related disasters

Frequency and amplitude

Although scientific analyses of the frequency and amplitude of water related disasters are scarce, the available information indicates that both these parameters are increasing. Recent data reveals that Sri Lanka has already experienced two years of serious drought, one major flood event and a tsunami within the first five years of the 21st Century. It has also been observed that the frequency of landslides has increased since 1980s (Ratnayake and Herath, 2005). In the case of landslides it is said that the developments in the information and communication technology would also have to be considered as a factor when such data pertaining to developing countries are analysed. Increase in the numbers of affected people due to natural disasters is also aggravated by the intensity and growth of population.

Economic and social consequences

The consequences of water related disasters could be significant. Increased rainfall intensity would induce floods and landslides and reduce groundwater recharge. Increased length of dry spells, especially in the dry zone, would lead to an increase of drought conditions. It may be noted that the dry zone gets the major part of its rainfall during the north-east monsoon and the first inter-monsoon from March to April. The decrease of rainfall volume in these periods will make the impact of droughts more severe in the dry zone. This change was prominent in the north-central and south -western regions. Recent analysis of the spatial rainfall pattern indicates an expansion of the dry zone as well, (Figure 40).

Water related disasters mostly impact on agriculture, drinking water supplies, industrial water supplies and the natural environment. Landslides, debris flow, floods and droughts cause severe negative effects to livelihood of the people and to the national economy. Loss of lives, damages to property and infrastructure, disruption of livelihood, disruption of services and essential necessities for relief work, are the major socio-economic effects of these disasters. In Sri Lanka such events have also affected the exchange patterns of water, sediment, nutrients, and organisms between the water bodies and their ecosystems. Further, the increased intensity had caused changes in rainfall-runoff relations, sediment generation and transport, which again can have severe adverse effects on vulnerable ecologies.

The available information shows that the impact on the economy by natural disasters is highly variable from year to year. The data from 1993 to 2003 show that approximately 105,000 families were affected annually from natural disasters. On an average, the annual damage had been approximately US$ 300,000, (Pers. Comm.. N. Kamaladasa, information from Department of Social Services and ADPC, 2003).

The damage to assets due to the tsunami of 26th December 2004 is estimated to be about US$ 1 billion, which is about 4.5% of the GDP. This does not include the loss to the output from sectors affected, such as fisheries and tourism. The social component of the disaster is even more prominent, though not clearly visible. 443,000 people were displaced and many of them lost all their property. It is also estimated that about 900 children have lost their parents or have got separated from them (NCED, 2005). When the number of persons who lost their spouses and children are added, the impact on vulnerable sections of the society is severe and harsh, and will constitute a substantial social problem for years to come.

On the other hand, economic and social conditions contribute to the intensity of natural disasters as well. The high population density in Colombo and suburbs has resulted in an increase of

the built-up lands and decrease of the flood detention and retention areas such as paddy fields and wetlands. This has led to frequent localized flooding resulting from local rainfall. Socio-political factors including poverty have contributed to people encroaching on the disaster-prone areas resulting in the difficulty to manage disasters and to restrict the number of affected persons.

Management tools against extreme events

Data management

A GIS database has been developed to manage natural disasters on the highway system (Ratnayake & Herath, 2005). This consists of descriptive, technical and social data associated with the historical natural disasters and the other relevant and related data. The descriptive data include the coordinates of the disaster, the native name of the location, the electoral and administrative divisions. The technical details are the special features observed in the field such as cracks on the surface and water seepage from the ground, movement details, monitoring details, geological and soil details, test results, water levels and discharges. Social data reflect the impact on the people directly affected by the disaster, and they include the number and form of casualties, their observations related to the disaster, audio clips of interviews, relief measures, accounts of temporary or permanently displaced people and the changes to their livelihood. Other related data include the highway and road network, railway lines, locations of km posts, streams and rivers, contours, locations of rain gauging stations, rainfall measurements, human settlement, land use pattern details, access roads, de-route information, closest hospitals, places for emergency evacuations, damage estimations and allocations for relief and rehabilitation measures etc. (Source: Ratnayake *et al*, 2004)

Structural measures against disasters

The structural measures adopted in Sri Lanka to address floods include construction of reservoirs to retain water and flood protection embankments. Although there are no reservoirs in Sri Lanka specifically constructed for flood protection, certain reservoirs have been build with flood protection as a key objective. The total storage capacity of the reservoirs in Sri Lanka is estimated as 7000 MCM. The reservoirs constructed for irrigation, hydropower and drinking water also serve the purpose of flood mitigation. For example, it has been observed that floods have been controlled to a substantial extent after large reservoirs were constructed in the Gal Oya river basin in the Eastern Province. Reservoir capacities do not reflect the flood mitigation capabilities since most of the reservoirs are mostly for irrigation. A comparison can be made between the Kirindi Oya where nearly 57% of the annual flow can be retained within the basin, and Kalu Ganga, where a negligible proportion can be retained. A proposal has been prepared to construct a reservoir on the Kalu Ganga to retain 500 MCM of water mainly for the flood protection, but has been delayed due to fund restrictions and displacement of people (Official correspondence of Ministry of Irrigation & Water Management with Irrigation Department, 2002).

Gin Ganga and Nilwala Ganga in the southern part of the wet zone and Kelani Ganga in the Western Sri Lanka are equipped with the major flood protection schemes implemented by the Irrigation Department. Main components of the Gin Ganga and Nilwala Ganga projects include flood protection bunds and pumping facilities. The Irrigation Department had prepared several proposals for reservoirs to detain flood waters at strategic locations of selected rivers. Once implemented, some of these reservoirs will serve for hydropower generation and drinking water supply in addition to flood control.

The Dahasak Wew (Rehabilitation of 10,000 tanks) Program initiated by the Ministry of Agriculture, Livestock, Lands and Irrigation is expected to increase the ability to cope with flash floods especially in the dry zone as a result of the increased water storage capacities.

The Sri Lanka Low Lying Area Reclamation and Development Corporation (SLRDC) and Urban Development Authority (UDA) are two other institutions that contribute to the structural measures for flood control and mitigation. The functions of the SLRDC include design and construction of surface drainage schemes and drainage improvement in the declared areas. The UDA addresses issues related to urban land use. However, local authorities including Municipal Councils execute certain urban drainage development functions and infrastructure.

Non-structural measures against disasters

Responsibility of activating the flood warning system of major rivers is vested with the Hydrology Division of the Irrigation Department. Only the Kelani River flood warning system is capable of providing advance warning in the case of a flood. Most gauging stations in the Kelani river are provided with high frequency radio transceivers which are capable of transmitting water level and rainfall information even from remote areas in the upper catchment of the river, enabling the early execution of precautionary measures in the downstream to ensure protection against a major flood event (Dias, 2005).

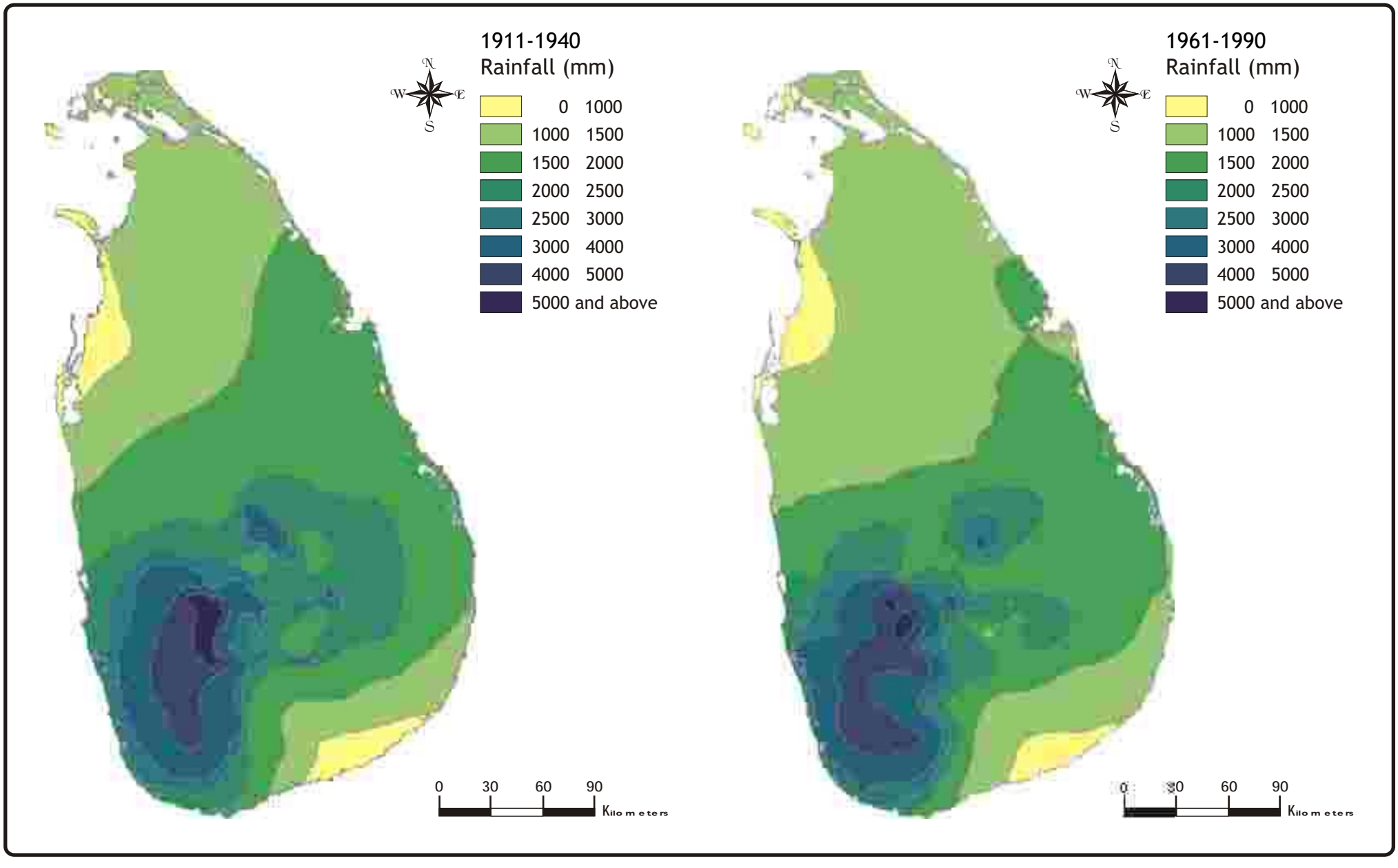


Figure 40. A comparison of average rainfall 1911-1940 and 1961-1990

Prepared by U.R. Ratnayake (Base data: Dissanayake, D.T. E. (1950),(Director of Meteorology), Report on the Colombo Observatory with maps and statistics for 1950, Department of Meteorology (1911-40 period); Jayatillake et al (2005) (1961-90 period)

The Disaster Management Act, is expected to provide the answer to many of the legal issues prevalent in the present system of disaster management. An initial framework for the act was worked out in 1992, which was expanded later by the National Disaster Management Centre (NDMC). The Act is expected to provide for a National Council for Disaster Management, a high-powered umbrella organization that will direct policy and plans with regard to disasters- both natural and man-made. The Council is meant to be a body corporate, with perpetual succession and a common seal. It will be headed by the incumbent Prime Minister of the country who will act as the Chairman, and the Ministers of Rehabilitation, Environment, Home Affairs, Health, Provincial Councils, Science and Technology, Housing and Construction, Fisheries, Irrigation, Power and Energy and the Social Services serving as members. Deputy Ministers of Finance and Defence will also serve as members of the Council. The National Council is to serve as the central body coordinating the different governmental and non governmental segments involved in resource management and emergency response, while the NDMC will be the secretariat for the Council and the body that will implement decisions and plans of the Council (Ariyabandu, 2005).

Present status of warning systems

Presently the Kelani Ganga flood warning system functions satisfactorily in comparison with other systems. After assessing available data and when the Director General of the Irrigation Department is agreed that a flood is imminent, the Sri Lanka Broadcasting Corporation(SLBC) and Sri Lanka Television services will be informed to issue a warning to the people living in the low lying areas. In case of a continuing flood threat the flood committee meetings will be held frequently until the river subsides below the flood level. Actions to be taken by the Government Agents/ District Secretaries are described in the Standing Orders. The Irrigation Department has issued 24 hour lead-time qualitative flood forecasts for the Kelani River. However, the flood forecasting system in the Kelani Ganga basin has the potential to be improved with real time data acquisition, and use of forecasting computer models(Dias, 2005).

In case of Kalu Ganga, due to the short travel time of the flood wave reaching Ratnapura town, efforts to warn the people in the town have not been successful. There are no effective warning systems in the other basins. Presently in these basins flood warnings are made based on the rainfall events and the past experiences. Such warnings are conveyed to the Government Agents/District Secretaries to disseminate among the people living in low lying areas.

Constraints for effective disaster management

Irrigation Department has identified the need for a pilot project for real time flood forecasting in the Kelani Ganga. Installation of rain gauges and stream gauging stations with communication facilities, a central station with computer facilities and adequate software for early warning, a field operations unit and standing orders have been identified as requirements for upgrading of existing flood forecasting systems (Dias, 2005). The low priority for data collection with low financial allocations is clearly visible from less and less amounts of data gathered in each year. Inadequacy of public awareness and education mechanisms and the absence of a single authority to issue warnings have been identified as the major constraints for effective disaster management. Other problems include; duplicated and non uniform data collection, lack of coordination in research and implementation of results, inadequately managed relief works, lack of a dependable communication network during disasters, and inadequate forewarning of impending disasters (Ratnayake and Herath, 2005).

Land-use planning

The Land Commission (1990) (quoted in Ariyabandu, 2005) reported the need of a comprehensive policy and an authority for watershed management. The Forestry Sector Master Plan of 2000 also incorporated watershed management aspects which are considered as non structural measures against disasters. The watershed management policy was approved subsequently. The proposed National Land Use Policy has incorporated elements of natural disaster into the planning phase which includes a specific objective to reduce vulnerability to natural and man-made disasters (Ariyabandu, 2005). The Draft National Physical Planning Policy identifies the environmentally and hydrologically important lands, landslide-prone areas and unutilized lands with high-intensity rainfall, steep slopes and erodible soils to be strictly protected (NPPD, 2001).

Responding to disasters

Disaster response and recovery

Sri Lanka's response focus has been mainly oriented towards post-disaster activity. The Social Services Department under the direction of the Ministry of Women's Empowerment and Social Welfare carry out activities relating to disasters and other social service requirements. The Department of Social Services handles relief distribution and co-ordination. The Secretaries of the 25 districts and 300

divisions report to this Department in the event of a disaster whether natural or man-made with the department extending both short term and long term support.

The National Disaster Management Centre (NDMC) under the Ministry of Social Services conducts awareness raising programmes for disaster mitigation, and manages micro-scale preparedness and relief programmes. The National Plan for Disaster Management (NPDM) specifying measures that are to be taken during and following a disaster has been completed in 1999, but it is yet to be fully operational. The NDMC identifies the relationships to vulnerability in flooding and the need for watershed management in disaster prone areas. This plan calls for hazard resistant designs and constructions, structural and non-structural measures for protection on disaster prone areas as protective measures (Ariyabandu, 2005).

Contingency plans and legal framework

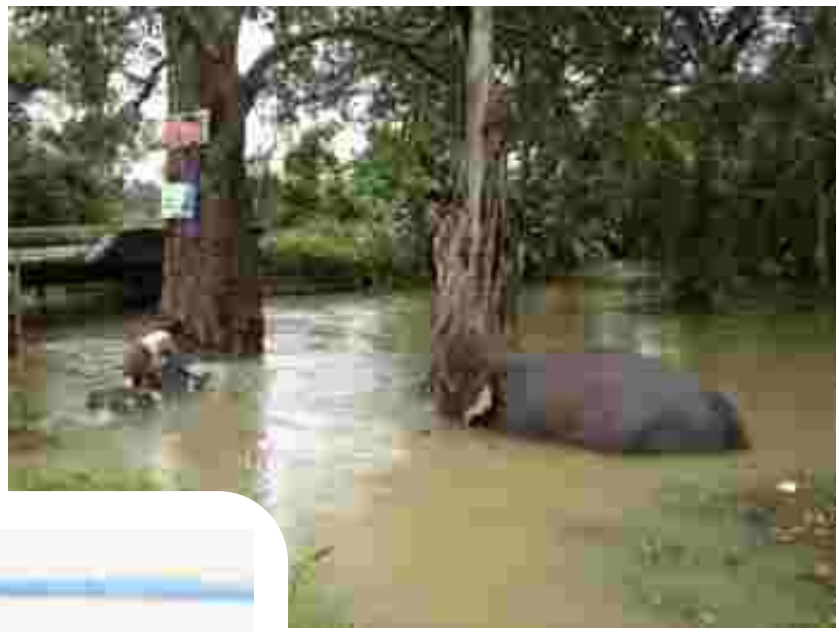
Floods are the only natural disaster that has a law for itself which is the Flood Protection Ordinance No. 20 of 1931, implemented by the Irrigation Department. Coastal erosion is dealt with in the provisions of the Coast Conservation Act of 1981 implemented by the Coast Conservation Department. Drought and landslide hazards are significantly mentioned in the draft National Land Use Policy. Though the existing legislation on land use prohibit activities that could lead to slope instability, soil erosion on hilly terrain and deforestation, the implementation of land use laws has exposed the diffused nature of existing legal provisions and the lack of a central implementing body.

The Town and Country Planning Ordinance of 1946 contains provisions for zoning land for planned land use schemes, thus providing important measures against threats of disasters like floods and landslides due to unplanned development activities. But on the whole, the laws reviewed under human settlements development, emphasize on development programmes disregarding the consequences of such development on the surrounding environment. The Disaster Management Act of 2005 addresses several gaps in disaster management related legislation. (Ariyabandu, 2005).

Indicators

Adequacy of structural measures against risk management	: moderately satisfactory
Adequacy of early-warning systems	: unsatisfactory
Length of wet spells in the wet zone	: increasing
Length of dry spells in the dry zone	: increasing
Annual rainfall to the dry zone	: decreasing

Chapter 10



Sharing Water between Uses and Users

Sri Lanka being an island nation does not face any trans-boundary water sharing concerns. However, the major issue related to water sharing is the allocation of this resource among different water user sectors, especially during periods of the droughts. Decisions in this regard are taken with due consideration for social and economic factors. In general, water requirements for drinking, sanitation and livelihood purposes get the priority consideration during crisis situations (Abeygunawardane and Imbulana, 2005).

Hydropower and other sectors

Hydropower is a non-consumptive user of water. It adds value to water as it passes through the turbines and the generator of power. The Ceylon Electricity Board (CEB) has identified and practiced giving priority of water use for drinking, sanitation, irrigation and then for power generation, in that order.

The existing cooperation among State institutions in sectoral water distribution became evident after the occurrence of the recent drought periods. In March 2004, CEB cooperated with the National Water Supply and Drainage Board in overcoming salinity intrusion at the Ambatale intake of the Kelani River by releasing water stored for power generation. This became necessary when the river water level fell due to the drought, and salinity intrusion increased during the high tidal period. Similar cooperation existed for allocation between irrigation and hydropower.

Furthermore, stored water is used to prevent salinity intrusion and to maintain water quality on the request of relevant authorities. However until recently, navigation, fisheries and aesthetic aspects have not given sufficient attention in respect of the existing reservoirs.

In the recent times, sharing of water resources between hydropower and conservation issues of the environment has become an important issue as well. The Upper-Kotmale Hydropower Project, designed in 1987, ran into considerable opposition from various interest groups, on account of the doubts harboured in relation to conservation of the environment. Located on the mountainous region of the country, one of the major concerns was the effect of the project on the aesthetic value of several waterfalls downstream of the dam.

Though water sharing practices are not articulated by statutory obligations, CEB gives priority to the needs of society in managing water resources developed for power generation

(Seneviratne and Handagama, 2005). This approach is also followed by the Panel of the Water Management Secretariat at the Mahaweli Authority of Sri Lanka which coordinates water distribution for different users.

The assignment of priorities is important in water allocation in the Mahaweli system. The schematic diagram of the organizational framework of the Mahaweli system (Figure 41) explains to complexity of decision-making hierarchy. After generating hydropower at the uppermost Kotmale reservoir, water reaches the Polgolla barrage, where an allocation decision has to be made. Releases downstream of Polgolla benefits hydropower generation; with Victoria (210 MW), Randenigala (126 MW) and Rantambe (49 MW) located below Polgolla. Diversion to Sudu Ganga-Ambanganga system enables lesser power generation with only Ukuwela (38MW) and Bowatenne (40MW) located in the downstream. However, diversion to the latter sub-system will benefit Mahaweli Systems D, G, H and MH areas which extends over 180,600 ha, and which are heavily dependent on Mahaweli waters, compared to Mahaweli A, B, C and E areas in the downstream of Polgolla, extending over about 95,500 ha. Quite often the allocation decisions are taken in favour of irrigation demand.

Similar issues exist in sharing water between Kaltota irrigation farmers and the alternative use for power generation through the Samanala Wewa Power Station in the Walawe basin. Kaltota is an ancient irrigation system while the power station was built in the 1980s. The hydropower station upstream of the irrigation scheme, discharges water from the powerhouse downstream of the irrigation diversion structure. As a result, farmers at the Kaltota scheme have had to face occasional water shortages. After a period of intensive negotiations and bargaining, a consensus is being built among the farmers and the authorities dealing with irrigation and hydropower. At present, a special irrigation outlet releases the irrigation water requirement, at the expense of power generation.

Irrigation and other uses

Water sharing between irrigation and other sectors is a complex issue. Some attempts based on the economic value of the produce have failed, and the relevance of social and cultural values in the equation has been recognized. In the case of irrigation, depriving water will result in loss of livelihoods for many smallholder farmers. The needs of water for drinking, sanitation and irrigation cannot be postponed, and alternative sources are difficult to find.

In the Mahaweli system, the major water use is for hydropower generation and irrigation. Although drinking water and sanitation are important needs, the quantity used by that sector is quite small. However, at the individual irrigation scheme level, the quantity diverted for drinking water constitutes a significant amount, especially during dry periods. At present water allocation issues exist in several locations, including Kantale (irrigation) -Trincomalee (Drinking water) and in Anuradhapura (town supply-irrigation).

Almost all the irrigation reservoirs in the country are used for drinking and sanitation purposes. When such uses are made by the direct beneficiaries (irrigation farmers) themselves, the conflicts are rare. However, when the beneficiaries are distinctly different, as in the case of the above examples, conflicts do occur.

The NWSDB operates water supply schemes using about 35 irrigation facilities as the source. In addition, the extraction from dry zone rivers will also have an impact on water resources. The demand as estimated by NWSDB is given in Table 55.

Seasonal allocations in large irrigation schemes are decided at a special Project Management Committee meeting chaired by the District Head of Administration, who is the District Secretary or the Divisional Secretary, and with representation from Custodian and management agencies, other related government agencies and the water users including non-agricultural users. The Project Management Committees, that are established in many large irrigation schemes meet regularly at least once a month to monitor, review and to decide any

Table 55. The demand for domestic water supply from sources linked to irrigation

Source	Demand in 2005 (MCM/year)	Demand in 2025 (MCM/year	Increase 2005 - 2025
Irrigation facilities	67	254	278.8%
Dry zone rivers	68	191	181.5%

Source: Official correspondence between NWSDB and Ministry of Irrigation and Water Management, 2003.

subsequent changes to the plan that would become necessary from time to time. Any allocation problems caused by events such as droughts etc are dealt with within those constituencies through mechanisms that have developed over time. Future water resources development will ensure that there would a minimum of conflicts, especially during the droughts.

Traditional water sharing

In most parts of Sri Lanka, the village tanks provide water for domestic water supply, irrigation, water for livestock, and the recharge of groundwater. In ancient Sri Lanka the village tank comprised the major resource base of the village community. Therefore, its management had been based on Integrated Water Resources Management (IWRM) principles. The tanks were located in a cascade, so that drainage water of one tank constituted the inflow of the one downstream, thus enhancing the water use efficiency. The use of water in small village tanks had been mainly for domestic water supply and for livestock and was used for bathing, washing and supporting inland fishery, in addition to conventional irrigated agriculture. Village tanks were traditionally managed by farmers with little state intervention, and water-sharing methodologies adopted by them deserve careful study in future policy formulation. A system of compulsory labour for stakeholders was developed under the patronage of the King to ensure proper maintenance of the irrigation system (Panabokke et al, 2002). Associated with such water resource management responsibilities, the village community leadership evolved for the local governance of the water resources and hence of water allocations.

Several traditional water sharing methods had been practiced by traditional village communities. One system is the "Bethma" which determines the cultivation extents during a drought period. Under this system, the total land to be cultivated under the reservoir is decided based on the total water availability. The feasible land is selected immediately below the irrigation tank to ensure higher efficiency of water use. This land is then divided proportionately among the farmers with respect to their land ownership (Dissanayake, 2000). Even at present this system has an influence on the water sharing systems practised in major irrigation schemes, which are usually overseen by the government officials.

Sharing water between sectors is being widely discussed in relation to the prior water rights of downstream users. The allocation mechanisms are not well established, and therefore water releases from upstream developments are often challenged by the downstream users. One such example is the water releases from the Samanala Wewa reservoir and the water shortages at the Kaltota Irrigation scheme. After a period of intensive negotiations and bargaining, a consensus is being built among the farmers and the authorities dealing with irrigation and hydropower. The Upper Kotmale Hydropower Project, which is a high priority hydroelectric development proposal of the government to harness the potential upstream of the Kotmale reservoir, could not take off the ground for a significant period of time due to conflicting ideas related to the quantity of water releases for down stream sustenance. Several studies carried out in the Kirindi Oya project highlights the water-sharing aspects in major irrigation systems. It has been observed that water is used not only for paddy irrigation, but also for irrigating other field crops and for domestic use. Domestic use is both depletive piped water supply and non-depletive in-stream uses such as for bathing and washing. The use of irrigation reservoir water for inland fisheries has been increasing in importance in recent times.

Water sharing mechanisms

National level

The Mahaweli Authority of Sri Lanka (MASL) is the responsible agency for the implementation of development programme, and the operation and maintenance of water distribution systems in the biggest water resources development programme in Sri Lanka. This programme developed the Mahaweli river basin and four other adjacent basins mainly for agriculture and hydropower.

The Water Management Secretariat (WMS) of the MASL established in the early 1980s, is the decision making body for sectoral water allocations in Mahaweli and other beneficiary basins as well as the Walawe river basin. The WMS is also responsible for collection and analysis of hydro meteorological, cultivation, energy productions, and system performance data for macro level seasonal planning, regulation and forecasting the sectoral water allocations of the said systems that extend to nearly 33% of Sri Lanka's land area.

Weekly meetings of the Water Panel consisting of officers from Irrigation Department, MASL, Ceylon Electricity Board, National Water Supply & Drainage Board etc., discuss and decide weekly water allocations for different sectors especially for irrigation and energy generation. At the beginning of each cultivation season, the WMS prepares a Seasonal Operation Plan (SOP), and discusses at a special meeting attended by officers and farmer representatives from each irrigation scheme under Mahaweli and Walawe river basins and other benefited river basins. Water issue priorities in case of droughts, floods, emergency repairs, water shortages,

and adverse weather conditions are determined through discussions. The success of the water allocation mechanism in the Mahaweli basin has led to the inclusion of such issues in Kelani river basin in the agenda of the Water Panel of MASL (personal communication: Mahaweli Authority of Sri Lanka, Irrigation Department and Irrigation Management Division, Sri Lanka)

Regional level

Seasonal allocations in large irrigation schemes are decided at a special Project Management Committee meeting chaired by the District administrative head (the District Secretary or the Divisional Secretary), and with representation from Custodian and management agencies, other related government agencies and the water users including non-agricultural users. The Project Management Committees that are established in many large irrigation schemes meet regularly at least once a month to monitor, review and to decide any subsequent changes to the plan that would become necessary from time to time. Any allocation problem caused by events such as droughts etc., are dealt with within those constituencies through mechanisms that have been developed over time, such as Bethma,

A large number of irrigation reservoirs are used for inland fisheries. In most cases the agricultural and fisheries communities are distinctly different. The need of the fisheries industry to maintain certain water levels in the reservoirs occasionally causes conflicts with agricultural requirements. The other matters of concern between these two sectors are the safety of irrigation structures and water quality. Decisions regarding fisheries are usually taken at the irrigation scheme level.

Both in the dry zone and the wet zone conflicts arise between the domestic water supply and other water users such as agriculture, hydropower, environment and industries. These conflicts are kept to a minimum due to good coordination among agencies. Most of the conflicts occur when water is withdrawn from the agricultural command area and used for the requirements of a community outside. In case of conflicts, customarily there is little intervention by the authorities when water is shared by the people within an agricultural command area, unless there is a drought and water supply is in shortfall to meet the demand.

Decision support systems for sharing water

The Mahaweli Authority of Sri Lanka uses ACER's Reservoir Simulation Programme (ARSP) for the preparation of seasonal operating plan. It is a multi-purpose, multi-reservoir simulation model. The irrigation demand is separately calculated using "Irrigation Demand Model". The allocation priorities are normally assigned to drinking water and irrigation respectively. Important inputs to the model include:

- hydrological conditions
- crop data and irrigation requirements
- hydropower generating characteristics
- current reservoir status
- diversion capacities
- maintenance programme of main infrastructure (Abeygunawardane and Imbulana, 2005)

For the long-term planning, CEB prepares load forecast (taking into account low, medium and high growth rates) using econometric techniques. To capture different consumption patterns of various consumer categories, sector-wise forecast are prepared separately. The analyses carried out using the load forecast is considered as base case, and sensitivity analysis are carried out for various input parameters.

During the medium term planning, attempt is made to minimize the power generation cost, while ensuring the downstream requirements. In order to ensure downstream requirements, CEB assigns a pseudo fuel cost to hydro plants and then minimizes the generation cost. All irrigation demands have been imposed as high-priority hard constraints to the system. The computer technique used for this purpose is called "METRO" (Medium Term Reservoir Optimisation). It uses the concept of "Water Value" (incremental long-term replacement cost of hydro in storage by thermal) in deriving an optimal operating policy for the power reservoirs of the system and uses optimal reservoir balancing factors to balance reservoir draw downs (maintain the optimal mix) on simulation of the operating policy. This results in an allocation policy among the power control reservoirs based on their water values, in the form of dynamic rule curves giving due consideration to variations in hydrology among respective catchments and plant availabilities (Seneviratne and Handagama, 2005).

Indicators

Formal mechanisms to share water = Unsatisfactory to moderately satisfactory

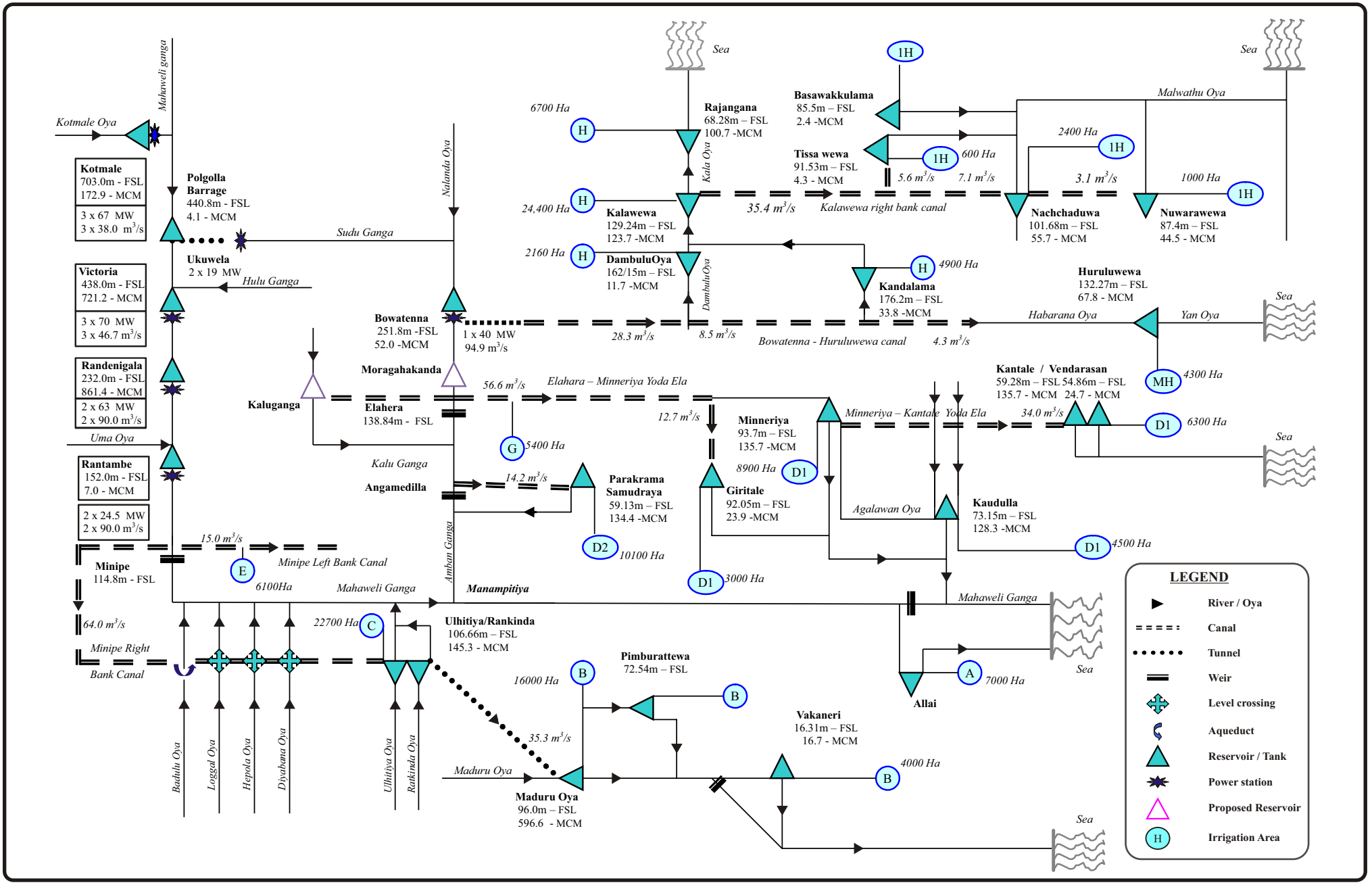


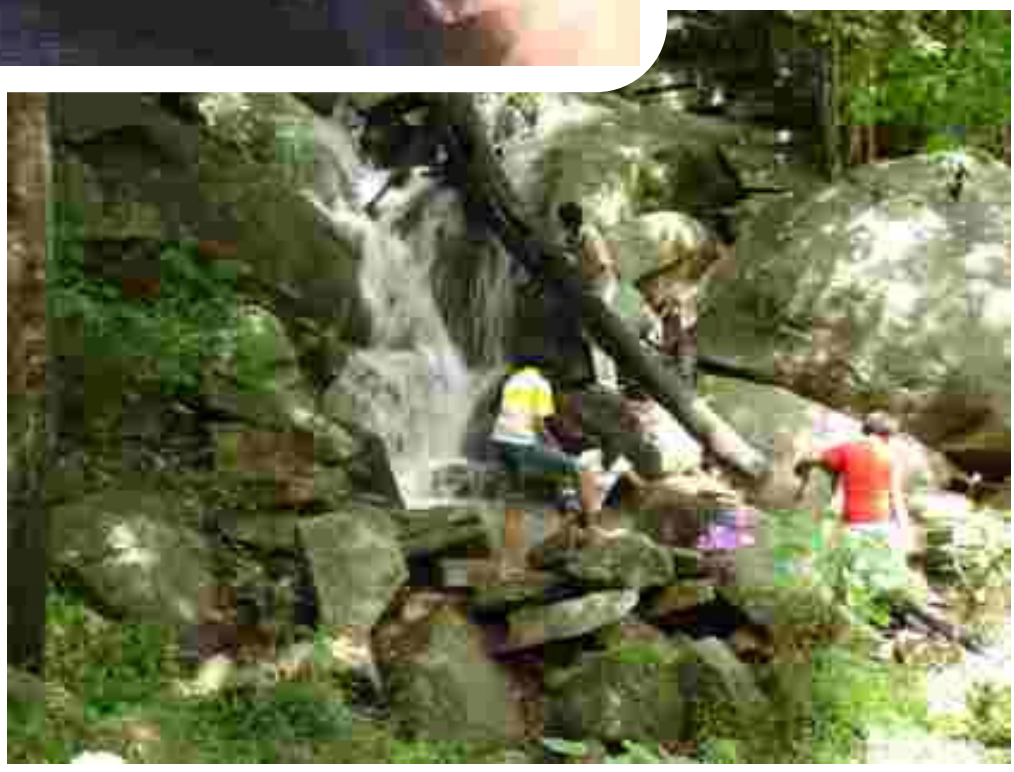
Figure 41. Mahaweli water distribution system

Source: Water Management Secretariat, MASL

UN-Water/WWAP/2006/11

Chapter 11

Valuing Water



It is recognized that water is a valuable resource. The equity to access of fresh water, especially to the provision of basic human needs of the poor and vulnerable sections of the society, is an important concern of policy makers of Sri Lanka. This chapter examines the many facets of the value of water in the cultural and social context of Sri Lanka.

Economic, social and cultural

Water-related rituals continue to be important traditions of both urban and rural life. For most of Sri Lankans, the first transaction in the Sri Lankan New Year begins with the domestic well. This highlights the intimate socio-cultural relationship with the source of domestic water supply. In Sri Lanka pouring water on the tied fingers of the bride and bridegroom at a wedding ceremony symbolises an eternal bond. When offering flowers in homage to the Buddha, devotees sprinkle water on flowers as a means of spiritual purification. The "Water-cutting" ceremonies common in most major Buddhist religious festivals symbolizes the successful completion of a traditional ceremony. The Kataragama and Kandy festivals are two such world re-known cultural events performed in the south and central Sri Lanka.

These customs and traditions add a value to water that cannot be easily ascribed on an economic scale, but which are extremely valuable to the community and individuals. Though the value of water was well recognized from ancient times, it was not converted to a monetary value in order to access water.

Access to water was considered a basic human right. In the villages' community wells for drinking, bathing, washing etc were common. At wayside resting places a *Pin Thaliya* (a pot of water) was provided for travellers to quench their thirst. In both cases, water was provided free of charge but the value was considered in terms of the returns in merit from the noble deed.

The centuries-old traditions in Sri Lanka recognize that water has social, environmental, cultural and spiritual values in addition to its economic value. In minor irrigation works, the provision of water was for domestic use and livestock, and also for recharging of groundwater. The traditions in water sharing and multiple uses in small irrigation systems are not reflected in the practice of estimating water productivity in terms of the weight of produce or the market or economic value of production. Such multiple dimensions in the value of water must be considered equitably in water

resources planning, development and management. The social and cultural norms established within the Sri Lankan society, have for a long period placed great emphasis on the optimum use and prevention of wastage of this vital resource.

The history of Sri Lanka is replete with evidence of the existence of a governance structures that recognized the high value of water. Ancient records indicate that irrigators had to pay a fee to the King for water, and were even made to pay fines for overuse of water and delayed land preparation. A tradition of paying for irrigation water in kind is ingrained in the custom of '*Rajakariya*' where it was required that community labour was used for the maintenance of community water sources (Atapattu, 2005).

The neglect of irrigation-based food-crop agriculture during the early periods of European rule hastened the disintegration of water related customs and the related value structure. Subsequently when the new irrigation-based colonization schemes were introduced, settlement of people became state driven, with the development of infrastructure including free irrigation provision being treated as essential incentives, and a state responsibility. The financing of water resource development has traditionally remained the responsibility of the state. While there are legitimate public concerns, there is also a growing consensus that Government involvement is not required in all aspects of service provision.

The distinction between raw water and value-added water has been recognized. NWSDB, which supplies potable water in urban areas, has been levying fees for water services for many years. The recent expansion of community-based management of water services through local councils etc, would transfer a part of the infrastructure development and management costs to the beneficiaries.

Multiple values and costs of irrigation water

Studies carried out in 1999 at the Kirindi Oya project indicate that financial returns to irrigated paddy production (value of the marketed output less cash costs of production) averaged approximately Rs 22,053 per ha (US$315 per ha). The costs, listed in decreasing order, are labour (35%), materials (23%), land (20%) and machinery (14%). Based on estimates of paddy water use in this scheme, the average economic return to water per ha has been estimated at Rs 16,748(US$239). Similarly, the economic return per unit of water is Rs 1.41 per m^3 (Renwick 2001) (which can be translated as US$ 20,140 per MCM).

Inland fisheries are now becoming popular with the support of government. These fisheries are an important source of protein for the rural population as well as a reliable source of income to the fishermen. The studies carried out in the Ruhuna basins (Kirindi Oya) show that inland fishermen operate on an average of 318 days per year, and about 70 percent of the fishermen have their own boats. The catch per unit effort or per boat trip averaged about 35 kg of which about 1.4 kg are retained for home consumption. According to the same survey carried out in 1999, the annual average economic return to a fisherman was about US$ 1,395. It is estimated that the value of fisheries is about 18% of the total economic returns to water in irrigated paddy production in the Kirindi Oya Project (Renwick 2001).

In economic terms, the diversions for irrigation result in opportunity costs. As discussed previously, diversion of Mahaweli water downstream to Polgolla barrage, will optimize hydropower generation, but diversion to the Sudu Ganga-Amban Ganga system will optimize irrigation productivity. If the latter option is adopted, the energy produced will be in the order of 0.3 GWH per one MCM of water. However, if the water is released downstream to Polgolla via Victoria, Randenigala and Rantambe, it could produce around 0.8 GWH of hydropower per one MCM of water. This difference in times in the annual diversion, is the annual incremental energy lost to the country due to irrigation diversions, assuming that total flow of Mahaweli could be stored in the hydropower reservoirs below Polgolla. This emphasizes the need for good water management in the irrigation schemes (Seneviratne and Handagama, 2005).

Water and gender

As in many other countries, rural Sri Lankan women are normally responsible for the supply of domestic water, and water for domestic sanitation and laundering etc. The studies in minor irrigation systems show that 75%-85% of women are actively involved in agricultural activities. It is also noted that 4-8% of women play a major role in agricultural activities compared to men. Women play a major role in transplanting, harvesting and selling the products at home, while machinery-related activities such as ploughing, land levelling, threshing and transporting the products to home and town are done by men (van der Molen, I. 2001).

However, female participation in agricultural activities seems to be influenced by the economic conditions of the household. Studies show that female labour (as a component of family labour) is

replaced by hired labour, when the family becomes more affluent (Zwartween, 1994.).

Role of water in poverty eradication

The value of the output of crop and livestock production from agriculture provides the most value addition from multiple uses of water in the country. Water used for irrigation and crop production also provides value in ways other than producing crops i.e. groundwater recharge, aesthetic and recreational value, domestic and human requirements during water-scarce dry seasons. The magnitude of non-irrigation benefits from water diverted for irrigation could be significantly higher than the direct economic benefits from crop output.

Irrigation water has a high social value through the creation of opportunities for development in the Dry and Intermediate regions of Sri Lanka which are poorly served by infrastructure development, and severely lacking in alternative opportunities in other non-agricultural enterprises. Irrigation expansion in Sri Lanka has been a critical investment for employment generation that would not have otherwise happened. Irrigation investments have contributed significantly to reducing rural-urban migration due to expansion of economic activities, albeit low in the dry zone.

For Sri Lankan farmers finding water for farming crops is a critical livelihood issue, and the variability in access to water frequently determine the levels of poverty. 'Marginal' farmers on marginal farm lands remain dependant on vagaries of weather. Often they are on the periphery of irrigation systems, but almost never able to reliably access water, resulting in low productivity and frequent crop failures that lead to food insecurity and perpetuate indebtedness, which compound their misery. Children of such families are deprived of receiving a basic education or from acquiring skills, and are perpetually locked in poverty.

On the other hand, the lack of access to water and sanitation further accentuates hardships of the poor. Clean drinking water becomes a luxury, and proper sanitation remains an unaffordable luxury often confined to consumption levels well below those required for decent living. Proper sanitation facilities are never available to them. This forces them to be poorly served by public utilities where conditions quickly deteriorate leading to environmental hazards from poor sanitary facilities and practices (Atapattu, 2005). Poor hygiene practices quickly translate into poor health. The resulting inequity is often harsh making the poor fall sick more often, leaving them with less time to spend on productive work earning an income, and forcing to spend a high percentage of meagre incomes on medication. Therefore the environmental justice denied by lack of water is most harsh on the poor.

Financing of water related MDGs

Identification of investment in the water sector is sometimes difficult because the responsibilities are distributed among several government institutions and ministries. For example, a part of the investments in health, education and rural development are in the water sector. Apart from the major government agencies, many local government institutions, individuals and NGOs invest in water related activities.

As will be discussed later in Chapter on Governing Water, the annual investments in the water resources sector (mainly irrigation and water supply), has been declining when compared with the total government commitment. A declining trend in investments in irrigation (both in terms of foreign aid and local funds), especially in new construction work is noted (Kikuchi et al, 2002). However, even in recent times, 25% of the investment in agriculture goes to the irrigation sub sector, though investment in agriculture itself as a part of public investment has declined considerably. The percentage share of new irrigation infrastructure construction has decreased from as high as 90% up to the early 1980s, to less than 30% by the late 1990s, while irrigation infrastructure rehabilitation has increased its share by more then 40% (Ratnayake, 2005).

The cost of maintenance of infrastructure varies across the sectors. The operation and maintenance cost of irrigation systems has been calculated as Rs. 1000/ ha approximately. However, there are wide variations of this value across the schemes. Senaratne (2002) describes the average capital cost of investment in drinking water supply schemes in the Table 56. This study was carried out in the case study of the Ruhuna basins for WWDR-I.

Cost recovery and pricing policies

During the times of the Sinhala kings, as a result of repeated foreign invasions, people in the dry zone of Sri Lanka who mainly practised irrigated agriculture gradually migrated to the wet zone where agriculture was mainly rain-fed. Agriculture was neglected in the early periods of European rule. When new colonization schemes were started, settlement of people in the irrigated areas became a national or government need rather than the needs of the settlers. The government provided the new settlers with many facilities such as housing as incentives to migrate to the new schemes. The settlers had to face many

Table 56: Average capital investment needed for different water supply facilities

Technology Option	Average Capital Investment/Person (Rs)
Hand dug wells (House hold)	4,000.00
Hand dug wells (Shared by 5 families on average)	1,300.00
Hand Pump Tube wells (Shared by 15 families on average)	1,600.00
Village gravity piped schemes with basic components and chlorination for treatment	3,500.00
House hold Rain water tanks	3,000.00
Village pumping piped schemes with basic com ponents and chlorination for treatment	4,000.00
Small town gravity piped schemes with basic components and partial treatment (aeration, filtration and chlorination)	4,250.00
Small town pumping piped schemes with basic components and partial treatment (aeration, filtration and chlorination)	4,800.00
Town water supply schemes with full treatment facilities	7,000.00

Source: Senaratne, (2002)

problems such as malaria, social shock due to relocation etc. In such circumstances charging for water was seen as impracticable.

Irrigated agriculture provides benefits not only for the community that is engaged in agriculture but to the rest of the community through food security, contributing to national security and providing environmental benefits. Therefore, traditionally the cost of infrastructure development and their maintenance has been borne by the state. Even at present this remains the government policy. While participation of farmers in the management of irrigation system is encouraged, this is considered as a measure to improve the management rather than merely a cost recovery measure. However, several well-functioning farmer organizations have developed their own methodologies to recover the cost of maintaining the canals under their management.

Water pricing is practiced in domestic and industrial water supplies, and the tariff structures accommodate provisions to minimize wastage. The details of these procedures are described in the appropriate sections.

Indicators

- Water related investment in State investment = unsatisfactory
- Provisions to ensure accessibility to poor and vulnerable : moderately satisfactory

Chapter 12

Governing Water

Good governance of water is crucial for the sustainability of the resource. The experience show that a major part of the water related problems are the outcome of poor governance. Sri Lanka has practiced integrated water resources management principles for a long period of time. This chapter discusses the present issues and status of water governance in Sri Lanka.

National policies

Water related policies in Sri Lanka were evolved with time. The proclamation by King Parakramabahu the Great (1153-1186 AD) "In my kingdom are many paddy fields cultivated by means of rain water, but a few indeed are those which are cultivated by means of perennial streams and great tanks. By rocks, and by many thick forests and by great marshes is the land covered. In such a country let not even a small quantity of water obtained by rain, go to the sea without benefiting man. Paddy fields should be formed in every place, excluding those only that produce gems, gold, and other precious things." (Arumugam, 1969 quoted from Mahawamsa). This can be described as one of the earliest statements of state policy on water resources, overlain by the Buddhist philosophy on natural resources management. Thus it is clear that the ancient policies on water had emphasized on making it available for livelihood needs, environmental needs and other requirements in an equitable manner.

The policy on water resources development had a heavy emphasis on providing water for agriculture from the colonial times. There were fewer conflicts during the early part of the 20th century between different water users, due to low urban population and industrialization. However, the growth of industrial and commercial activities since 1980s, increasing urbanization and pollution of water bodies has resulted in placing developed water resources at stress.

Sri Lanka has a number of ways of establishing policy, including the constitution, the Governing Party's manifesto, the Public Investment Programme, and the Annual Budget and Policies adopted by the Cabinet (Mosley, 1994). Mosley (1994) listed six National policies that have had a particular significance to the water sector. They are as follows:

- The National Industrial Policy, designed to enable Sri Lanka achieve the Newly Industrialised Country (NIC) status by the turn of the century.
- Economic stabilization and reform, including macro economic stabilisation, public sector rationalisation, promotion of the private sector and export industry, and restructuring of welfare programmes.
- A strong commitment for social equity, expressed through programmes to provide for all by the year 2010, electricity, safe drinking water, shelter, and adequate sanitation.
- A group of policies relating to national self-sufficiency in food, poverty alleviation, land tenure, rural settlement, and agricultural development.

- Devolution of powers from the Central Government to provincial councils and Pradeshiya Sabha/Divisional Secretariats
- Environmental policies enunciated in Articles 24 and 28 of the constitution, in the National Environmental Action Plan

Sri Lanka has been working on a water resources policy since the mid 1990s (NPD, 1994). The need for such a policy arose due to the increasing competition among water-use sectors, and the deteriorating water quality characterized by spatial and temporal variations. The fragmented legal and institutional structures were inadequate to find sustainable solutions to the emerging problems. The policy making process has been subjected to extensive debate and discussion for nearly a decade.

Although a comprehensive national policy is yet to be adopted, the discussion has yielded many benefits. One of the major achievements is the understanding that developed water resource has been considerably stressed and scientific management is necessary. There is also a general consensus that water is a basic human right, and that the supply of water for basic human needs and livelihood needs should be ensured regardless of the cost.

Although the policy formulation process for water resources is yet in progress, there have been many water-related policies that have evolved over the time. Three policies have been formulated to promote the sustainable management of land resources. The first was the National Policy Framework formulated by the Ministry of Agriculture, Forestry and Lands in 1980s, for the three sectors of Agriculture, Forestry and Lands. Under this policy framework, eight management issues pertaining to land were identified, and policy recommendations made pertaining to each issue. The main land issue that was addressed was the degradation of land resources due to overuse and mismanagement. The National Forestry Policy (1995) which was the second policy document designed to address a number of problems facing the forestry sector, notably included the continuing decrease in the forest cover, the expanding conflicts between forestry and agriculture, and the ineffectiveness of the efforts at protecting forests. An important policy objective in this regard has been to conserve forests for posterity with particular regard to biodiversity conservation, and soils and water. The third policy document was the Draft National Physical Land Use Policy formulated in 1996 to promote "the utilization of the land resources of Sri Lanka on a scientific basic to obtain goods, services and recreation needs on a continuing basis for maintaining a high quality of life by the present generation without adversely affecting the quality of land resources that would deny similar opportunities to future generations". This policy focused on both conservation and development. Under conservation, policies were outlined for the protection, conservation and sustainable use of the land resources of the country, and the management of biodiversity. Under development, policies were outlined for allocation of land to the different sectors of the national economy, institutional development, and land use planning (Batagoda, 2005).

Policies have also been formulated for watershed management (ME&NR, 2004a), forestry and wild life (Batagoda, 2005), water supply and sanitation (Senaratne, 2002) etc., and such policies are described in detail under the relevant chapters. The Rainwater Policy recognizes that rainwater is an under-utilized resource. When this policy is implemented, rainwater harvesting will be made compulsory in certain categories of buildings in municipal and urban council areas. It is intended to promote rainwater harvesting in rural areas as well (National Rainwater Policy of Ministry of Urban Development and Water Supply, 2005). The National Solid Waste Management Strategy adopted by the Ministry of Environment and Natural Resources is an important initiative to address waste management issues. However, in the absence of a single landfill in the country the problem still is an acute one. The newly established Waste Management Authority of the Western Province is expected to co-ordinate the issue and come up with an immediate solution for the waste management problem in the country (Batagoda, 2005).

Strategies

With regard to the formulation of strategies, two important strategies have been formulated i.e. the National Agriculture, Food and Nutrition Strategy of 1984, and the National Conservation Strategy of 1988. The former recognized that proper management of land resources was crucial for future agricultural development of the county, and drew attention to the very little planning done on the basis of watersheds. A programme was prepared for the future development of land resources, and in this a high priority was accorded to watershed management and land resource planning. The National Conservation Strategy set out the national policy on the conservation and development of natural resources. The strategy spelt out the objectives of conservation,

outlined the strategic principles to be followed, identified constraints on conservation, and outlined plans for overcoming these constraints indicated in each sector.

Action plans

Several plans have also been prepared to promote the management of natural resources. A National Environmental Action Plan (NEAP) was prepared in 1992, which has been updated twice since then. The third NEAP prepared for the period 1998 - 2001 set out the agenda for the 21st century. The main issues pertaining to nine key sectors were identified including land, water, biological resources, and coastal and marine resources. Recommendations were made to address the issues in each of the identified sectors. The Forestry Sector Master Plan prepared in 1995 (Batagoda, 2005) provides a long - term development framework for the forestry sector, to conserve natural forests along with wild life and biodiversity, while providing environmental services and forest products to meet the needs of the country on a sustainable basis. The Coastal Zone Management Plan which was prepared in 1997 (Batagoda, 2005) by the Coast Conservation Department, outlines interventions to reduce coastal erosion, minimize depletion and degradation of coastal habitats, and minimize the loss and degradation of areas of archaeological, historical, recreational and aesthetic value. The Biodiversity Action Plan prepared in 1998 by the Ministry of Forestry and Environment (Batagoda, 2005), outlines the principles, goals and broad objectives of biodiversity conversation, and submits proposals for action in the major ecosystems i.e. forests, wetlands coastal and marine systems and agricultural systems.

The National Disaster Management Plan prepared in 1999 by the Ministry of Social Services (Batagoda, 2005) covers four major phases of disaster management i.e. mitigation, preparedness, response and recovery. The vital areas covered include preparedness, mitigation and preventive action; recovery relief, rehabilitation and re-construction; control of floods, landslide hazards and cyclones; and improvement of meteorological observation, forecast and waiving systems (Batagoda, 2005).

The need for a water resources development master plan has been a long felt need. At present, the Ministry of Agriculture, Irrigation and Mahaweli Development is formulating proposals in this connection.

National goals and programmes currently in progress

The water related components of the National Policy Framework have been outlined in the CBSL (2005) as follows:

- Disaster management is recognized as a priority issue. The adverse impact on the economy by floods, droughts and the tsunami of 2004, underlines the necessity for national disaster avoidance and management strategies to address the issue.
- Sri Lanka needs to facilitate both technology improvements, and research and development activities to achieve sustainable growth.
- Sustainable growth has to be environment friendly and environment policies should not be an obstacle to growth.

In the case of agriculture, trade policy measures attempted to achieve the two objectives of reducing the cost of living and providing protection to producers. In the case of water resources management, several goals have been identified (NARESA, 1991). They are as follows:

- 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
- Groundwater development for agriculture and domestic use
- Development of small scale hydropower projects
- Drainage and flood protection improvement
- Systematic watershed management

The present policy outlined in the government policy statement of 2005, identifies programmes to develop irrigation by linking watercourses to reservoirs. Action will be taken to prepare a national irrigation management plan. Some major water resources development projects have been identified for implementation.

The programmes and activities within the above policy frameworks are described under the relevant chapters, addressing the WWAP challenge areas.

Towards millennium development goals (MDGs)

Successive governments have always recognized the UN Declaration on Human Rights (1948), that every one has the right to a standard of living adequate for the health and well being of oneself and one's family including food, clothing, shelter, provision of health care and education. This has served as the motivating factor for successive governments to provide free health services and free education. This has also helped Sri Lanka to achieve good health standards. There is a decline of infant mortality rate, maternal mortality rate, crude birth rate and other health indicators over the past several years. Life expectancy of both males and females had increased (Shanmugarajah, 2005).

Incidence of childhood infections and other communicable diseases had declined due to the expanded programme of immunization and other disease prevention programmes launched by the Ministry of Health. Health education programmes were successful due to the high literacy rate of the population and equal opportunities for female education. As a result of all these activities and programmes, Sri Lanka has achieved better health status at a modest per capita GDP (Shanmugarajah, 2005).

The U.N Millennium Development Goals (MDGs) Country Report 2005, subscribed to by Sri Lanka, has references to the water sector strategies and goals. Target 10 of Goal 7 on environmental sustainability deals with water supply, and the global target is to have the problem of people without sustainable access to safe drinking water, halved by the year 2025. With around 75% of the country's population having access to safe drinking water, and 73% of the population with access to safe sanitation, Sri Lanka appears to be on target of achieving the UN millennium goals.

The MDG achievements in respect of the health sector are shown in Table 57 -(Shanmugarajah 2005)

The water supply sector has set a target of 85% of population having access to safe drinking water by 2010, and 100% by 2025, and piped water supply to 100% of urban population by 2010 (Table58).

The NWSDB sanitation programme targets are 70% coverage by 2010 and 100% by 2035. The NWSDB has projected an investment requirement of approximately Rs.115 billion to meet requirements of 2010 (Corporate Plan 2003-2007, National Water Supply and Drainage Board).

The food-related MDGs are adequately dealt with in the Chapter 6 - Water for Food.

Despite these gains the country is not "well on track" to achieve several other MDGs. The income-based poverty alleviation seems to be stagnating and there are no significant gains during the last decade. Although malaria incidence has been effectively controlled in comparison to the situation prevalent during the 1950s, there has been a recurrence and the gains in the recent times have not been significant. In addition there are occasional outbreaks of more deadly diseases such as Dengue and Japanese Encephalitis (NCED, 2005).

Water rights and customs

The right to extract water is normally linked to the land rights, and therefore appropriation and extraction is based on land ownership. This also applies to groundwater, which without regulation or physical impediments to extraction, is said to have led to over exploitation. Surface water extraction is

Table 57. Millennium Development Goals - Health Indicators for Sri Lanka

	Bench mark	Target for 2015	Target for 2025
% Population with sustainable access to an improved water source	75.4 % (DHS 2000)	85%	100%
% of population with access to imprdve sanitation(water seal)	72.6 % (DHS 2000)	85%	100% (in2035)

Table 58. Projections for water supply coverage

	Projections			
Water Supply Coverage (as % of Population)	2005	2006	2007	2010
By the NWSDB (pipe borne)	34	37	39	42
By 3rd and 4th ADB projects in Rural Sector	2	2.6	3	2.5
By other sector agencies & NGOs including individuals	43	42	41	40.5
Overall access to safe water	79	81.6	83	85

Source: Corporate Plan 2003-2007, National Water Supply and Drainage Board

mostly by the State for irrigation, water supply and hydropower. Several industries and industrial estates also extract water. The present environmental regulations necessitate a clearance for water extraction and/or disposal.

There are many local customs and traditions that affect water governance. Most of them are related to agriculture and irrigation. Water rights include formal rights embodied in official titles, permit, entitlements, and seasonal irrigation schedules, while less formal rights are based on customary patterns and rights implicit in social norms and practices. Some examples could be stated as follows:

- In irrigation schemes, a cultivation meeting is held before each season. This meeting is attended by farmers and relevant government officials. The decisions taken at the meeting include the date of water issue and period of issue. The decisions taken at the cultivation meeting are legally recognized, and therefore infer a right to use water.
- In old irrigation systems, which were expanded later to accommodate new farmers, the farmers of the former system receive prior access rights.
- A traditional "*Bethma*" system in a village tank irrigation system provides for proportional stream flow rights coupled with consolidated cultivation to optimize water use.

Institutions

Governance of water, in keeping with government policies is the task of a number of agencies and several ministries covered by a plethora of parliamentary acts. Some institutions such as the Irrigation Department were established at the turn of the 20th century, and some others such as the Irrigation Management Division of the Ministry of Irrigation are of recent origin. The Ministry of Lands and Land Development, for a significant time had been the most important ministry responsible for the water resources development of Sri Lanka. This ministry established in 1978, was responsible for the three major water resources development sectors, land, irrigation and forestry.

The Irrigation Department in the past had the primary responsibility for water resources planning, development, and maintenance. The Water Resources Board established in 1964, later took over the work on groundwater exploration and development.The National Water Supply and Drainage Board is the agency that is responsible for the domestic and industrial water supply and sanitation. The Mahaweli Authority of Sri Lanka is responsible for the water and related infrastructure development in the declared Mahaweli Project regions, and also other major basins which have been declared by the government as special areas.

The institutions that contribute to governing water comprise international, national and local agencies. All agencies that are not restricted to a particular geographic location(s) and serving the entire nation are categorized as national institutions. The rest are grouped into international and local categories. The international agencies are those which are recognised by the government and receiving direct external support for their activities. Local institutions are those which are closer to the stakeholders and hence often referred to as field level operational institutions. In order to facilitate development administration, there are operational institutional mechanisms set up to coordinate and integrate sectoral and sub-sectoral activities at field and national level (Table 59).

International

Sri Lanka collaborates closely with several international organizations related to water resources. They include several UN Agencies including FAO, UNESCO, UNICEF, WHO and WFP. Sri Lanka is an active member of organizations such as International Hydrological Programme (UNESCO), International Commission of Irrigation and Drainage, International Commission of Large Dams, Dams and Development Project (UNEP) and World Water Assessment Programme (UN) and programmes such as International Network on Water and Ecosystem in the Paddy Field (INWEPF). Other international organizations include International Water Management Institute (IWMI), whose headquarters is located in Sri Lanka. Global Water Partnership (GWP) and International Union for Conservation of Nature & Natural Resources(IUCN) are some of the major, water-related international NGOs that operate in the country.

National

There are over 30 national institutions contributing to water resources development and management in Sri Lanka. These institutions perform various service functions such as irrigation, drainage, drinking water supply, sanitation, hydropower generation, recreation, environmental protection, education, research and policy formulation. In addition, the national universities contribute by including water resource management in the curricula, and carrying out related research and projects.

Local

Provincial Councils, Municipal Councils, Urban Councils and Pradeshiya Sabhas are the institutions that perform several water related functions at lower implementation levels than the national operational level. They include local water supply and sanitation, small-scale and provincial irrigation and drainage activities, and environmental protection.

Legislation

Legislation of Sri Lanka enacted since the 19th century contain provisions to guide the development of land, water and forest resources. The legislation contain provisions for the prevention or mitigation of soil erosion on state owned land and privately owned lands; the identification of "conservation" areas; the protection of critical watersheds; the promotion of watershed management; protection of irrigation and water resources infrastructure; and the conservation and utilization of forest and water resources. Further details are available in the relevant chapters.

National legislation

Sri Lanka is a Parliamentary democracy with an Executive President as the Head of State. The amendments to the constitution of Sri Lanka in 1987 provided for the establishment of Provincial Councils.

It is said that there are over 40 acts of parliament with relevance to the water sector. The Comprehensive Water Resources Management in Sri Lanka Report done in 1994 lists 29 legislation as directly linked to water (Table 60 - Mosley, 1994).

Provincial

Several water-related functions were handed over to the Provincial Council through the implementation of the 13th Amendment to the Constitution of 1987. Any legislation desired by a Provincial Council becomes valid law only after endorsement by the President, other Provincial Councils and the Parliament. The Constitution lists the following functions related to water as responsibilities of the Provincial Councils:

Table 59. Co-ordinating arrangements of the water sector

Operating level	Type	Legally Constituted	Administratively Formed
National Level (Legislative)	Parliament	Parliamentary Consultative Committee	Economic Affairs/ Infrastructure Sub Committee
National Level Policy Implementation	Cross Cutting		a) Secretaries Committee b) Committee Integrating Environment & Development Policy (CIEDP) c) Committee on Environmental policy management (CEPOM for water)
	Sectoral		a) Central Co-ordinating Committee on Irrigation Management (CCCIM) b) National Committee on Water Supply and Sanitation (NWSS)
	Project Based (Time Bound)		National Steering Committee for Project Implementation
Regional/ Basin	Cross Cutting		MASL Water Panel
Provincial	Cross Cutting		a) Provincial Co-ordination Committee b) Provincial Environmental Co-ordinating Committee c) Provincial Co-ordinating Committee for Water and Sanitation.
	Sectoral		
District/ Division	Cross cutting	Environment and Law Enforcement Committee	a) District Co-ordinating Committee (DCC) b) Divisional Co-ordinating Committee
	Sectoral	District Agriculture Committee (DAC)	
	Sectoral	Sub Committee of DAC	
Major Irrigation Projects	Project based/ Sectoral	Project Management Committee (PMC)	

Source: Ratnayaka, 2005

Table 60: Identified Legislation Directly Related to Water

1	Crown Lands Ordinance (1947)
2	Thoroughfares Ordinance (No 10 of 1861)
3	River Valleys D.B. Act (No. 6 of 1861)
4	Water Resources Board (No. 29 of 1964)
5	C.M.C. Water Works Ordinance (1907)
6	Fauna and Flora Protection Ordinance (1937)
7	Water Hyacinth Ordinance (1909)
8	Plant Protection Ordinance (1924)
9	Forest Ordinance (1907)
10	Fisheries Ordinance (1940)
11	Pearl Fisheries Ordinance(1925)
12	Town and Country Planning Ordinance (1946)
13	Tourist Development Act (14 of 1968)
14	Irrigation Ordinance (1900)
15	Ceylon Electricity Board Act (17 of 1967)
16	Atomic Energy Authority act (19 of 1969)
17	Mahaweli Development Board Act (14 of 1970)
18	National Water Supply and Drainage Board (2 of 1974)
19	National Science Council Law (19 of 1968)
20	Wells and Pits Ordinance (1864)
21	Control of Pesticides Act (33 of 1980)
22	Food Act (26 of 1980)
23	National Environmental Act (47 of 1980)
24	Coast Conservation Act (57 of 1981)
25	Maritime Pollution Prevention Act(59 of 1981)
26	National Aquatic Resources, Research and Development Agency Act (54 of 1981)
27	National Resources, Energy & Science Authority of Sri Lanka Act (78 of 1981)
28	Land Development Ordinance (1935)
29	Agrarian Services Act (58 of 1978)

Source: Mosley 1994

- Agriculture and irrigation, except in inter-provincial irrigation schemes
- Rehabilitation and maintenance of minor irrigation schemes
- Health
- Land, including land use, land improvement and land settlement
- Protection of the environment within the limits set by the Parliament

Provincial / Local administration

The Provincial and Local government systems in Sri Lanka at present comprises 09 Provincial Councils, 18 Municipal Councils, 37 Urban Councils and 256 Pradeshiya Sabhas. Local Government constitutes the sphere of state action that is closest to the people. Local government institutions are directly responsible for ensuring that concerns of the people are taken care of on behalf of the State. They are being called upon to work ever increasingly through a complex network of partnerships, contracts and influence in order to take care of the development concerns of the local community.

In Sri Lanka the local government system provides the institutional opportunity for mobilizing all sections of the local community when addressing issues of environment and water resources development directly affecting them. These local authorities failed to formulate and implement the local provisions of Agenda 21 as envisaged at the World Summit on Sustainable Development, due to weaknesses resulting from inadequate resources and influence. However, there are two distinct areas of achievement with regard to re-defining the role and functions of local authorities from a sustainable development perspective during the nineties and into the new millennium. The first is the sustainable development demonstration experience based upon urban local authorities, essentially a good city management initiative. The second is the initiative of the centre i.e., the Ministry of Environment, to link up with local authorities in an environmental management partnership (Batagoda, 2005).

International conventions and treaties

There are several international conventions and treaties that have been supported by the Government of Sri Lanka. The main one is that pertaining to the climate change.

Sri Lanka is a signatory to the UN Framework for Convention on Climate Change (UNFCC, 1993). The Ministry in-charge of the subject of Environment with the participation of other agencies and stakeholders have given due recognition to this by its publication of the Initial National Communication (INC) on Climate Change in 2000. The INC attempts to identify issues arising out of climate change, and lists out possible general measures to either counter or mitigate the impacts. It identifies that though distinct policy documents are absent for measures to mitigate climate change, there are many provisions in the existing policies and enactments. The INC proposes that adaptation measures must be based on sectoral studies and long-term research on climate change, but identifies some priority areas that need attention. They include protection of arable soils; improvements to water management; enhancing agro-technology; formulation of land use policies; maintaining food reserves and providing disaster relief. All these areas have a strong link to water resources. Specific recommendations are for the inclusion of the aspect of climate change in the national water resources policy that is currently under discussion.

Climate change however, is still not mainstreamed in most relevant sectors including the water resources sector, where awareness gaps at different levels exist. Though some agencies such as the Department of Meteorology are already in the process of conducting climate change awareness programmes at different levels, the implementation of climate change related activities is still slow, apparently because short-term needs are given precedence over long term obligations, since effects of such activities are not immediately felt. There are also gaps in institutional mechanisms, laws and their implementation, and some times in the value system. Covenants such as International Treaties, capacity building including awareness at all levels development of comprehensive methodologies for assessment and management, could help to reduce the existing gaps (Batagoda, 2005).

Sri Lanka ratified the Framework Convention on Climate Change in December 1993. Action has been taken to establish a climate change secretariat and two national Clean Development Mechanisms (CDM) centres at two major universities to facilitate the implementation of the provisions stated in the convention, and to ratify Kyoto Protocol by the Ministry of Environment and Natural Resources.

Sri Lanka has ratified the Vienna Convention for the Protection of the Ozone Layer in 1989, the Montreal Protocol on Substances that Deplete the Ozone Layer in 1989. Regulations were also gazetted in 1994 specifying time targets for phasing out Ozone Depleting Substances. The Montreal Protocol Unit under the Ministry of Environment was established to implement the Montreal Protocol. This unit has successfully reduced the consumption of Ozone Depleting Substances (ODS), and shows a steady decline in the recent years (Montreal Protocol Unit 2003).

Human resources

Irrigation Department, National Water Supply and Drainage Board and the Mahaweli Authority of Sri Lanka are the agencies that have a comparatively large number of professionals involved in the water related activities, of which a significantly large number is involved in development and maintenance. The number of professionals engaged in activities such as, conservation awareness, research etc. are relatively low. The number of local professionals in water sector agencies involved in project formulation and development is also limited. These services are carried out with foreign inputs, which are usually influenced by the funding sources. The contributions of in-house staff of water sector agencies are commonly for project implementation and maintenance.

Senior professionals in most of the water sector agencies possess either a postgraduate diploma or a masters Degree. Doctoral degrees among water professionals are still a rarity probably due to lack of opportunities. Water professionals mostly get their overseas postgraduate education from the Netherlands, United Kingdom, India, Japan and Australia. Other than this most of the professionals receive structured short-term training at various training centres. The opportunities for strengthening at the public sector institutions mostly target the senior officers. These opportunities for long-term training of professionals are usually one in two years or lesser for most of the agencies. In recent times it has been noted that there is a trend among the young to expand their professional knowledge by obtaining postgraduate qualifications on their own without waiting for employed agency support. In almost all the water sector agencies, a training division is in existence mainly to identify and organize local training in specific areas, and to identify and establish the preferential order of training of the professional staff (Wijesekera, 2005).

Financial resources

Budget for water related investments

Table 61 summarizes the financial allocations from the Government Budget, Public Investment Programme, and the Public Irrigation Investments during the period 1950-1997 (Kikuchi et al, 2002).

The declining trend in investments in irrigation, especially on new construction work (both Foreign Aid and Consolidated Fund) is clearly evident from the data presented in this table. 25% of the investment in Agriculture is for the irrigation sub sector, though investment in agriculture itself as a part of public investment has declined considerably. The percentage share of new constructions had been as high as 90% up to the early 1980s, but since then decreased to less than 30% by the late 1990s, whereas rehabilitation expenditure had increased its share to more then 40%. Currently more then 50% of public investment in irrigation is for rehabilitation activities. Significant investment as private investment in irrigation (agro wells, pumps, drip etc.) is noted during the last decade (Ratnayake, 2005). There had been concomitant investment in drinking water supplies as well though not as in the order of irrigation investment. Total investment in water resources had varied from around 8% a decade ago to around 2% of total capital investment in the country. A decline in irrigation investment had been offset by increased investment in the water supply sector. Table 62 provides information on the investment undertaken over the last decade.

Management approaches

Demand management

The approach to demand management differs across the sectors. In irrigated agriculture, demand management is mainly attempted through improved water management and encouragement of the farmers' participation in management activities. In drinking water supply the tariff structure is designed in such a way, that use beyond basic requirements is subjected to a higher rate. Similar conditions apply for industrial water use. The details of the approaches undertaken by the respective agencies are described in the chapters on Water and Food, Industry and Energy.

Table 61. Public investment in irrigation

Year	Value (LKR. Billion in 1995 prices)				
	Total Government Budget	Total Public Investment	Total Public Investment in Agriculture	Total Foreign Assistance	Total Public Irrigation Investment
1950	37	8	4	-	3
1955	50	10	5	1	2
1960	72	13	7	1	2
1965	90	16	8	14	2
1970	117	21	13	8	3
1975	150	27	13	15	3
1980	176	49	16	39	9
1985	165	50	24	31	9
1990	191	36	10	29	3
1995	231	32	6	23	2
1997	230	31	5	18	2

Table 62: Investment in Water Resources (LKR. M)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total Capital Investment	68,168	68,386	108,501	92,734	91,434	137,297	121,767	294,935	195,771	260,523	319,545
Agriculture & Irrigation	2,924	2,700	3,194	2,078	1,727	1,451	1,600	2,147	2,531	2,750	3,138
Water Supply	2,333	2,302	3,155	3,313	2,512	2,390	4,770	4,695	3,571	8,990	3,969
Sub- total	5,257	5,002	6,349	5,391	4,239	3,841	6,370	6,842	6,102	11,740	7,107
Percent	7.71	7.31	5.85	5.81	4.64	2.80	5.23	2.32	3.12	4.51	2.22

Source: INWRA, 2004 cited in Ratnayake, 2005

Stakeholder participation

Stakeholder participation in major irrigation management decisions has been practiced for a long time in the irrigated agriculture sector. Dates to start cultivation and completion are decided at a Cultivation Meeting held before each crop season, where the farmers and officers participate. The policy of participatory management has been accepted by government since 1989. Since then a more formal structure for stakeholder participation had been introduced to the irrigation sector, which improved both water management and officer-farmer relationships to a considerable level.

Presently all minor irrigation works which are classified as having less than 80 ha of command area, have been managed by the stakeholders. The tertiary systems in major / medium schemes are also managed with stakeholder participation. The process of the Kanna meeting as a decision-making forum for the use of water for irrigated agriculture is a stakeholder participating institutional arrangement that has shown to be very effective. However, in major / medium irrigated agricultural system management, the first attempts of farmer involvement were as a result of independent interventions at Minipe and Kimbulwana Schemes, and also with the implementation of the Gal Oya Rehabilitation Project in 1979/80. The concept of stakeholder participated Tank Committees for rehabilitation was included in the Tank Improvement and Modernisation Project (TIMP) in 1976, which has been recorded as the first foreign funded rehabilitation project (Ratnayaka 2005).

The registration of farmer organisations under the Agrarian Services Law in addition to informal groupings for water management gradually evolved under changes to the law. The "vel vidane" was replaced by the Cultivation Committee and an Irrigation Agent under the Paddy Lands Act, and then by the Farmer Organisations set up by the Irrigation Management Division of the Ministry of Irrigation, the Irrigation Department and the Mahaweli Authority of Sri Lanka since the mid 1980s.

Further dimensions to beneficiary involvement were introduced when the National Development Council (NDC) in 1995 recommended the formation of Farmer Companies on the one hand, with the transfer of medium schemes (<400ha) to farmers, and on the other hand to incorporate Joint System Management of larger systems (Ratnayake, 2005). However, these recommendations were subject to substantial debate in recent times. At present, the joint management of irrigation systems with the government institutions playing a major role especially in the main irrigation systems, is the model that is being promoted. Participation of the farmers in scheme level decision-making is being actively promoted.

In the water supply sector as well in rural/ community based water supply schemes collective community based operations, maintenance and management systems are in place as components of stakeholder participation. Interventions are underway to develop river basin level organizations to ensure stakeholder participation in the management of water resources in such river basins as Kalaoya (Ratnayake, 2005).

Several NGOs are active in promoting stakeholder participation in water resources management.

Recent programmes and policy implications

Several recent studies reveal the link between water resources development and poverty alleviation, in the following manner:

- A study carried out in the Uda Walawe scheme shows that irrigation blocks located in the tail end of the irrigation system and experiencing water scarcity is endowed with higher incidence of both chronic poverty and transient poverty. The level of transient poverty in water-scarce irrigation blocks is comparable with that of rain-fed lands within the same scheme area. The study concludes that provision of irrigation infrastructure may lift the chronically poor groups out of poverty (JBICI & IWMI, 2002).
- Studies carried out for Ruhuna Basins in the same geographic area under the World Water Assessment Programme, are complementary to the above findings. Ruhuna Basins comprise of Walawe, Kirindi Oya and Menik Ganga river basins located from west to east. The water resources of the lower western and middle portions of the river basins are substantially developed, except for some patches of land, while the Menik Ganga basin in the eastern parts very much less developed. The upper reaches of the river basins are located in the wet and intermediate zones, and the lower reaches are in the dry parts of the country. The study shows that only a small percentage of the people in areas with inadequate irrigation development are provided with safe drinking water. The high availability of safe drinking water in Lunugamvehera in the Kirindi Oya basin can be largely attributed to the Kirindi Oya Irrigation and Settlement Project constructed in mid 1980s in that area. It may be noted that the Kirindi Oya Project is considered to have not achieved the agricultural

productivity targets, but its contribution in terms of socio-economic development is often overlooked. Low levels of safe drinking wate are available in upstream areas of the Ruhuna basins, though being located in the wet zone with substantial rainfall.

- The Malala Oya basin is one of the driest river basins in Sri Lanka. It has an annual rainfall of about 1,100 mm compared to the national average of 1,900 mm. It spreads over 405 sq km. The Mau Ara- Malala Ara diversion project was completed in 2000 by the Irrigation Department. The Project envisages diversion of Mau Ara (which is endowed with better water availability) waters to Malala Oya basin benefiting 30 Tanks and their command areas. The new infrastructure includes a storage reservoir and a trans-basin diversion canal which feeds the village tanks and their command areas.

Most of the earlier water resources development projects comprised of large reservoirs and extensive canal systems. However, a major feature of this project was utilizing the existing infrastructure comprising the village tanks and their irrigation system for major part of storage and distribution of water. Although augmentation of the village tanks is not an entirely a new concept, incorporation of the impacts of such interventions to macro policy is an innovative idea.

Studies carried out by the Water Resources Board under the advice of Ministry of Agriculture, Irrigation and Mahaweli Development show that diversion of water has resulted in sustained groundwater levels during dry periods. In the Malala Oya basin, there is a rainfall peak in November followed by a smaller peak in April. The driest months are June to August. In the wells located above the diversion canal, which do not benefit from the diversion, the groundwater levels draw down after May. However, in the area benefited from the diversion, the water levels remain steady until July.

There are several policy implications of these results that need careful scrutiny and incorporation into the national policies.

Indicators

- Public participation in water resources decisions: moderately satisfactory, but requires improvement
- Comprehensiveness of water related policies: policies are fragmented and not holistic.
- Legislation: fragmented and not holistic.
- Participation by women in water related decision making: Inadequate
- State investment in water related activities = 2.2% of total capital investment. It shows a declining trend.

Chapter 13

Ensuring the Knowledge Base

The knowledge in water resources should be developed, maintained and disseminated in such a way that all societies feel that they are part of these processes and benefit from them. Sri Lanka is a nation having close ties with water, and it had been so for many centuries. Being an island and hence surrounded by water, it has a land area which receives significant quantities of water mainly through two monsoons. Documentation with respect to the knowledge base of the country has indicated that Sri Lanka has a long history of water related infrastructure construction and management, a culture that has strong links with water and a background of sustainable use of water. It has also been observed that Sri Lanka has a significantly strong database on water and water related activities. Conservation of water and its distribution for rice cultivation became the foremost and solemn duty of the Kings of ancient Ceylon. History indicates the existence of a water-knowledge base especially in irrigation, dating back to the pre Christian period of the 6th and 5th centuries B.C. The present knowledge base of the water sector in Sri Lanka is known to have been created over time mainly through tradition and experience. More recently, this has been greatly influenced by foreign domination (Wijesekera 2005).

Traditional knowledge

Sri Lanka has the unique distinction in the history of mankind of having developed a hydraulic civilization based on irrigation even before the beginning of the Christian era. As recorded by R.L. Brohier in the year 1934, the knowledge base in the water sector during that era had been one of the best of this kind. While Brohier (1934) has documented the irrigation works of Sri Lanka, several other authors such as Arumugam (1969) have described the history of the ancient works of water resources development. From these sources it is evident that the ancient Sri Lankans have developed complex and intricate irrigation systems in almost all the river basins in the dry zone of the country.

Deterioration of the ancient civilization along with poor record keeping has apparently caused a decay of this valuable knowledgebase. A number of events such as the invasion from south India, the advent of malaria, climate change, and impoverishment of soil etc., have been identified as probable contributory causes for the decline of the ancient systems. In his book, Engineer S. Arumugam (1969) mentions that Tissa Wewa, the city tank of the ancient capital Anuradhapura, dates back to the period from 250-210 BC, indicating that water knowledgebase at that time was equipped with reservoir and associated structure construction and

water management. In addition, achievements such as the construction of river diversions and canal construction, reflect the wealth of knowledge during the period of ancient monarchies.

The continuity of development in the field of irrigation in ancient Sri Lanka indicates that many ancient sciences and technologies were highly developed. The art of the science of surveying and levelling was the first in these fields of knowledge that would have been used in planning the ancient systems. Knowledge of climatology, and an awareness of the importance of hydrological cycle would have led to scientific conservation programmes to preserve the environment. The science of hydrology and hydraulics would have been used to design the ancient irrigation channels and storage reservoirs. Cross sections of these ancient works reveal the use of impervious clay in the core, and of semi pervious material to provide necessary bulk, exactly as in modern designs. Sand filters, rock-toe filters, wave breakers (known as Rela-Panawa), irrigation tank sluices and spillways had also been constructed. The cascade tank systems in the dry zone have been identified as an extensive man-made water and soil conservation ecosystem, which had functioned over many centuries.

The knowledgebase of the ancient hydraulic civilization of Sri Lanka had grown over the centuries through an evolutionary process by accumulated experience as well as from inputs external to the nation. It has been identified that much of the knowledge of the forefathers had been destroyed or lost along with the collapse of the settlements mainly in Anuradhapura and Polonnaruwa. The knowledge of the water resources nobility, customarily passed through word of mouth, which sometimes restricted certain expertise elements being passed down from teacher to student (commonly referred to as Guru Mushtiya) would have disappeared with the annihilation of these civilizations (Wijesekera, 2005, Dissanayaka, 2000, Senevirathna, 1989).

Developments after the ancient hydraulic civilization

The colonial period of Sri Lanka began in the early sixteenth century with the occupation of Portuguese and the Dutch. The Dutch were in this country for about 150 years from 1656. Water resources development activities during this period had been focused along the coastal belt. The most noticeable features during this era are the Dutch canals which were primarily meant for economical transport, but also said to have aided drainage for agricultural development. The northern flood protection bunds of the Kelani River, the Kirama Oya scheme, the water conservation dam of the Urubokke are some of the works pertaining to this era. However, traditional water resource practices have continued to remain in the remote parts of the country.

During the 150 years of British occupation, attention shifted to the interior where they promoted plantation-agriculture. During later stages the British had been interested in renovating the ancient irrigation works. The irrigation department and the department of agriculture had both been established during the British period. The initial irrigation ordinance, which is said to have been passed in 1887, pertains to this period. These organizations represent the main repositories of knowledge on water resources of Sri Lanka.

The British also set up a Survey General's Department, which has completed a remarkable topographical survey of the entire island. After gaining national independence in the year 1947, efforts were made to develop water resources through major irrigation projects and more recently the Mahaweli Diversion Project. Rehabilitation of irrigation systems has been an ongoing activity to ensure the sustenance of the agricultural systems. In the meantime, hydropower development, flood control, water supply and sanitation, and land reclamation programmes gained political recognition through successive regimes.

Education

Enrolment in schools

Education is considered as either formal education through schools, or any other forms of education where a person undergoes systematic learning. According to the census of Sri Lanka, the average adult literacy rate in 2001 was 90.7%. This rate varies according to the sector (urban, rural and estate), and according to sex.

Table 63 presents a cross section of the society showing literacy according to the sectors and the gender. In all these sectors, males show a slightly higher literacy rate than the females. Only about 2.3% of total population possess qualifications of a university degree or a higher educational qualification. It can also be noted that while 8.7% of the total population had never attended school, 26.3% leaves school at primary level. More than 50% of the students who are in secondary schools do not receive higher education. Only 8% of the total population appears for the university entrance examinations after completing formal education.

Table 63: Literacy Rate by Sector and Sex

Sector and Sex		1990/91* (%)	2001* (%)
All Island	Average	86.6	90.7
	Male	90.1	92.2
	Female	83.1	89.2
Urban	Average	92.3	Not available
	Male	94.0	Not available
	Female	84.3	Not available
Rural	Average	87.1	Not avalable
	Male	89.9	Not available
	Female	84.3	Not available
Estate	Average	66.1	Not available
	Male	79.0	Not available
	Female	52.8	Not available
Note: * Estimates for all provinces other than Northern & Eastern Province			

Source: Department of Census and statistics (2001)

Water sciences in school curriculum

Water education in schools has not been developed in an explicit manner. School curricula are blamed as being overloaded and plagued with an academic focus, which is also exam oriented. Water related contents are scattered across several disciplines, which do not assist in providing a holistic picture of water to schoolchildren. In the Year - 6 syllabus, considerable attention is paid to water related topics in relation to "environmental studies", but unfortunately in Year 7, 8 9 and 10 syllabuses this stress is substantially reduced, and this is the level at which a child commences methodical learning about water. The topics covered include the importance of water availability in the context understanding water as a limited resource, the cultural value of water and water conservation. The entire attention given to water is about 4% of the total workload in the Year-6. The Year-7 students learn about water under the same topics and as a continuation of the work in Year-6. However the total time assigned for this aspect in Year-7 is not more than half of what is in Year-6. For the children in Years 8, 9 and 10 of the education system, the school curriculum does not appear to pay enough attention for water related matters. One finds that the syllabuses of years 8, 9 or 10 contribute not more than 1% of the total course content for water related studies.

High school curriculum in almost all the fields aims at formal higher education, especially the university entrance. The studies concentrate mainly on basic sciences, theory and other themes, which are the prerequisites for universities and other tertiary educational institutions. Although the students in the science stream have some water related topics in subjects such as chemistry, biology, physics, agriculture and home sciences, it is felt that these topics do not sufficiently contribute to enhance the awareness of water as a resource (Wijesekera 2005).

Water in university education

The universities in Sri Lanka do not conduct undergraduate courses dedicated to water resources, or topics directly related to water resources. However, the fields of civil engineering, agricultural science and some other science programs contain water related studies, and this varies with the nature of the degree. A Civil Engineering degree course includes water related subjects such as hydrology, hydraulics, irrigation engineering, sanitary and water supply engineering, coastal engineering, environmental aspects of water etc. Generally all these subjects as a whole in a bachelors degree programme in civil engineering, does not exceed more than 15-20 % of the total course content. This is because most of these topics are taught as optional subjects.

In general, there are only a very few programmes concentrating on water resources at any level of the university education system. Most of the postgraduate programmes allocating at least 30% of the content for water related topics are programmes associated with engineering or agriculture. Almost all the water related programmes conducted by various universities have a component concerning the environmental aspects of water. Water related subjects in the undergraduate or postgraduate level degree programmes in most of the Sri Lankan Universities, and the approximate percentage of water studies in comparison with the total course content, are indicated in a special study (Wijesekera 2005). Details pertaining to the coverage of water related studies at various levels in the life cycle of a person show that the aspect of water as a resource is taught to society only when one has reached a reasonable degree of maturity.

The average number of students graduating from each undergraduate program varies from university to university. Annually the Sri Lankan

Table 64: Identified Postgraduate level programs with contents related to water

Postgraduate (PG) Program	Course contents related to water	% on water in course content
PG/ Environmental Water Recourses Engineering, University of Moratuwa	Water Resources Engineering, Water Resources Development, Environmental aspects	>70%
PG / Environmental & Water Engineering, University of Peradeniya	Water Resources Engineering, Water Resources Development, Environmental aspects	>70%
MSc in Integrated Water Resources Management, University of Peradeniya	Hydrology, Meteorology, Water resources economics, resource and river basin planning, management, Aagriculture, social and environmental management	>70%
PG/ Natural Resources Management, University of Peradeniya	Environmental, Water and other natural resources	30-70%
PG/ Engineering Geology and Hydrology, University of Peradeniya	Hydrology, Hydrogeology, Water resources management. Environmental aspects	>70%
PG/ Environmental Science, University of Peradeniya	Water and other natural resources, Environmental aspects	30-70%
PG/ Oceanography, University of Peradeniya	Oceanography	>70%
PG/ Wildlife Management, University of Peradeniya	Wildlife, Fisheries, Aquaculture, Forestry	<30%
PG/ Atmospheric physics and Dynamic Meteorology, University of Colombo	Meteorology	30-70%
PG/ Environmental Science,University of Colombo	Environmental aspects, Watershed management, Forestry, Water treatment	<30%
PG/ Fisheries and Aquatic Resources University of Sri J'pura	Limnology, Aquaculture, Fisheries	>70%
PG/ Forestry, Environmental Management University of Sri J'pura	Forestry, Environmental management, Watershed management, Water resources management	30-70%
PG/ Biodiversity and Environmental Management, University of Kelaniya	Environmental aspects, Natural recourses management	<30%
PG/ Aquaculture and Fisheries Management, University of Kelaniya	Aquaculture, Fisheries management	<30%
PG/ Social Water Management University of Ruhuna	Irrigation, Hydrology, Watershed management, Environmental aspects, Social sciences in water management	>70%

Source: Wijesekera 2005

Universities produce a substantial group of civil engineers who are exposed to water related studies among other subjects.

In Sri Lanka educational programmes that have a significant emphasis on water resources, are available only at the postgraduate level. Postgraduate programmes which operate on a self-supporting and fee levying basis attract lesser number of personnel, and on average the students per batch amounts to about 10-20. Most of the postgraduate programmes are not conducted on a routine basis, instead they have commenced on demand from industry.

There are water related educational programs conducted by tertiary education institutions. Most of these institutions are either associated with or incorporated to government institutions, and these courses of studies lead up to either diploma or to a specific certificate type (Wijesekera, 2005).

Research institutions

Currently scientific research on water, and directly water related aspects are carried out only by few agencies, as one of their main functions. During the last decade a reasonable number of socio-economic and policy related research studies on irrigated agriculture have been carried out by International Water Management Institute. The Central Environmental Authority, National Aquatic Research and Development Agency and the Industrial Technology Institute etc. carry out water pollution studies. Water Resources Board concentrates on groundwater research. Hector Kobbekaduwa Agriculture Research and Training Institute concentrates mainly on research in agriculture. Even though other organizations are interested in research in their own fields, attention and outcomes are not very significant for the water knowledgebase. The role of universities in research on water related aspects could be very significant.

According to the Report titled "Status and Future Direction of Water Research in Sri Lanka" the following research areas have been identified as most important (Samad et al, 2000). The first five broad areas of topics include policy planning and institutions, irrigation and agriculture, water quality and treatment, environmental and coastal, and economics of water use. Policy, planning and institutional issues have provided the most important topics for water related research in Sri Lanka. One of the main limitations in the research field has been cited as the lack of coordination due to unavailability of a centralized agency to manage water resources and related research activities. This results in a duplication of effort and wastage of resources. Apart from the funding problem, the lack of an apex body to avoid duplication of efforts and give guidance is a serious limitation for strengthening the knowledgebase through scientific research.

The majority of agencies including universities are involved in applied research rather than in basic or fundamental studies. Most organizations that undertake water research seem to address a wide variety of issues but with greater concern on environmental and watershed related topics. Presently water research appears to be primarily a task of civil engineers and agricultural scientists. Most research and experiences from studies and work resulting from internationally funded water-related projects remain unpublished. Consultancy reports, EIAs and master plans can be considered as alternative sources for research findings with other valuable information. Professional societies such as IESL and SLAAS provide a forum for researchers to present and discuss their findings related to water and other knowledge base studies.

In Sri Lanka, educational programs that have a significant emphasis on water resources are available only at the postgraduate level. Most of the postgraduate programmes allocating at least 30% of the content for water related topics are programmes associated with engineering or agriculture (Table 64). The postgraduate programmes, which operate on a self-supporting and fee-levying basis, attract lesser number of personnel and on average the students per batch amounts to about 10-20. Most of the postgraduate programmes are not conducted on a routine basis. Instead they are commenced on demand from the industry (Wijesekera, 2005).

Public access to databases

In Sri Lanka public access to data is very limited. Some water data collecting agencies have data dissemination mechanisms with a pricing structure. The publications of data summaries are not regular and do not provide free public access.

Data and information dissemination mechanisms

Modes and organizations

At present the knowledge or awareness dissemination from the water sector agencies to the public is achieved through several methods. The agencies such as Irrigation Department, Mahaweli Authority of Sri Lanka, Department of Agrarian Development, Irrigation Management Division of Ministry of Agriculture, Irrigation and Mahaweli Development, Provincial Councils and Department of Agriculture, which involved in irrigation and agriculture, disseminate knowledge through community participation and extension programmes.

More than 3000 farmer organizations are registered in these agencies. The Irrigation Management Division coordinates project management committees in selected major irrigation schemes.

Seasonal farmer meetings (Kanna meetings) are one of the main means of disseminating knowledge regarding irrigation water management, issues in agriculture, new developments in the field etc. At such instances, the knowledge dissemination takes place from officials to farmers and vice versa.

Community participation has been practiced and ensured in most of the recent projects for rural development. The farmer contribution for planning, implementation and maintenance is considered as an important element in the optimum utilization of knowledgebase for successful projects. This has been given a prominent place in the recently concluded National Irrigation Rehabilitation Project, North Western Province Water Resources Development Project etc. Water resources development works through village tank rehabilitation funded by United Nations World Food Program is entirely based on the participatory approach for knowledgebase interchange. Almost all minor irrigation works, either under construction or in operation and maintenance, have been executed with the participation of farmer organizations.

Rural water supply schemes carried out by the National Water Supply and Drainage Board and watershed management activities under Mahaweli Authority of Sri Lanka and Upper Watershed Management Project, generally rely very heavily on community participation. Most of these projects are planned with public consultation and in the later stages the beneficiaries are given training or awareness of the project, and this has proven to be a very effective way of knowledge dissemination.

The role of dissemination of knowledge through NGOs mainly via community participation is very strong in programmes on environmental water resources issues. These non-governmental organizations launch awareness and advocacy campaigns on various environmental issues (Environmental Foundation Ltd, Rukrekaganno, Citizens Trust, Green Movement of Sri Lanka, Centre for Environment Justice[1]), and carry out awareness programmes and publications (Sri Lanka Environmental Journalists Forum, NetWwater), and undertake work connected with community participation programmes on development activities (Sarvodaya). A knowledgeable public can play an effective and a significant role in using water as a sustainable resource.

Some state organizations do not directly communicate with the public. Community participation programmes conducted by these agencies are specific to the projects undertaken by them, and these do not take place on a long-term or island wide basis. These agencies communicate and disseminate knowledge to stakeholders and professionals in their own specialized areas by means of project reports, research papers, conferences, seminars, workshops etc. Daily weather reports and reservoir water levels at the hydropower stations are broadcast by the Department of Meteorology and the Ceylon Electricity Board, and transmitted island wide through TV and radio channels.

Gender disaggregated data related to landownership and farmer organization membership are not available with the key line agencies dealing with water management, the Irrigation Department and the Mahaweli Authority. However, in studies of Irrigation Management Transfer, it has been observed that participation of women is generally very low in Farmer Organisations due to fewer number of female landowners, social and administrative constraints and inadequate interest. (Athukorala 2002). Nevertheless gender supportive staff in a water related agency or development project, is seen to have a positive impact on encouraging women's participation in decision-making related to water management, especially in the drinking water sector as is seen in the case of rural water supply projects in Sri Lanka.

Media

For the enhancement of the knowledge and awareness about water resources among the public the media plays a vital role. Generally these media include newspapers, radio and televisions. The role of the media is claimed to ensure transparency and to help combat corruption. Both printed media and electronic media play a substantial role in ensuring public awareness concerning water resources. During the last 10-15 years new forms and channels of electronic media have emerged in the country: New FM radio channels, new television channels owned by both public and private entrepreneurs, and international television channels. These offer public awareness programs such as environmental aspects of water ('Pavithra Ganga, 'Parisara Sirisara', Mihithalaya, Haritha Nimnaya among radio Programs), water-recycling ('Diyawara' Radio Program) issues in agriculture and new technical developments (Kamatha TV Program), as well as

1 The cited NGOs do not make a comprehensive list, but noted as example only

Table 65: Availability of Public Communication Media

Communication Media	Availability
Radios	3.85 million (1997)*
Televisions	1.53million (1997)
Radio broadcast stations	16 Government FM Channels and 15 private FM cannels (2004)
Television broadcast stations	10 TV channels including 1 cable TV channel (2004)
News paper circulation	12 daily news papers and 81 weekly/ monthly news papers (2004)

Source : Wijesekera, 2005
*Note *Total population in Sri Lanka: 19million (approx.)*

corruption or mismanagement in the water sector (Helidarawwa, Warenthuwa and some other TV and Radio programs).

Through the novel approaches of electronic media, based on listeners' participation programmes, they tackle such issues as health, hygiene and rural development, new developments in the water sector, water policy or water rights, tariff for water, issues in implementing development projects and water pollution etc. These stations enhance dialogue within communities and promote the free flow of information and public accountability. Even though these programmes do not fully uplift the public awareness knowledgebase, the role played by them in raising awareness of the value, promoting better water usage practices, and facilitating dialogue between stakeholders is remarkable. Table 65 shows the availability of radios, televisions and circulation of newspapers among the general public. This indicates the strength of the infrastructure available for the execution of programmes to ensure the knowledge base in the water sector.

Internet and telephone

Internet access is a vital tool for improving knowledge about water, providing specific information on water quality, risks of flooding or drought, tariff and other matters. It is critical for researchers and the other professionals who deal with water to update their information in order to address the current issues. In Sri Lanka only about 2% of the population is connected to the Internet. The average number of fixed telephone lines is significantly low compared to the developed world. In the year 2004, there were 11 Internet providers for about 40,000 users. According to statistics published, there were about 500,000 (1998) main telephone lines and 230,000 (1999) mobile telephones Sri Lanka. Present estimates are closer or around one million mobile phones.

Nearly three fourths of the agencies related to water have an official website. Among all these websites, the International Water Management Institute (IWMI) gives a wide range of information on current topics, research findings, and full coverage of their activities worldwide. The web site of the National Science Foundation has a Sri Lanka Scientific and Technical Information Centre which too has a database where a search can be conducted for books, journals, research titles, and newspaper articles etc. This database also provides facilities to search information about the water professionals.

Although the websites of few other agencies such as Mahaweli Authority of Sri Lanka, National Aquatic Resources, Research and Development Agency, Central Environmental Authority and Ceylon Electricity Board provide links to other informative websites, there is a need to improve these and update regularly. The websites maintained by universities provide general information about the university including information on courses, course contents and staff. However, these websites are also not regularly updated, or fully constructed. Most of the official websites of other organizations are neither informative nor regularly updated. The website of the Sri Lanka Environmental Journalists Forum, an NGO on environmental journalism, is reasonably well updated and informative, linking with other NGOs and some other useful environmental websites. The Internet access even for the professional staff of most water agencies is limited due to resource unavailability; lack of interest of the management and cost of using the facility (Wijesekera 2005).

Publications of water sector agencies are generally limited to consultancy or project reports, feasibility studies, operations and maintenance manuals, EIA/IEE etc. Most of these publications are available only in the respective organizations. There are hardly any journals specially devoted to

publication of water research.There are few newsletters, and popular magazines published by some government agencies that contain papers of informative and educational value. The most common local publications for research seem to be in the journals published by Department of Agriculture, Institution of Engineers (IESL), publications of Sri Lanka Association for the Advancement of Science (SLAAS), and in the universities. The Journal of the IESL, "Engineer" and the newsletter "Sri Lanka Engineering News", play a leading role among them in setting a stage for water related research papers. At the Universities, many postgraduate dissertations concerning water resources and related maters remain unpublished, although some papers arising from them are published either in local publications mentioned above or elsewhere.

International Water Management Institute (IWMI) is a CGIAR organization which has contributed significantly to the water related studies mainly in the field of irrigation, both nationally and globally. In terms of publications and dissemination of knowledge, IWMI is presently taking an active role in the field of water resources studies. It has a large number of publications having easy access, and possesses a very good library of water related publications. The university academics are by far the largest group of personnel carrying out publications. From the non-governmental agencies water publications are mostly from the International Water Management Institute. There are a limited number of publications from the industry (Wijesekera 2005).

Indicators

- Availability of databases: moderately satisfactory
- Public access to databases: unsatisfactory to moderately satisfactory
- Water in the national education system: moderately satisfactory

Chapter 14

Conclusions

There is a gap to be bridged .....

Based on the information collected, retrieved, analysed and collated in Chapters 1 to 13 of this study, the achievements, issues and challenges in Sri Lanka's Water Sector can be summarized as follows:

Challenge Area	Achievements	Issues	Challenges/Threats
The resource	Water resources development activities have been significant, especially after 1950	Lack of a comprehensive national plan	Over-exploitation of groundwater and pollution of water bodies
Water and health	Improved health services Significantly high level of access to safe drinking water and sanitation	Occasional outbreaks of diseases such as malaria, dengue and Japanese Encephalitis	The water supply reduces in quality and quantity in the dry periods Access to poor and vulnerable sectors needs to be improved and this could be in conflict with cost recovery policies Investment in health sector was 3.2% of GDP in 1997 and 1.53% in 1990s.which is on the low side (WHO,2002)and therefore the sustainability of the achievements is in question

Challenge Area	Achievements	Issues	Challenges/Threats
Water for ecosystems	Within a small surface area, there is a high degree of bio diversity Protected areas are 14% of the total area Adoption of national policies related to environment and becoming a partner in global conventions	Most of the protected area lies in the dry zone, but the biodiversity is higher in the wet zone	Wet zone is heavily populated and highly industrialized and land values are high. Therefore, the preservation of ecosystems is a major challenge
Water and food	Self sufficiency in rice has increased from about 40-45% in early 1950s to more than 90% at present Per capita calorie availability also shows an increasing trend Considerable improvements with respect to nutrition-related indicators Improved public participation in decision making is achieved through farmer organizations	Inadequate investment in agriculture and water resources development Despite improvements malnourishment remains a matter of much concern	Inadequate investment in agriculture and water resources development Competition for water from other sectors has increased
Water and human settlements	High level of access and increasing trends of access to safe drinking water and sanitation A significantly increasing trend in public participation and private investment in services is evident	A high proportion of the safe drinking water comes from untreated sources, especially groundwater. The quality of such sources depend on climatic variations, and as such, they are vulnerable to risks Urban planning requires improvement On site sanitation threatens the quality of fragile groundwater resources	Expansion of urban centres, peripheral areas getting inadequate attention and facilities compared to the designated urban areas, and increased pollution Most of the major cities are located close to the sea;the rivers contain re-used water and heavy with industrial and agricultural pollutants towards the downstream Groundwater resources are low in quantity and sometimes chemical properties are not desirable; provision of safe drinking water is a challenge
Water and industry	Adoption of environmental assessment regulations has helped to control and manage pollution to some extent	Heavy concentration of industries in the wet zone. Lack of incentives for conservation and development of the resource. Inadequate implementation of regulations are the issues	Industrial pollution is an increasing concern especially in the wet zone

Challenge Area	Achievements	Issues	Challenges/Threats
Water and energy	Electrification of the households has increased from 8% in 1970 to 65%	Frequent droughts make hydropower unreliable Dependence on hydropower as electrical energy dwindled from near100% in 1990 to about 42% in 2000	However, hydropower is an indigenous and renewable form of energy.Dependency on other forms of energy could raise the prices affecting the poor, increase pollution and affect the ecosystems through increased use of fuel wood etc.
Water and risk management	Flood warning system installed in one major river basin Institutional arrangements for risk management evolving	Rainfall intensity increasing irregularly Decrease in rainfall mainly confined to the period during which the dry zone gets rain The pre-warning systems for risk management are generally inadequate	Irrigated agriculture practiced mainly in the dry zone will be the most affected Unless ill effects of climatic variations are addressed through water resources development and better management, there will be adverse impacts on food security, nutrition, poverty and sustainability of the ecosystems
Sharing water	Traditional water sharing methodologies are practiced in rural areas Formal arrangements exist in some large river basins	Lack of national-level water sharing methodologies	Water conflicts and sharing issues are emerging Modernization of society could under-value traditions;Lack of formal arrangements for water sharing could adversely affect access to water by the poor and vulnerable
Valuing water	Traditionally, water was considered a valuable resource	Considering the significant poverty incidence, equitable access to water and cost recovery could be in conflict Multiple uses and multiple benefits of water use make valuation of water using economic criteria difficult	Over-use and wastage could threaten the equitable access

Challenge Area	Achievements	Issues	Challenges/Threats
Governing water	Traditions, ancient knowledgebase, development of sectoral policies and action plans and international activities are major achievements/strengths	Fragmented institutional and legal structure, and lack of consensus on national policy issues are concerns to be addressed	Most of challenges in the previously mentionedchallenge areas are governance-related
Ensuring the knowledge base	The literacy rate is very high compared with the GDP A strong traditional knowledge base is available There is a water education system in universities Community participation in water related activities is increasing	Non-availability of a comprehensive data base and access difficulties to data and information Inadequate opportunities in water education Lack of coordination in research	Inadequate funding for research and inadequate mechanisms for dissemination of information Development of guidelines for public access of data and data publication knowledge base enhancement and strengthening through tiered water education and training

List of References

- Abeygunawardane, M.H. and Imbulana, K.A.U.S. (2005), *Inter/Intra basin water transfers and management in Mahaweli systems,* paper presented in Consultation/Seminar on River Basin Management as a Strategy for Sri Lanka Water Sector, September 2005, Colombo, Sri Lanka (unpublished).
- ADB (Asian Development Bank). (1998). *Information systems analysis, Final report* TA2422Sri. Water Resources Secretariat. Sri Lanka
- Aluwihare, P.B. and Kikuchi, M. (1990), *Irrigation investment trends in Sri Lanka: New construction and beyond*. IWMI, Sri Lanka.
- Amarasinghe, U.A. Mutuwatta, L and Sakthivadivel, R. 1999. *Water scarcity variations within a country: A case study in Sri Lanka*. IWMI. Sri Lanka
- Amarasuriya, N.R. (1995), *Women and technology: the Sri Lankan perspective*, Economic Review, No. 20:12,Sri Lanka
- Ariyabandu. M.M. (2005), *Hazard risk and water resource management*, Proceedings of the Preparatory Workshop on Sri Lanka National Water Development Report, (eds. Wijesekera, N.T.S., Imbulana, K.A.U.S. and Neupane, B), World Water Assessment Programme, Paris, France.
- Arumugam S. (1969), *Water resources of Ceylon -its utilization and development*, Water Resource Board Publication, Colombo.
- ADPC (Asian Disaster Preparedness Centre). (2003), Proceedings of Workshop on *Lessons learned in the recent disaster events and approaches for long term disaster risk management in Sri Lanka,* Thailand, 2003.
- Atapattu, N.K. (2005), *Valuing water*, In Proceedings of the Preparatory Workshop on Sri Lanka National Water Development Report, (eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B.) World Water Assessment Programme. Paris, France
- Athukorala K. (2005), *Water transfers out of Asian agriculture meeting the challenge in the New Millennium*, in International Journal on Paddy and Water Environment
- Athukorala, K. (2002), *Gender gaps-governance gaps-A view of Sri Lankan water management.* In Proceedings of World Water Assessment Programme, Sri Lanka Case Study Ruhuna Basins(eds. Imbulana, K.A.U.S. Droogers, P. and Makin, I.W.), IWMI , Sri Lanka .
- Batagoda, B.M.S., (2005). *Institutional aspects for the protection of ecosystems*. Proceedings of the Preparatory Workshop on Sri Lanka National Water Development Report, (eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B.) World Water Assessment Programme. Paris, France.
- Brohier, R.L.(1934), *Ancient irrigation works in Ceylon.* Ceylon Government Press, Colombo. (re-published by Ministry of Mahaweli Development,1979).
- CBSL (Central Bank of Sri Lanka). (1998), *Economic progress of independent Sri Lanka*, Sri Lanka.
- CBSL (Central Bank of Sri Lanka). (2001), *Annual report 2000*, Sri Lanka
- CBSL (Central Bank of Sri Lanka). (2003), *Economic and social statistics of Sri Lanka*, Sri Lanka.
- CBSL (Central Bank of Sri Lanka). (2004), *Annual report 2003*, Sri Lanka.
- CBSL (Central Bank of Sri Lanka). (2005), *Annual report 2004*, Sri Lanka.
- Central Environmental Authority CEA, *ARCADIS/ EUROCONSULT.* (1999) *Wetland Atlas of Sri Lanka*. Sri Lanka.

List of References

- Chandrajith R, Senarathna, A. and Dissanayake C.B.(2004), *Environmental geochemistry related to human endemic fluorosis in Sri Lanka.* 4th International Workshop on Fluorosis Prevention and defloridation of Water in Sri Lanka, 2-4 March, 2004, College of Community Dentistry, Sri Lanka.
- Chandrapala, L. (1996), *Calculation of Arial precipitation of Sri Lanka on district basis using Voronoi Tessalation (Thiessen Polygon) method*. Proceedings of the National Symposium on Climate Change, Colombo, 7-8 March 1996.
- Cooray, P.G. (1984), *The geology of Sri Lanka.* National Museum, Sri Lanka
- Correspondence with Irrigation Department-(Official communication).
- De Silva K.M. (2003), *A history of Sri Lanka*. Vijitha Yapa Publications, Sri Lanka.
- De Silva, C.S. (2002), *Regulation of shallow groundwater resources in hard rock areas of Sri Lanka.* Symposium on Use of Groundwater for Agriculture in Sri Lanka. AESL/Post Graduate Institute of Agriculture, Sri Lanka
- De Silva, M.P (2005). (personal communication).
- DAS (Department of Agrarian Services). (2000), *Data book for village irrigation schemes of Sri Lanka Island summary,* Water Management Division, Department of Agrarian Services, Sri Lanka.
- DCS (Department of Census and Statistics). (1997), *Changing role of women in Sri Lanka,* Sri Lanka
- DCS (Department of Census and Statistics). (1998), *Statistical abstract 1997*, Sri Lanka.
- DCS (Department of Census and Statistics). (2001), *Social conditions of Sri Lanka*, http://www.statistics.gov.lk/social/socialconditions.pdf, Sri Lanka.
- DCS (Department of Census and Statistics). (2002a). *Demographic and health survey 2000*, Sri Lanka.
- DCS (Department of Census and Statistics). (2003a) *Statistical abstract 2002,* Sri Lanka.
- DCS (Department of Census and Statistics). (2003b), *Agriculture statistics 2003*, Sri Lanka.
- DCS (Department of Census and Statistics). (2004a), *Poverty statistics/ indicators for Sri Lanka*, Sri Lanka
- DCS (Department of Census and Statistics). (2004b), *Food balance sheet 1998-2003,* Sri Lanka
- DCS (Department of Census and Statistics). (2004c). *Statistical abstract 2003*, Sri Lanka.
- DCS (Department of Census and Statistics). (2004d), *Household income and expenditure survey-2002,* Sri Lanka.
- Dharmasena, G.T. and Premasiri, S.M.(1990) *Rainfall intensity studies for Sri Lanka*, Engineer - Journal of the Institution of Engineers , Sri Lanka
- Dharmasena, G.T. and Premasiri, S.M.(1998) *Investigations of trends in hydrological time series with special reference to climatic and land use changes* in Transactions Vol 1, Institute of Engineers, Sri Lanka
- Dias, P.P.G.,(2005). *Hydrometic network*, Proceedings of the Workshop on Sri Lanka National Water Development Report eds. Wijesekera, N.T.S., Imbulana, K.A.U.S. and Neupane, B., World Water Assessment Programme, Paris, France.
- Dissanayaka, J.B. (2000), *Water heritage of Sri Lanka*, The Ministry of Mahaweli Development, Sri Lanka
- Dissanayake, C.B. and Weerasooriya, S.V.R. (1985), *The Hydrogeochemical atlas of Sri Lanka,* Natural Resources Energy and Science Authority of Sri Lanka.
- Emitiyagoda, G.M.S.(2005) Personal communication.
- Fernando, M.P.A.U.S.(2005), *Combating deforestation in Sri Lanka,* Working Paper No. 11, Environment Treaties Reference Centre, Ministry of Environment Natural Resources, Sri Lanka.

- Fernando, T.K. and Chandrapala L. (1992), *Global warming and rainfall variability - The Sri Lankan situation.* Proceedings of 5th International Meeting on Statistical Climatology. Toronto, Canada, 1992.
- Fernando, W.P. (2001), *Malaria risk mapping in Sri Lanka. Implications for its use in control.* Proceedings of a Workshop held in Colombo (ed.) Klinkenberg, E. Working Paper 29. IWMI, Sri Lanka.
- Gaussen,H., Legris,P., Viart, M. and Labroue,L. (1964), *International map of the vegetation, Ceylon 91:1,000,0000*, French Institute of Pondicherry, India.
- George, R.S.C.(2005). *Water and human settlements.* Proceedings of the Preparatory Workshop on Sri Lanka National Water Development Report, (eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B.) World Water Assessment Programme. Paris, France.
- Greller, A.M. and Subramaniam, S. (1990), *Physiognomic, floristic and bioclimatological characterization of the major forest types of Sri Lanka*, Proceedings of the Symposium on Ecology and Landscape Management, Sri Lanka.
- Gunetilleke, N., Cader, A.A. and Fernando, M. (2004), *Understanding the dimensions and dynamics of poverty in underserved settlements in Colombo*. CEPA Working Paper Series no. 3. Centre for Poverty Analysis, Sri Lanka
- Handawala, J. (2002),. *Use of water for protecting eco-systems*, Proceedings -World Water Assessment Programme Sri Lanka Case Study Ruhuna Basins. eds.Imbulana, K.A.U.S. Droogers,P . and Makin, I.W., IWMI, Sri Lanka
- Herath S. and Ratnayake, U.R. (2004), *Monitoring rainfall trends to predict adverse impactsa case study from Sri Lanka. (19641993),* Global Environmental Change, Elsevier, Vol 4
- Imbulana, U.S. and Neupane, B. 2005. *Water, rural poverty and development options in Sri Lanka.* In Proceedings of the XII World Water Congress "Water for Sustainable Development - Towards Innovative Solutions". 22-25 November 2005, New Delhi, India
- Interim National Water Resources Authority - INWRA (2004), *Outline of strategies to achieve water sector goals*, Sri Lanka.
- Irrigation Department - ID (1999), *Hydrological annual 1998/1999*, Sri Lanka
- Irrigation Department - ID (2000), *Water statistics handbook*, Sri Lanka.
- Irrigation Department ID (1988), *Hydrological annual*, Hydrology Division of Irrigation Department, Sri Lanka,
- IUCN (2000), *National red data book of Sri Lanka*, IUCN ,Sri Lanka
- Jacobs Gibb Ltd. (2003), *Dam safety and reservoir conservation program. Activity 13: Catchment land use, peripheral, reservoir and riverine impacts*. Draft Reservoir Management Plan. Mahaweli Authority of Sri Lanka, Sri Lanka
- Japan Bank for International Cooperation Institute (JBICI) and International Water Management Institute (IWMI) (2002) *Impact sssessment of irrigation infrastructure development on poverty alleviation: A case study from Sri Lanka*. Japan Bank for International Cooperation.
- Jayasekara, J.M.L. (2002), *Provision of drinking water to the dry zone of Sri Lanka: A national perspective*. Paper presented at the International Conference on Water for Cities. Perth, Australia.
- Jayatillake, H.M., Chandrapala, L., Basnayake, B.R.S.B. and Dharmaratne, G.H.P. (2005), *Water Resources and climate change* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Kamaladasa, G.B.U. Dep. Director, ID (personal communication-2005).
- Kamaladasa, N. (personal communication-2004).

List of References

- Karunarathna, A.D.M and Pathmarajah, S. (2000): *Groundwater development through introduction of agro wells and micro-irrigation in Sri Lanka*. Proceedings of Symposium on The use of Groundwater for Agriculture in Sri Lanka, Sri Lanka.
- Karunaratne, A.D.M. and S. Pathmarajah (2002), *Groundwater development through introduction of agro-wells and micro-irrigation in Sri Lanka*. Symposium on Use of Groundwater forAgriculture in Sri Lanka. Post Graduate Institute of Agriculture, Peradeniya, Sri Lanka
- Kikuchi, M., Barker R., Weligamage P. and Samad, M (2002). *Irrigation sector in Sri Lanka; Recent investment Trends and development path ahead,* IWMI, Sri Lanka
- Kodituwakku, A.O.(2002) "Livestock Industry in Sri Lanka." Economic Review, no. 28
- Konradsen, F. Amerasinghe, F.P., van der Hoek, W. and Amerasinghe, P.H. , (2000), *Malaria in Sri Lanka: Current knowledge on transmission and control.* IWMI, Sri Lanka.
- Kuruppuarachchi, D.S.P., Fernando, W.A.R.N., (1999), *Impact of agriculture on groundwater quality: leaching of fertilizer to groundwater in Kalpitiya peninsula*. J. Soil Sci. Soc Sri Lanka. Vol.11.
- Madduma Bandara, C.M. (1985) *Catchment ecosystems and village tank cascades in the Dry Zone*. Dordrecht, Holland. Riedel Publishing Company.
- Maldeniya, R. (1997) *Marine fisheries resources current status and potential for development*, Economic Review, no. 23: 06.
- Manchanayake,P. and Madduma Bandara, C.M. (1999), *Water resources of Sri Lanka*, National Science Foundation, Sri Lanka.
- Meegastenne, J. (2005), *Irrigation and water resources of Sri Lanka, R*eport prepared for Sri Lanka National Water Development Report, unpublished.
- Mendis, D.L.O.(2001) *Evolution and development of water and soil conservation ecosystems- from ancient dry zone forest garden to modern Jaffna market garden,* Sri Lanka Pugwash Group Publication, Sri Lanka
- MAL&MIWM (Ministry of Agriculture and Lands and Ministry of Irrigation & Water Management). (2003), *Proposal for granary area programme*, Sri Lanka.
- MALL&I (Ministry of Agriculture, Livestock, Land and Irrigation - (2005) *Progress and programme 2004.* Sri Lanka.
- ME&NR (Ministry of Environment and Natural Resources). (2002), *State of the environment in Sri Lanka*: A National Report Prepared for the South Asian Association for Regional Cooperation, Sri Lanka.
- ME&NR (Ministry of Environment and Natural Resources) (2002), *Sri Lanka's* m*iddle path to sustainable development in the 21st Century*, Sri Lanka.
- ME&NR (Ministry of Environment and Natural Resources) (2004a), *National watershed management policy.* Ministry of Environment and Natural Resources. Sri Lanka.
- ME&NR (Ministry of Environment and Natural Resources) (2004b), *National wet land policy, Sri Lanka*.
- MF&P (Ministry of Finance and Planning). (2005), *Sri Lanka: New development strategy, framework for economic growth and poverty reduction,* Sri Lanka.
- MF&E (Ministry of Forestry and Environment), (1998), *Biodiversity Conservation Action Plan: A Framework for Action,* Ministry of Forestry and Environment, Sri Lanka.
- MF&E (Ministry of Forestry and Environment). (1998a), *National environmental action plan,* Sri Lanka.
- MF&E (Ministry of Forestry and Environment). (2000*), Statistical compendium on natural resources management, Sri Lanka*, Sri Lanka
- Molden, D., Amarasinghe, U. and Hussain I. (2001), *Water for rural development.* Working Paper 32. IWMI, Sri Lanka.

List of References

- Montreal Protocol Unit. (2003), *The use of methyl bromide in the tea plantations,* Environment Treaties Reference Centre, Sri Lanka.
- Mosley P. (1994), *Institutional issues,* Working Paper 1 in Comprehensive Water Resources Management in Sri Lanka. Volume II: Annexes. ADB and USAID.
- Nagarajah, S., Emerson, B.N., Abeykoon, V. and Yogalingam, S. (1988), *Water quality of some wells in Jaffna and Kilinochchi with special reference to nitrate pollution.* Tropical Agriculturist, 144, Sri Lanka.
- NARESA. (1991), *Natural resources of Sri Lanka: Conditions and trends*. 1991.
- NCED (National Council for Economic Development). (2005), *Millennium* d*evelopment goals country report,* Sri Lanka.
- NPD (National Planning Department of Sri Lanka), 1994, *Comprehensive Water Resources Management in Sri Lanka, Draft Strategic Framework and Action Plan, Volume 1: Main Report, TA 1918-Sri*, NPD, Sri Lanka.
- NPPD (2001). National Physical Planning Policy (draft). National Physical Planning Department.
- Nimal Rohana, K. W. (2005), *Bridge report on water and human settlements.* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Padmakumara N.I. (2004), "*Mitigation of natural disasters on Sri Lankan highways*", Thesis, University of Peradeniya, Sri Lanka.
- Panabokke, C.R. (2002), *Review of data on soils and geology in the basin area and their relevance to groundwater in the area: Sri Lanka Case Study, Ruhuna Basins*. Proceedings of the Workshop on World Water Assessment Programme, IWMI, Sri Lanka.
- Panabokke, C.R., Sakthivadivel, R. and Weerasinghe, A.D.. (2002), *Small tanks in Sri Lanka: Evolution*, *present status and issues*. IWMI. Sri Lanka.
- Panabokke, C.R. 2003. Nature and occurrence of regolith aquifer in the hard rock region of Sri Lanka. Symposium on use of groundwater for agriculture in Sri Lanka. AESL/PGIA. Sri Lanka.
- Panabokke, C.R. and Perera, A.P.G.R.I. (2005). *Groundwater resources* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Park K. (1995), *Parks textbook of preventive and social medicine*, 14th edition, Banarsidas Bhanot publishers, India.
- Parker, H. (1909). *Ancient Ceylon*, Reprint by Asian Educational Services, New Delhi, India 1999.
- Pemadasa,M.A. (1984), *Grasslands*, *in ecology and biogeography of Sri Lanka,* (ed C.H.Fernando),Sri Lanka
- Perera, L.H. (1955). *Ceylon under the western rule*. Macmillan & Co. Ltd. India.
- Ratnayake, R. (2005). *Governing Water,* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Ratnayake, U. & Herath G. (2005) *Changes in water cycle: effect on natural disasters and ecosystems,* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Ratnayake, U.R, Edirisinghe E.J.H.J and Padmakumara N.I. (2004), "*GIS database for management of landslides on Sri Lankan highways* ", Geo Informatics Society of Sri Lanka, Vol. 1, Sri Lanka.
- Rev. Walpola Rahula. (1956), *History of Buddhism in Ceylon*. The Buddhist Cultural Centre, Sri Lanka.
- Renwick, M.E. (2001). Valuing water in irrigated agriculture and reservoir fisheries. A multiple use irrigation system in Sri Lanka. Research Report no. 51IWMI. Sri Lanka
- Samad, M., Wijesekera, N.T.S. and Birch, A (ed.s) (2000) *Status and future direction of water research in Sri Lanka*, Proceedings of the National Conference. International Water Management Institute Sri Lanka

List of References

- Senaratne, S. (2002), *Water for basic needs, water supply and water quality - Sri Lanka Case Study Ruhuna Basins*. Proceedings -World Water Assessment Programme (Imbulana, K.A.U.S. Droogers, . and Makin, I.W. eds) . IWMI , Sri Lanka
- Senaratne, S. (2005)- *Water and industry*, Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Seneviratna, A. (2002), *The Springs of Sinhala civilization*. Godage International Publishers (Pvt.) Ltd. Sri Lanka.
- Seneviratne, B.K.C.C. and Handagama, T.D. (2005). *Water and energy,* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Shanmugarajah, C.K. (2005). *Water, health and sanitation* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Shanmugarajah, C.K. *Health, water and sanitation*. Proceedings - *Sri Lanka Case Study Ruhuna Basins*. World Water Assessment Programme (Imbulana, K.A.U.S. Droogers, Peter. Makin, I.W. eds.).
- Sirimanne, C.H.L. (1952), *Geology for water supply*. Presidential address. Section D. Ceylon Association for the Advancement of Science: 87-11.
- SLNCOLD Database- 2005-chapter- Water resources of Sri Lanka-under "Surface water, main tributaries, lakes, reservoirs.
- Somaweera, N. (2002), *Urbanization issues in Sri Lanka*. A paper presented at the International Conference on Water for Cities. Perth, Australia
- Somaweera, W A N (personal communication, 2005).
- Steele, P., Konradsen, F. and Imbulana, K.A.U.S. (1997), *Irrigation, health, and environment*, A Literature Review with Examples from Sri Lanka. Discussion Paper no. 42. IWMI. Sri Lanka
- *Strategy for the preparation of a biodiversity action plan for Sri Lanka*, Ministry of Transport, Environment and Women's Affairs, Sri Lanka.
- Sugathadasa, S. (1995), *Women's participation in the sustainable development*. Economic Review, no. 20:12(March 1995), 11- 13.
- Survey Department (1988). National Atlas of Sri Lanka. Survey Department
- UNDP (United Nations Development Programme). 2004. Draft report on Millennium Development Goals of Sri Lanka. UNDP. Colombo.
- UNEP (United Nations Environment Programme) (2005), *Sri Lanka: State of the Environment 2001*. UNEP. www. rrcap.unep.org/reports/soe
- UNEP (United Nations Environment Programme), (2005a), http://www.unep.org/tsunami reports/TSUNAMI_SRILANKA_LAYOUT.pdf
- UNFCCC. (1992), *United Nations Framework Convention on Climate Change*. United Nations Environment Programme and World Meteorological Organization .
- Van der Molen, I. (2001), *An assessment of female participation in minor irrigation systems of Sri Lanka*. Working Paper 8. IWMI. Sri Lanka
- Vidyaratne, S. and Tilakaratne, K.G. (2003), *Sectoral and provincial poverty lines for Sri Lanka*. Department of Census and Statistics. Sri Lanka.

- WRS (Water Resources Secretariat). (2000) *Draft proposals for national water resources policy* Water Resources Council and Secretariat, Government of Sri Lanka.
- Weeramantry, C.G. (2003), *Environmental aspects of Sri Lanka's ancient irrigation system,* Sri Lanka.
- Weerasena, S.L., Mahrouf, A.R.M., Senanayake, N. and Emitiyagoda, G.A.M.S. (2005). *Water for food security.* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Weerasinge, K.D.N., de Silva, M.P., Wickremasinghe, U. and Karunaratne, R.N. (2005) *Water and ecosystems in Sri Lanka and human impacts* , Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Wickramage, M. (2002), *Meeting basic needs: Domestic water supply - Sri Lanka Case Study Ruhuna Basins*. Proceedings -World Water Assessment Programme (Imbulana, K.A.U.S. Droogers, . and Makin, I.W. eds.). IWMI, Sri Lanka.
- Wijesekera, N.T.S. (2005) *Ensuring the knowledge base of water sector.* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- Wijesekera, N.T.S., Malone, D.C., Ranwala, D.A.J. and Mendis, B.P.N. (1998). *Recommendations for water data planning and coordination in Sri Lanka,* Proceedings of the National Conference on Status and Future Directions of Water Research in Sri Lanka, ISBN 92-9090-396-1, November.
- Wijesinghe, M.W.P. (1973), *Groundwater hydrology*. CAAS Symposium, Colombo.
- Wijesuriya, L.T. (2005). *Surface water resources,* Proceedings Workshop on Sri Lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S, and Neupane, B., World Water Assessment Programme. Paris, France.
- World Bank (2003), *Sri Lanka: Promoting agricultural and rural non-farm sector growth*. Vol. I&II. Rural Development Unit. South Asia Region, The World Bank
- World Health Organization (2002), *Macroeconomics and health initiatives - Sri Lanka*, Colombo. Sri Lanka.
- Zwartween, M.Z. (1994), *Gender issues, water issues*, *a gender perspective to irrigation management,* Working paper no. 32, International Water Management Institute

Annexes

Annex 1. Details of major river basins of Sri Lanka

No.	Name of the River	Catchment Area (sq. km)	Average Annual Rainfall (mm)	Discharge Volume to Sea (MCM)
1	Kelani Ganga	2,278	3,797	3,417
2	Bolgoda Ganga	374	2,952	409
3	Kalu Ganga	2,688	4,035	4,032
4	Bentara Ganga	622	3,598	358
5	Madu Ganga	59	3,143	30
6	Madampe Lake	90	3,115	45
7	Telwatta Ganga	51	2,786	23
8	Ratgama Lake	10	2,750	4
9	Gin Ganga	922	3,290	1,268
10	Koggala Lake	64	2,750	28
11	Polwatta Ganga	233	1,554	58
12	Nilwala Ganga	960	2,894	1,152
13	Nilwala Ganga	38	1,750	20
14	Seenimodara Oya	223	1,609	108
15	Rekawa Oya	76	1,250	29
16	Urubokka Oya	348	1,493	86
17	Kachcigala	220	1,250	83
18	Walawe Ganga	2,442	2,025	350
19	Karagan Oya	58	1,250	4
20	Malala Oya	399	1,250	25
21	Embilikala Oya	59	1,250	4
22	Kirindi Oya	1,165	1,455	74
23	Bambawe Aru	79	975	23
24	Mahasiliwa Oya	13	950	4
25	Butawa Oya	38	950	11
26	Menik Ganga	1,272	1,576	347
27	Katupila Aru	86	1,083	28
28	Kuranda Aru	131	1,100	43
29	Nabadagas Aru	108	1205	39
30	Karambe Aru	46	1120	19
31	Kumbukkan Oya	1218	1342	472
32	Begura Oya	92	1350	37
33	Girikula Oya	15	1750	8
34	Helwa Aru	51	1750	27
35	Wila Oya	484	1750	254
36	Heda Oya	604	1912	394
37	Karanda Oya	422	2000	253
38	Semana Aru	51	1750	27
39	Tandiadi Aru	22	1750	12
40	Kanchikudichi Aru	56	1750	29
41	Rufus Kulam	35	1750	18
42	Pannel Oya	184	1750	97
43	Ambalan Oya	115	1900	66
44	Gal Oya	1792	2190	237
45	Andella Oya	522	1775	278
46	Thumpan Keny	9	1500	4
47	Namakada Aru	12	1500	5
48	Mandipattu Aru	100	1500	45
49	Panthanthoppu Aru	100	1500	45
50	Vett Aru	26	1500	12
51	Mahila Wettuwan	346	1880	195

52	Mundeni Aru	1,280	1,973	757
53	Miyangolla Ela	225	1,500	101
54	Maduru Oya	1,541	1,908	226
55	Pulliyanpota Aru	52	1,500	23
56	Kirimechchi Odai	77	1,500	35
57	Bodigola Aru	164	1,500	74
58	Mandan Aru	13	1,500	6
59	Makarachchi Aru	37	1,500	17
60	Mahaweli Ganga	10,327	2,313	4,009
61	Kantalai Aru	445	1,500	15
62	Palampotta Aru	69	1,500	2
63	Panna Oya	143	1,500	5
64	Pankulam Aru	382	1,500	13
65	Kunchikumban Aru	205	1,500	7
66	Palakutti Aru	20	1,500	1
67	Yan Oya	1,520	1,500	132
68	Mee Oya	90	1,500	41
69	Ma Oya	1,024	1,500	461
70	Churiyan Aru	74	1,500	33
71	Chavar Aru	31	1,500	14
72	Palladi Aru	61	1,500	27
73	Manal Aru	187	1,500	84
74	Kadalikallu Aru	74	1,500	33
75	Per Aru	374	1,500	168
76	Pali Aru	84	1,500	38
77	Maruthapillay Aru	41	1,500	18
78	Theravil Aru	90	1,500	41
79	Piramanthal Aru	82	1,250	31
80	Methalli Aru	120	1,250	45
81	Kanakarayan Aru	896	1,250	323
82	Kalawalappu Aru	56	1,250	21
83	Akkarayan Aru	192	1,250	72
84	Mandakal Aru	297	1,250	111
85	Pallavarayan Kadu Aru	159	1,250	60
86	Pali Aru	451	1,250	169
87	Chappai Aru	66	1,250	25
88	Parangi Aru	832	1,250	312
89	Nay Aru	560	1,250	210
90	Malwatu Oya	3,246	1,226	192
91	Kal Aru	210	1,050	66
92	Moderagama Aru	932	1,175	329
93	Kala Oya	2,772	1,367	386
94	Moongili Aru	44	1,000	13
95	Mee Oya	1,510	1,250	40
96	Madurankuli Aru	62	1,250	23
97	Kalagamune Oya	151	1,250	57
98	Rathmbala Oya	215	1,250	81
99	Deduru Oya	2,616	1,735	1,608
100	Karambala Oya	589	1,750	165
101	Ratmal Oya	215	1,750	60
102	Maha Oya	1,510	2,703	1,746
103	Attanagalla Oya	727	2,564	774

Source: Wijesuriya, 2005; ID, 2000

Annex 2. District-wise percentile rainfall values

Districtwise Percentile Rainfalls based on 1961-1990 rainfall												
	Yala				Maha				Annual			
	25th Percentile	Average	Median	75th Percentile	25th Percentile	Average	Median	75th Percentile	25th Percentile	Average	Median	75th Percentile
Ampara	420	353	370	271	1353	1148	1069	929	1843	1604	1561	1348
Kalutara	2297	2146	2175	1976	1509	1378	1423	1256	3977	3741	3725	3517
Galle	1975	1844	1863	1668	1405	1291	1301	1161	3589	3341	3332	3077
Matara	1509	1394	1395	1257	1275	1134	1189	964	2922	2700	2697	2381
Hambantotala	441	415	400	366	773	693	691	539	1327	1197	1140	1023
Colombo	1884	1662	1709	1443	1267	1138	1188	991	3273	2981	2961	2627
Batticaloa	415	346	368	278	1398	1182	1115	929	1833	1624	1551	1376
Trincomalee	459	408	415	314	1245	1053	1005	783	1709	1525	1524	1229
Mullaitivu	389	326	303	263	1094	943	916	779	1528	1313	1291	1124
Jaffna	263	207	211	148	1060	869	901	638	1331	1102	1149	849
Kilinochchi	262	227	224	180	1105	920	878	718	1436	1179	1160	928
Mannar	312	249	242	198	917	735	695	563	1178	1034	1009	864
Puttalam	526	436	432	352	797	674	688	550	1289	1185	1155	1060
Gampaha	1472	1303	1341	1126	1086	948	971	852	2662	2399	2387	2095
Kegalle	2311	2089	2153	1791	1427	1235	1274	1075	3781	3521	3613	3199
Ratnapura	1831	1631	1666	1398	1359	1210	1227	1153	3243	3062	3064	2865
Moneragala	520	473	488	403	1164	1022	985	876	1723	1610	1567	1493
Badulla	701	612	591	543	1453	1290	1266	1106	2320	2040	2043	1857
Polonnaruwa	518	412	386	307	1332	1142	1112	912	1881	1651	1646	1410
Vavuniya	485	394	415	297	1067	892	911	661	1572	1342	1305	1163
Anuradhapura	463	382	374	322	944	839	853	671	1478	1290	1263	1127
Kurunegala	780	670	667	549	940	835	871	715	1806	1601	1584	1387
Matale	596	525	529	425	1493	1249	1181	999	2140	1884	1830	1665
Kandy	1193	1083	1094	937	1398	1252	1269	1050	2708	2458	2480	2230
Nuwara Eliya	1796	1526	1511	1337	1232	1117	1105	988	3036	2775	2787	2585

Source: Jayatillake et al,2005

Annex 3. List of large dams

	Name	Completion	River or Basin	District or City	Province	Dam Type	Height above Lowest Foundation (m)	Crest Length (m)
1	Akkrayan	1962	Akkrayan Aru	Jaffna	NP	TE	22	884
2	Alahena	1959	Ekgal Aru	Ampara	EP	TE	11	1320
3	Ambalan Oya	1961	Ambaln Oya	Ampara	EP	TE	11	3048
4	Basawak kulama	1874	Kala Oya	Anuradhapura	NCP	TE	10	1189
5	Bommurella	1979	Bomurella Oya	Nuwara Eliya	CP	PG/TE	19	183
6	Bowatenna	1976	Amban Ganga	Dambulla	CP	PG	23	313
7	Canyon	1974	Maskeli Oya	Maskeliya	CP	PG	28	181
8	Castlereagh	1958	Keheigamu Oya	Nuwara Eliya	CP	TE	47	203
9	Chandrika Wewa	1967	Hulanda Oya	Balangoda	SABP	TE	19	2500
10	Dambulu Oya	1978	Kala Oya	Matale	CP	TE	12	1680
11	Denagama	1876	Mah Ela	Matara	SP	TE	11	625
12	Dewahuwa	1950	Kuda kalugal Oya	Dambulla	CP	TE	12	1311
13	Ekgal Aru	1957	Ekgal Aru	Ampara	EP	TE	12	1128
14	Ellawela	1876	Nilwala	Matara	SP	TE	12	111
15	Galamitiyawa Oya	1970	Gaamitiyaawa Aru	Trincomalee	EP	TE	12	564
16	Girithle *	1905	Nehinna Ela	Polonnaruwa	NCP	TE	23	488
17	Hakwatuna	1962	Hakwatuna Oya	Kurunegla	NWP	TE	22	884
18	Hali Ela	1876	Kirama Ara	Matara	SP	TE	12	149
19	Huruluwewa	1953	Yan Oya	Anuradhapura	NCP	TE	25	2377
20	Inginimitiya	1984	Mee Oya	Kurunegla	NWP	TE	24	4115
21	Inginiyagala /Senanayaka Samudra	1956	Gal Oya	Ampara	EP	TE	44	1043
22	Iranamadu	1922	Kanagarayan Aru	Jaffna	NP	TE	21	3018
23	Kadulla	1960	Gal & Aluth	Polonnaruwa	NCP	TE	15	9236
24	Kalatuwawa	1954	Kalatuwa Ela	Awissawella	WP	TE	20	287
25	Kalawewa	1887	Dambulla Oya	Anuradhapura	NCP	TE	12	9657
26	Kanatale	1869	Peraru	Tirincomalee	EP	TE	20	2524
27	Kandalama	1956	Miris Goni Oya	Dambulla	CP	TE	20	975
28	Kekanadua	1871	Kirama Ara	Matara	SP	TE	18	130
29	KimbulWana	1958	Kimbulwana Oya	Kurunegala	NWP	TE	14	732
30	Kirindi Oya /Lunugamvehera	1984	Kirindi Oya	Tissamaharama	SP	TE	25	5030
31	Kotmale	1985	Kotmale Oya	Gampola	CP	ER	87	600
32	Kukele H.P	1999	Kalu Ganga	Kaluthara	WP	PG	16	110
33	Labugama	1886	Wak Oya	Awissawella	WP	TE	21	111
34	Laxapana	1950	Maskeliya Oya	Nuwaraeliya	CP	PG	29.6	137.2
35	Maduru Oya	1983	Maduru Oya	Polonnaruwa	NCP	ER	43	1008
36	Mahadiul Wewa	1979	Neli Oya	Trincomalee	EP	TE	14	2109

37	Mahakanadarawa	1961	Kanadara Oya	Anuradhapura	NCP	TE	17	3219
38	Mahawilachihchiya	1958	Talawe Oya	Anuradhapura	NCP	TE	12	3103
39	Malayadi	1961	Ekgal Aru	Ampara	EP	TE	12	1823
40	Mapakada	1956	Dambarawa	Mahiyangana	UP	TE	14	579
41	Mauara	1996	Mauara	Hambantota	SP	ER	25	
42	Minneriya	1903	Kiri Oya	Polonnaruwa	NCP	TE	21	1890
43	Morawewa	1960	Pankulam Aru	Tirincomalee	EP	TE	20	549
44	Mousakelle	1969	Maskeli Oya	Maskeliya	CP	PG	41	188
45	Muruthawela	1975	Urubokke	Tangalle	SP	TE	32	1463
46	Muthu Iyan Kaddu	1965	Per Aru	Vavuniya	NP	TE	20	1829
47	Muthukandiya	1979	Meeyal Oya	Monaragala	UP	TE	22	1113
48	Nachchaduwa	1917	Malwathu Oya	Anuradhapura	NCP	TE	17	1646
49	Nagadeepa	1964	Hepola Oya	Mahiyangana	UP	TE	23	1219
50	Nalanda	1957	Nalanda	Matale	CP	PG	31	123
51	Namal Oya	1965	Namal Oya	Ampara	EP	TE	21	2042
52	Navakiri	1954	Navakiri Aru	Ampara	EP	TE	11	3310
53	Norton	1950	Kenelgamu Oya	Nuwara Oya	CP	PG	29	103
54	Nuwara Wewa	1888	Malwathu Oya	Anuradhapura	NCP	TE	11	6774
55	Padaviya	1957	Mara Oya	Medawachichiya	NCP	TE	18	4407
56	Pallang Oya	1960	Pallang Oya	Ampara	EP	TE	21	793
57	Palukadawala	1958	Mee Oya	Kurunegala	NWP	TE	13	1158
58	Parakrama Samudra	1952	Ambaln Ganga	Polonnaruwa	NCP	TE	15	13582
59	Paravipanchachan	1963	Paravipanchcahan Aru	Trincomalee	EP	TE	23	434
60	Pavatakulam	1957	Kal Aru	Vauniya	NP	TE	14	3139
61	Pimburettewa	1976	Kuda Oya	Polonnaruwa	NCP	TE	18	1951
62	Polgolla	1977	Mahaweli	Kandy	CP	PG	15	143
63	Polpitiya	1969	Maskeli Oya	Hattan	CP	PG	30	137
64	Rajangana	1962	Kala Oya	Anuradhapura	NCP	TE	22	4043
65	Randenigala	1986	Mahaweli	Mahiyangana	UP	ER	94	495
66	Rantembe	1990	Mahaweli	KAndy	CP	PG	41.5	420
67	Ratkinda	1982	Ratkinda Oya	Mahiyangana	UP	TE	24	1200
68	Rugam	1870	Thevali Odei Aru	Batticaloa	EP	TE	11	2272
69	Samanala Wewa	1992	Walawe Ganga	Badulla		ER	100	160
70	Sorabora Wewa	1870	Diyabeduma	Mahiyangana	UP			
71	Tabbowa	1925	Naneri Oya	Puttalam	NWP	TE	11	1811
72	Tissa Wewa	1904	Kala Oya	Anuradhapura	NCP	TE	11	3480
73	Udawalawa	1973	Walawe Ganga	Hambantota	SABP	TE	39	4023
74	Ulhitiya	1982	Ulhitiya Oya	Mahiyangana	UP	TE	28	4760
75	Unchchai	1919	Magalavattuvan	Batticaloa	EP	TE	15	1676
76	Vakaneri	1908	MaduruOya	Batticaloa	EP	TE	13	2073
77	Vaunikulam	1959	Pali Aru	Vauniya	NP	TE	14	3310
78	Vendrasan	1959	Kantalai	Trincmalee	EP	TE	13	1143
79	Victoriya	1984	Mahaweli	Teldeniya	CP	VA	122	520
80	Wahalkada	1976	Mara Oya	Medawachich	NCP	TE	19	5134

Source: Kamaladasa, G.B.U, pers. comm. and SLNCOLD Database
Note: TE= Earth fill, PG= Concrete gravity, VA= Concrete arch, ER= Rock fill

Annex 4. Proposed quality requirements for bottled water

Quality Characteristic	Proposed Requirement	
	Natural Mineral Water	**Drinking Water**
Colour (Max.)	5 Hazen Units	15 Hazen Units
Odour	Unobjectionable	Unobjectionable
Taste	Unobjectionable	Unobjectionable
Turbidity NTU (max)	5	5
pH	No standards	6.5 to 8.5
Total Dissolved solids mg/l (max)	1500	1000
Alkalinity as $CaCO_3$ mg/l (max)	No standards	200
Free Ammonia mg/l (max)	No standards	0.06
Total hardness as $CaCO_3$ mg/l (max)	No standards	250
Sulphates as SO_4 mg/l (max)	No standards	250
Total iron as Fe mg/l (max)	No standards	0.3
Arsenic as As mg/l (max)	0.01	0.01
Cadmium as Cd mg/l (max)	0.003	0.003
Cyanide as CN mg/l (max)	0.07	0.05
Chromium as Cr mg/l (max)	0.05	0.05
Mercury as Hg mg/l (max)	0.001	0.001
Nickel as Ni mg/l (max)	0.02	0.02
Zinc as Zn mg/l (max)	No standards	3.0
Aluminium as Al mg/l (max)	0.2	0.2
Selenium as Se mg/l (max)	0.01	0.01
Lead as Pb mg/l (max)	0.01	0.01
Copper as Cu mg/l (max)	1.0	1.0
Antimony as Sb mg/l (max)	0.005	No standards
Barium as Ba mg/l (max)	0.7	No standards
Manganese as Mn mg/l (max)	0.5	0.5
Chloride as Cl mg/l (max)	250	250
Free residual chlorine as Cl_2 mg/l (max)	-	0.2
Fluoride as F mg/l (max)	1.5	1.5
Nitrate as NO_3 mg/l (max)	50	50
Nitrites as NO_2 mg/l (max)	3.0	3.0
Sulfide as H_2S mg/l (max)	0.05	No standards
Chemical oxygen demand (COD) mg/l (max)	No standards	10.0
Phenolic compounds as Phenolic OH and mineral oil mg/l (max)	Absent	Absent
Grease and oil mg/l (max)	Absent	Absent
E. coli and Coliforms	Absent	Absent
Pathogenic organisms	Absent	Absent

Source: Shanmugarajah, 2005

Annex 5. List of threatened wetland sites

Name & Components	Values
1) Delft island- several shallow lagoons and a few fresh water ponds	Important for birds such as flamingos, ducks and shorebirds
2) Wetlands of Jaffna-shallow sea bays, intertidal mud flats, mangrove swamps, saline marshes, large shallow lagoon	Important for migrating ducks and shorebirds.
3) Uppu Aru Lagoon(3000ha)-Brackish lagoon with fringing mangroves, extensive mud flats, salt marshes	Important for flamingos, ducks and shorebirds.
4) Thondamannar lagoon (7787ha)-shallow brackish to saline lagoon and tidal, extensive mangrove swamps, sea grass beds, mud flats	Important for flamingos, shorebirds, Gulls and terns.
5) Chundikkulam (13500)-brackish with sea grass beds and fringing mangroves	Important for variety of water fowl, migratory ducks, shore birds, gulls and terns.
6) Chalai (1460ha) -long narrow brackish coastal lagoon, mangrove swamps, sea grass beds	Salt production, fishing, waterfowl.
7) Puttalam lagoon (36426)-brackish to saline coastal lagoon, broad connection to open sea, fringed by mangrove swamps, sea grass beds	finfish, prawns and mussels, Important breeding center for prawns and commercial fish, mangrove swamps and sea grass beds, pelicans, herons, egrets, ducks, shore birds, terns.
8) Wetland in Wilpattu National Park (131692ha)-small permanent and seasonal lakes, ponds and villus, tanks, 5 main river systems	Important for variety of resident and migratory birds, painted storks, spot-billed pelicans, mammals.
9) Nachchaduwa Tank (1784ha)-large irrigation tank	Fishing and water supply
10) Giant's tank (1840ha)-ancient water reservoir and canal	Fishing and large water birds, ducks and shorebirds.
11)Vankalai Kalapuwa, Periya Kalapuwa and Mannar causeway (200,650,7500ha)-complex of tidal lagoons, brackish to saline, mangrove swamps, salt marshes, intertidal mudflats	Important for large water birds, ducks, shorebirds, gulls and terns.

12) Iranaitivu Island (550 ha)- two small offshore islands, fringing coral reefs	Important for migratory ducks, shorebirds, gulls and terns.
13) Nayaru lagoon (1760ha)-estuarine lagoon, mangrove swamps, sea grass beds	Prawn fishery, important wintering area for migratory ducks, shorebirds, gulls and terns.
14) Kokkilai lagoon(2995ha)-estuarine lagoon, sea grass beds, mangrove swamps, mudflats	Prawn fishery, important for waterfowl.
15) Periakarachchi lagoon and Sinnakarachi Lagoon. (650,780ha)	Subsistence fisheries, Important for migratory ducks, shorebirds
16) Ullackallie lagoon (1,300ha)-brackish coastal lagoon, extensive mangroves, seasonal channel	Fisheries and important for water birds, migratory ducks and shorebirds.
17) Mahaweli Ganga Flood Plain (50,000 ha)-river channels, riverine marshes, seasonally flooded grasslands, freshwater swamp forests	Flood plain is of considerable value for fisheries and flood control. The villu mashes are important for livestock for diary production. Very important for water birds, large mammals, habitat of rare herb *Pentapetes phoenicea.*
18) Minneriya tank (2550ha)-ancient tank,Elahera canal	Important for water birds, fish production
19) Upaar (Panichchankeni) Lagoon and Uppu Alan (2590ha)-estuarine lagoon, extensive mangrove swamps	Important for water birds, migratory shore birds
20) Vandeloos Bay, Elephant point and Thenadi Bay-muddy islands, fringing mangrove swamps, brackish marshes, mudflats, salt marshes, coral reefs	Important for prawn fishery, migratory and shore birds, feeding area for terns.
21) Bellanwila – Attidiya Marshes (60ha);freshwater ponds, seasonally flooded grassland with trees and shrubs	Potential for conservation education and scientific research, water birds, migratory shore birds, endemic fish (4),butterflies(9),dragonflies
22) Muthurajawela Swamp (2,429ha)-brackish and freshwater marshes, mangrove swamps, navigation canal	Important for conservation and education, high attributes like biodiversity scientific value and uniqueness and its function as water regulator for both flood and quality, recreation ,fish production
23) Negombo lagoon (3,502ha)-estuarine lagoon with freshwater inputs, high tidal fluctuations	Fishery, high bio-diversity of species, important for wide variety of resident and migratory waterfowl
24) Mundel Lake (3,361ha)-brackish coastal lagoon ,fringing mangrove swamps, brackish marshes, extensive mudflats	Vegetation of botanical interest, important for water birds-herons, egrets, shorebirds, terns.

25) Batticaloa lagoon (14,118ha)-deep estuarine lagoon, channels, tidal sand bars, entire lagoon fringed with mangroves, extensive seagrass beds	Major prawn fishery, important for large wading birds and migratory shorebirds.
26) Maduru Oya National Park (10,000ha)-Oyas and reservoirs, river tributaries	Historical value and archeological sites, habitat for *Vatica obscura*-the only dry zone Dipterocarpus.
27) Senanayaka Samudra (7,700)	Fishery, irrigation, important for water birds and mammals including elephant.
28) Arugam Kalapuwa (248ha)-brackish lagoon, fringing mangroves, extensive marsh	Important for large water birds, migratory ducks, shorebirds, gulls and terns
29) Lahugala and Kitulana tanks (400ha)	Historic site of Magulmahavihara, important for large water birds
30) Wetland in Yala East National Park (626ha)	Important for botanical interest & wide variety of water fowl
31) Wetlands in Ruhuna (Yala) National Park (126781ha)	Important for great diversity of water fowl and rich mammalian fauna
32) Bundala Lewaya, Embilikala Kalapuwa, Malala Lewaya and Koholankala Lewaya (1990ha)	Important wet lands for birds, Most important wintering areas for migratory shore birds
33) Maha Lewaya and Karagan Lewaya (1160ha)	Important for water fowl
34) Lunama Kalapuwa and Kalametiya Kalapuwa (212&200ha)	Fish production, Important for water fowls

(Source: CEA/ARCADIS/ EUROCONSULT, 1999 and Weerasinghe et al, 2005)

Annex 6. Existing Standards for Industrial Effluents and Environmental Management

No	Aspect of the Standard	Description of Contents	Source	Name of the Standards and Year	Mechanism of application	Regulating Authority
1	Industrial Effluents discharged into inland surface waters	Prescribes tolerance limits and methods of sampling and test for industrial effluents discharged into inland surface waters	Sri Lanka Standards Institution	SLS 652:1984 Tolerance limits for industrial effluents discharged into inland surface waters	Through adoption by the relevant parties	Any complaints to CEA
2	Industrial and domestic effluents discharged into marine coastal areas	Prescribes tolerance limits and methods of sampling and test for industrial and domestic effluents discharged into marine coastal areas	Sri Lanka Standards Institution	SLS 721:1985 Tolerance limits for industrial and domestic effluents discharged into marine coastal areas	Through adoption by the relevant parties	Any complaints to CEA
3	Industrial effluents discharged on land for irrigation	Prescribes tolerance limits and methods of sampling and testing for industrial effluents discharged on land for irrigation purposes.	Sri Lanka Standards Institution	SLS 776: 2001 Tolerance limits for industrial effluents discharged on land for irrigation purposes	Through adoption by the relevant parties	Any complaints to CEA
4	Effluents from rubber industry	Prescribes tolerance limits and methods of sampling and testing for effluents from rubber processing factories after treatment before dilution at the point of discharge into inland surface waters.	Sri Lanka Standards Institution	SLS 819:1988 Tolerance limits for effluents from raw rubber industry.	Through adoption by the relevant parties	Any complaints to CEA
5	Effluents from tanning industry	Prescribes tolerance limits and methods of sampling and testing for effluents from tanning industry after treatment before dilution at the point of discharge into inland surface waters and marine coastal waters.	Sri Lanka Standards Institution	SLS 820:1988 Tolerance limits for effluents from tanning industry.	Through adoption by the relevant parties	Any complaints to CEA

6	Effluents from textile industry	Prescribes tolerance limits and methods of sampling and testing for effluents from textile factories after treatment before dilution at the point of discharge into inland surface waters.	Sri Lanka Standards Institution	SLS 822:1988 Tolerance limits for effluents from textile industry.	Through adoption by the relevant parties	Any complaints to CEA
7	Effluents from palm oil industry	Prescribes tolerance limits and methods of sampling and testing for effluents from palm oil extraction after treatment before dilution at the point of discharge into inland surface waters, marine coastal waters and on land for irrigation purposes.	Sri Lanka Standards Institution	SLS 1194:1999 Tolerance limits for effluents from palm oil industry.	Through adoption by the relevant parties	Any complaints to CEA
8	Effluents from coconut industry	Prescribes tolerance limits and methods of sampling and testing for effluents from coconut kernel based industry after treatment before dilution at the point of discharge into inland surface waters, marine coastal waters and on land for irrigation purposes.	Sri Lanka Standards Institution	SLS 1194:1999 Tolerance limits for effluents from palm oil industry.	Through adoption by the relevant parties	Any complaints to CEA
9	Environmental management systems : Specification with guidance for use	Specifies requirements for an environmental management system, to enable an organization to formulate a policy and objective taking into account legislative requirements and information about significant environmental impacts.	Sri Lanka Standards Institution	SLS ISO 14001:Environ mental management systems : Specification with guidance for use	Through adoption by the relevant parties	

10	Environmental management systems : General guidelines on principles, systems and supporting techniques	Provides guidance on development and maintenance of EMS and principles and their coordination with other management systems	Sri Lanka Standards Institution	SLS ISO 14004:Environmental management systems : General guidelines on principles, systems and supporting techniques	Through adoption by the relevant parties	
11	Environmental management systems : Guidelines for environmental auditing - general principles	Provides general principles of environmental auditing that are applicable to all types of environmental audits.	Sri Lanka Standards Institution	SLS ISO 14010:Environmental management systems : Guidelines for environmental auditing - general principles	Through adoption by the relevant parties	
12	Environmental management performance evaluation	Provides guidance on the design and use of the environmental performance evaluation within an organization.	Sri Lanka Standards Institution	SLS ISO 14031:Environmental management performance evaluation - Guidelines	Through adoption by the relevant parties	
13	Guidelines for quality of environmental management system auditing	Provides guidance for auditing, managing audit programmers, conducting quality management system audits and environmental system management audits.	Sri Lanka Standards Institution	SLS ISO 14031:Environmental management performance evaluation - Guidelines	Through adoption by the relevant parties	

Annex 7. The list of international conventions and protocols ratified or acceded to by Sri Lanka relevant to protecting ecosystems

No.	Name of Convention	Objective	Date of Adoption	Date of Signature by Sri Lanka	Focal Point
01	Convention on Wetlands Of International Importance Especially As Waterfowl Habitat (1971)- Ramsar	To stem the progressive encroachment on and loss of wetlands now and in the future, recognising the fundamental ecological functions of wetlands and their economic, cultural, scientific and recreational value.	02.02.1971		Department of Wildlife Conservation
02	Convention concerning the protection of the World Cultural and Natural Heritage (1972)	To establish an effective system of collective protection of the cultural and natural heritage of outstanding universal value organised on a permanent basis and in accordance with modern scientific methods.	16.11.1972		Forest Department & Cultural Department
03	Convention on International Trade in Endangered Species Of Wild Fauna and Flora (1973)- CITES	To protect certain endangered species from over-exploitation by means of a system of import/export permits	03.03.1973		Department of Wildlife Conservation
04	Convention on the conservation Of Migratory Species of Wild Animals (CMS 1979)	To protect those species of wild animals that migrate across or outside national boundaries	23.06.1979	23.06.1979	Department of Wildlife Conservation
05	United Nations Convention on The Law Of the Sea.	To set up a comprehensive new legal regime for the sea and oceans and, as far as environmental provisions are concerned, to establish material rules concerning environmental standards as well as enforcement provisions dealing with pollution of the marine environment.	10.12.1982	10.12.1982	Marine Pollution Prevention Authority
06	Vienna Convention for the Protection of the Ozone Layer (1985)	To protect human health and the environment against adverse effects resulting from modification of the Ozone layer	22.03.1985		My of Env. and Natural Resources
07	Montreal Protocol on Substances That Deplete the Ozone Layer (1987)	To protect the Ozone layer by taking precautionary measures to control global emissions of substances that deplete it	16.09.1987		My of Env. and Natural Resources

08	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989)	To set up obligations for Sta te Parties with a view to (a) reducing transboundary movements of wastes subject to the Basel Convention to a minimum consistent with the environmentally sound and efficient management of such wastes. (b) minimising the amount and toxicity of hazardous was tes generated and ensuring their environmentally sound management (including disposal and recovery options) as close as possible to the source of generation ; (c) assisting developing countries in environmentally sound management of the hazardous and other wastes they generate.	22.03.1989		My of Env. and Natural Resources
09	Convention on Biological Diversity (1992)	To conserve biological diversity, promote the sustainable use of its components, and encourage equitable sharing of the benefits arising out of the utilisation of genetic resources. Such equitable sharing includes appropriate access to genetic resources, as well as appropriate transfer of technology, taking in to account existing rights over such resources and such technology.	05.06.1992	10.06.1992	My of Env. and Natural Resources
10	United Nations Framework Convention on Climate Change (1992)	To regulate levels of greenhouse gas concentration in the Atmosphere, so as to avoid the occurrence of Climate Change on a level that would impede sustainable economic development, or comprise initiatives in food production.	09.05.1992	10.06.1992	My of Env. and Natural Resources
11	United Nations Convention To Combat Desertification in Those Countries Experiencing Serious Drought And / or Desertification, particularly In Africa (1994)	To combat desertifaction and mitigate the effects of drought in the countries affected through effective action at all levels supported by international corporation and partnership arrangements in the framework of an integrated approach which is consistent with agenda 21, with a view to contributing to the achievement of sustainable development in those areas.	17.06.1994	09.12.1998	My of Env. and Natural Resources
12	Agreement relating to the implementation of part XI of the United Nations of the United nations Convention on the Law of the Sea of 10 December 1982	To provide for revised modalities of the implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982, in particular the International Seabed Authority	28.07.1994	29.07.1994	Ministry of Foreign Affairs

13	Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the conservation and management of straddling fish stocks and highly migratory fish stocks	To ensure long-term conservation and sustainable use of straddling fish stocks and highly migratory fish stocks through effective implementation of the relevant provisions of the United nations Convention on the Law of the Sea of 10 December 1982	04.08.1995	09.10.1996	Ministry of Foreign Affairs
14	(Copenhagen) Amendment to the Montreal Protocol on substances that deplete the ozone layer	The strengthen the control procedures under the Montreal Protocol on Substances that Deplete the Ozone Layer (1987) to extend the coverage of the Protocol to new substances	25.11.1992		My of Env. and Natural Resources
15	Montreal Amendment to the Montreal Protocol on substances that deplete the ozone layer				My of Env. and Natural Resources
16	Agreement on the Network of Aquaculture Centres in Asia and the Pacific	To assist the member States in their efforts to expand aquaculture development	8.1.1988		My of Fisheries and Ocean Resources
17	Convention on the Prohibition of the Development, Production, Stockpiling and use of Chemical Weapons and on their destruction	To develop , production, stockpiling and use of chemicals weapons, to destruct the existing chemical weapons and related facilities		14.01.1993	Ministry of Foreign Affairs
18	Agreement for the establishment of the Indian Ocean Tuna Commission	To establish the Indian Ocean Tuna Commission with a view to ensuring the conservation and optimum utilization of tuna and tuna like species (stocks)	November 1993		Ministry of Fisheries and Ocean Resources
19	International Plant Protection Convention	To maintain and increase international co-operation in controlling pests and diseases of plants and plant products, and in preventing their introduction and spread across national boundaries.	06.12.1951		Ministry of Agricultur e and Livestock

20	Plant Protection Agreement for Asia and Pacific Region* (as amended)	To prevent the introduction into and spread within the region of destructive	27.02.1956		Ministry of Agriculture and Livestock
21	Convention on the Continental Shelf	To define and delimit the rights of States to explore and exploit the natural resources of the continental shelf	29.04.1958	30.10.1958	Ministry of Foreign Affairs
22	Convention on Fishing and Conservation of the living resources of the high seas	Through international co-operation, to solve the problems involved in the conservation of the living resources of the high seas, considering that through the development of modern techniques some of these resources are in danger of being over-exploited.	29.04.1958	30.10.1958	Ministry of Fisheries and Ocean Resources
23	Convention on the high seas	To codify the rules of international law relating to the high seas	29.04.1958	30.10.1958	Ministry of Fisheries and Ocean Resources
24	Convention concerning the protection of workers against ionizing radiations	To protect workers, as regards their health and safety, against ionizing radiations.	22.06.1960		Ministry of Fisheries and Ocean Resources
25	International Convention on Civil Liability for Oil pollution Damage (as amended)	To ensure that adequate compensation is available to persons who suffer damage caused by pollution resulting from the escape or discharge of oil from ships. To standardize international rules and procedures for determining questions of liability and adequate compensation in such areas.	29.11.1969		Marine Pollution prevention Authority
26	International Convention Relating to intervention on the high seas in cases of oil pollution casualties	To enable countries to take action on the high seas in cases of a maritime casualty resulting in danger of oil pollution of sea and coastlines; to establish that such action would not affect the principle of freedom of the high seas.	29.11.1969		Marine Pollution prevention Authority

27	International Convention on the establishment of an international fund for compensation for oil pollution damage (as amended)	To supplement the International Convention on Civil Liability for Oil Pollution Damage, 1969; to ensure that adequate compensation is available to persons who suffer damage caused by pollution resulting from the escape or by discharge of oil from ships; and to ensure that the oil cargo interests bear a part of the economic consequences of such oil pollution damage, to the relief of the shipping industry.	18.12.1971		Marine Pollution prevention Authority
28	Convention on the prohibition of the development, production and stockpiling of bacteriological (biological) and toxin weapons and on their destruction	To prohibit the development biological weapons and eliminate them as a step towards general disarmament for the sake of all man kind		14.01.1993	Ministry of Foreign Affairs
29	Convention on the prohibition of military or any other hostile use of environmental modification techniques	To prohibit the military or other hostile use of such techniques in order to consolidate world peace and trust among nations.	10.12.1976	08.06.1977	Ministry of Foreign Affairs
30	(London) Amendment to the Montreal Protocol on Substances that deplete the ozone layer	To strengthen the control procedures under the Montreal Protocol on Substances that Deplete the Ozone Layer (1987), to extend the coverage of the Protocol to new substances and establish financial mechanisms for the protocol.	29.06.1990		My of Env. and Natural Resources
31	The International Convention for the Prevention of Pollution from the ships (MARPOL)- 1973	To preserve the marine environment by achieving the complete elimination of international pollution by oil and other harmful substances and the minimization of accidental discharge of such substances.	11.02.1973		Marine Pollution Prevention Authority
32	Bio-safety Protocol	To protect biological diversity from genetically modified organism.	24.05.2000	24.05 2000	My of Env. and Natural Resources

Source: Batagoda, 2005

Annex 8 - Proposed MDG targets and Indicators for Sri Lanka

No.	Category	Theme	Indicator	Present situation	Target 2015
01	Land	Waste	Municipal waste generation	2704 tons in 2003	6809 tons
			Hazardous waste generation	35310 tons in 2002	75314 tons
			Clinical waste generation	11000 tons in 2003	16000 tons
		Agriculture	Loss of soil (clean weeded tea)	52.6 t/y/ha	0.24 t/y/ha
		Forests	Forest area as a % of land area	23%	30%
		Landslides and Floods	Number of affected families/persons/property	1753 families 86 deaths in 2003	Reduce the effects by 75%
02	Forest and wildlife	Natural and Man Made Forests	Area of natural forest cover % of total area	23%	30%
			Forest plantations ha	140000 ha	175000 ha
03	Atmosphere	Climate Change	Emission of CO_2	33630.22 (Gg) in 1994	75000 Gg
			Emissions of CH_4	098.375 (Gg) in 1994	2000 Gg
			Emissions of N_2O	162.8657 (Gg) in 1994	350 Gg
		Ozone Layer Depletion	CFC 11 CFC 12 CFC 115	12.47 tons I 999 202.35 tons in 1999 2.67 tons in 1999	6 tons 125 tons 1 tons
		Air Quality	Ambient PM10 concentration in Colombo	115 µg/m ^{3} (Maximum concentration)	60 µg/m^3 (Maximum concentration)
04	Mountain	Agriculture	Loss of soil (clean weeded tea)	52.6 t/y/ha	0.24 t/y/ha
		Landslides and Floods	Number Affected families/persons/property	1753 families 86 deaths in 2003	Reduce the effects by 75%

05	Oceans, Seas and Coasts	Coastal Zone Fisheries Coastal resources	Annual coastal fish catch Off shore fish production Volumes of sand removed/yr Quantity of Coral mining from coast Area of mangroves Area under authorised aquaculture farms	167530 tons in 2001 87360 tons in 2004 6 million m^3 4020 in 1994 6083 ha 2016 ha	235912 tons 1920059 . . . . . 0 6000 ha 2778 ha
06	Fresh water	Water Quality Urbanization	BOD, COD, faecal coliform, heavy metals and other pollutants Proportion of population access to improved water source Proportion of population access to improved sanitation	Kalani river COD level around 30 75% 81%	Kalani river COD level around 10 100% 100%

Source: Batagoda, 2005

Annex 9. Some policies, legislations and institutions on ecosystem protection

MDG indicators/ sub themes	Existing Policy & legislative environment
Natural and man made forests Protected areas Wood harvesting pattern	National Forest Policy – 1995 Forest Sector Master Plan (1995) National Wildlife Policy (2000)
Fresh Water Water Quantity Water Quality Urbanisation Intensity of agriculture Industrialisation	Water Resources Board Act National Water Policy (Draft) – 2003 The Irrigation Ordinance (No. 32 of 1946) The Mahaweli Authority of Sri Lanka Act(No. 23 of 1979 The National Wat er Supply and Drainage Board Law No. 2 of 1974) The Electricity Act (No. 19 of 1950) The Ceylon Electricity Board Act (No. 17 of 1969) The Fisheries and Aquatic Resources Act (No. 2 of 1996) The National Environmental Act No. 47 of 1980; amendment No. 56 of1988 Water Resources Council & Water Resources Secretariat Municipal Council Ordnance Urban Development Authority Act Land Development Ordnance CMC Water Works Ordnance
Coastal Zone Fisheries Coastal resources	National Environmental Act No. 47 of 1980 Coast Conservation Act No. 57 of 1981. National Biodiversity Co nservation: Framework for Action - 1999 National Coastal Zone Management Plan revised in 2003 Fisheries & Aquatic Resources Act – 1996 Marine Pollution Authority
Biodiversity Ecosystems Species Protected areas Wetlands	Fauna and Flora Protection Ordinance No. 2 of 1937 Forest Ordinance No. 10 of 1885 Plant Protection Ordinance No. 10 of 1924 National Environmental Act no. 47 of 1980 Fisheries and Aquatic Resources Act No. 2 of 1996 Customs Ordinance Animal Act No. 29 0f 1958 National Forest Policy (1995) & Forest Sector Master Plan 1995 National Wildlife Conservation Policy (2000) Conservation of Biodiversity: A framework for Action - 1999 National Conservation Strategy (1988) National Wetlands Policy - 2004 Coastal 2000 – Coast Conservation Master Plan Clean Air 2000 Action Plan First National Communication to UNFCCC Committee of Environment Policy Management (CEPOM) Biodiversity Secretariat National Biosafety guidelines Network of biodiversity parks and bird sanctuaries

Land Degradation Landslides and Floods Agriculture	Timber Ordinance No.2 of 1822 Forest Ordinance No. 10 of 1885 Forest Ordinance No. 16 of 1907 Fauna and Flora Protection Ordinance No.2 of 1937 • Amendment Act No. 44 in 1964 • Amendment Act No. 1 in 1970 • Amendment Act No. 49 in 1993 Agrarian Development Act National Forest Policy - 1995 Unesco Biological Programme and 1975 Unesco Man and Brosphere Programme National Heritage Wilderness Areas Act No. 3of 1988 National Policy on Wildlife Conservation – 2000
Air quality	National Policy on Air Quality Mgt. (2000) Clean air 2000 Action Plan - 1992 Gazzette Extraordinary No. 772/22 dated 24 June 1993 and Gazette No. 02/02/1990 Gazzette Extraordinary No. 1137/35 dated 23 June 2000 on Mobile emission, fuel, and ve hicle importation standards Cabinet decision on banning Leaded petrol (2002) Cleaner Production Centre (2002) Male Declaration on Control and Prevention of Air Pollution (adopted in 1998) Air Resource Management Centre (AIRMAC) established in 2001
Climate change	Framework Convention on Climate Change (ratified in 1993) Kyoto Protocol acceded to on 23 Sept. 2003 First National Communication to UNFCCC Establishment of Climate Change Secretariat Establishment of 2 CDM studies centers - 2003 Draft National CDM policy
Ozone layer depletion	Vienna Convention for protection of Ozone Layer & Montreal Protocol (ratified in 1989) Establishment of Montreal Protocol Unit Rregulations gazette controlling importing and using ODS (1994)
Land Degradation Landslides and Floods Agriculture Forests Mineral Extraction Built Environment	National Land Use Policy 2003 Soil Conservation Act , 1951 Flood Protection Ordnance State Land Development Ordinance No. 8 of 1947 Soil Conservation Act (1951) amended in 1996 The Agrarian Services Act (1979) Mahaweli Authority of Sri Lanka Act No. 23 of 1979 National Environmental Act No. 47 (1981) National Environemtal Action Plan - 2003 National Forest Policy & Forest Sector Master Plan (1995) Urban Development Authority Act Natural Resources Management Centre of the Ministry of Agriculture Land Use Policy Planning Division (LUPPD) Land Use Division of the Irrigation Department Landslide Unit of the NBRO

Source: Batagoda, 2005

Acknowledgments

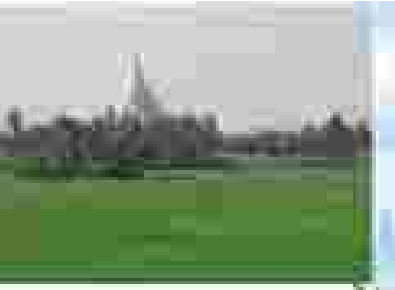
The contribution of following individuals, in the form of advice, participation in the Preparatory Workshop and granting permission to use maps and other documents is thankfully acknowledged.

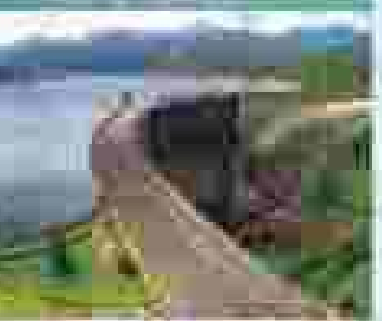
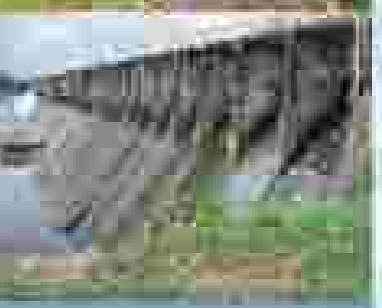
Mr. T.M. Abayawickrama	Secretary, Ministry of Agriculture, Irrigation & Mahaweli Development
Mr. E.M. Abeyratne	Snr. Asst. Secretary, Ministry of Provincial Councils & Local Govt.
Eng. J.C. Abeynayake	Director, WPC Irrigation Department
Eng. M.H. Abeygunawardane	Director, Water Management Secreta riat
Dr. Sarath Abayawardane	Director (Global Research Division), IWMI
Eng. (Mrs.) J. Amarakoon	Director, Irrigation Department
Mr. B.R. Ariyaratne	IWMI
Mr. R.de S. Ariyabandu	Research Fellow, Hector Kobbekaduwa Agr. Res. & Tra. Institute
Ms. K. Athukorale	ADRC
Mr. Dharmasiri de Alwis	Former Chairman, Mahaweli Consultancy Bureau (Pvt) Ltd.
Eng. K.S.R. de Silva	Former Director General of Irrigation
Mr. Asoka de Silva	Consultant
Mr. D.M.A.K. Dhanasekara	Asst. Director, Central Environmental Authority
Dr. G.G.A. Godaliyadda	Director, Irrigation Department
Eng. A.D.S. Gunawardane	Secretary, Irrigation
Dr. Hemantha Herath	Ministry of Health
Eng. (Ms.) P.I.L. Imbulana	Deputy Director, Irrigation Department
Eng. (Prof.) A.K.W. Jayawardane	Dean, Faculty of Engineering, University of Moratuwa
Mr. Ananda Jayasinghe	Director (GAP), IMD
Eng. Ananda Jayaweera	Director, Water Resources Secretariat
Mr. A.P.R. Jayasinghe	Addl. Director (Agronomy), IMD
Mr. R.D.U.J. Jayaweera	Senior Geologist, Water Resources Board
Mr. U.G. Jayasinghe	Former Secretary, Ministry of Water Management
Eng. (Ms.) Badra Kamaladasa	Deputy Director (Dam Safety), Irrigation
Dr. Engin Koncagul	Case Study Coordinator, UN -WWAP
Mr. P. Koralevidana	Director General, Mahaweli Authority of Sri Lanka
Dr. D.S.P. Kuruppuarachchi	Asst. Representative, FAO
Eng. M.L.A. Lathif	Director (Water Sector), M/Urban Dev. & Water Supply
Dr. C. Kudagamage	Director General, Department of Agriculture
Mr. B.J.P. Mendis	Surveyor General
Eng.(Ms.) T.J. Meegastenne	Chief Irrigation Engineer
Eng. K.R.P.M. Mullegamgoda	Addl. Director (Eng.), IMD
Mr. Ramraj Narasimhan	UNDP
Mr. S.M.A. Nelugolla	Resident Engineer, Weli Oya
Dr. (Ms.) Nirupa Pallewatta	Ministry of Health
Mr. S. J. Pathirana	Former Commissioner General, Land Commissioner's Dept.
Eng. K.W. Perera	Former Addl. Secretary (Irrig. Dev.)
Mr. Lakshman Perera	Director (Planning & Promotion), M/Urban Dev. & Water Supply
Eng. M.B. Pemasena	Former Director (PD&SS), Irrigation Dept.
Dr. B.V.R. Punya wardane	Department of Agriculture
Eng. (Prof.) Malik Ranasinghe	Vice Chancellor, University of Moratuwa

Acknowledgments

Eng. (Ms.) (Prof.) N. Ratnayake	Head, Dept. of Civil Engineering,University of Moratuwa
Ms. R.M.N.P. Ranasinghe	Environment Management Officer, Ministry of Environment & Natural Resources
Eng. B.M.S. Samarasekara	Director General of Irrigation & Former Addl. Secretary
Dr. Amara Satharasinghe	Department of Census & Statistics
Dr. Atula Senaratne	Chairman, Water Resources Board
Dr. Gamini Senevirat ne	Former Director, Hector Kobbekad uwa Agrarian Res. & Training Institute
Eng. J.W.M.R.T. Seimon	Director, Engineering , Ministry of Irrigation
Eng. P.D. Shelton	Actg. Director (RBPM), MASL
Eng. H.P.S. Somasiri	Addl. Secretary, Irrigation
Eng. W.A.N. Somaweera	Former Addl. Secretary (Tech.), Ministry of Urban Dev. & Water Supply
Mr. Roshan D. Suriyarachchi	PMU, MASL
Ms. Elizabeth Vasu	UNESCO, New Delhi
Mr. Tissa Warnasuriya	Secretary, Ministry of Agriculture Development
Mr. C. Wellappili	Director/PMU, MASL
Mr. B. Wickramarachchi	Senior Engineer, Dept. of Coast Conservation
Eng. (Prof.) Dayantha S. Wijeyesekara	Former Vice Chancellor, University of Moratuwa
Mr. E. Wijepala	Addl. Secretary, Ministry of Irrigation
Mrs. K.A.J. Wijesinghe	National Water Supply & Drainage Board
Mr. M.S. Wickramarachchi	Former Secretary, Ministry of Irrigation & Water Management
Eng. M. Wickramage	General Manager, NWS&DB
Mr. Rohitha Wickramaratne	Deputy Director, Dept. of National Planning
Mr. Ananda Wijesuriya	Director, Department of Forest Conservation
Dr. Gordon Young	Coordinator, United Nations World Water Assessment Programme
The provision of photographs by the following individuals and institutions is thankfully acknowledged.	
Mr. B.R. Ariyaratne	International Water Management Institute
Eng. Badra Kamaladasa	Irrigation Department
Eng. S.M.A. Nelugolla	Irrigation Department
Mr. Roshan.D. Suriyarachchi	Mahaweli Authority of Sri Lanka
Mr. Sajith Wijesuriya	
Mr. R. N. T. B. Ratnayake	Ministry of Agriculture, Irrigation and Mahaweli Development

Note: Designations indicated are those during the time of contact




UN-Water/WWAP/2006/11

ISBN 955 - 8395 - 01 - 3