Sri Lanka's Second National Communication on Climate Change






Ministry of Environment

DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

Second National Communication on Climate Change

submission to

UNFCCC Secretariat

by

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Ministry of Environment
Message of the Minister of Environment

Ratification of the UN convention on Climate Change is one step forward for committing Sri Lanka to address climate change and related issues, and implement strategies for adaptation and mitigation programmes within a broader framework of sustainable development. Since the submission of the Initial National Communication to the UNFCCC, the country has established an institutional set-up in order to mainstream climate change issues in to the national agenda.

We are already experiencing significant changes in our climate system including drastic variations in rainfall patterns and other extreme climatic events such as droughts and flash floods in most of the places in the country. Most of these adverse climatic events that we are experiencing today are most likely due to impacts of climate change, which have been caused by human activities. The impacts of these climate related events directly affect the nation's economic, social and environmental systems. We need to implement adaptation practices to address the negative impacts of climate change.

Having considered the importance of addressing local climate issues as well as the national commitments towards the global community under the Climate Change Convention, the Ministry of Environment has implemented very significant institutional reforms and actions during the recent past. In order to overcome these climate change related problems, number of national environmental and related policies have been prepared and adopted by the government to guide the implementation of the initiatives that address environmental issues, in collaboration with the relevant sectoral agencies. "Mahinda Chinthana - Vision for the Future", the National Development Plan of Sri Lanka along with the National Environmental Policy and "Haritha (Green) Lanka" Action Plan provide the framework and overall strategies for the country's sustainable economic development.

Being part of our obligations to the convention on climate change, the Second National Communication on Climate Change (SNC) for Sri Lanka has been prepared, and it is an important step towards assessing and addressing the negative impacts of climate change.

I take this opportunity to express my sincere appreciation to all those who contributed to the Second National Communication including the United Nations Development Programme (UNDP) and the Global Environmental Facility (GEF) for financial support extended towards this achievement.

Anura Priyadarshana Yapa MP
Minister of Environment

Foreword

Sri Lanka has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in November 1993. As a part of its obligation, Sri Lanka is required to submit the National Communication on Climate Change periodically. Sri Lanka is one of the most vulnerable nations to the impacts of climate change including extreme weather conditions like droughts and floods. Although the per-capita Greenhouse Gas (GHG) emission in Sri Lanka is as low as 0.6 t per year, according to the data of the Department of Meteorology, an increasing trend in annual maximum temperatures with rates up to 0.046^{0}C per year has been observed during the last four decades. The impacts of climate related events are felt right across the nation's economic, social and environmental systems, thus making future changes in climate, including extreme events, an issue of great national concern.

Having considered the importance of addressing local climate change issues as well as the national commitments towards the global community under the climate change convention, the Ministry of Environment has implemented many activities with the objective of identifying the causes of climate change and its impact on Sri Lanka. Since the submission of the Initial National Communication, a number of significant national environmental and related policies have been prepared and adopted by the government to guide the implementation of the initiatives that address environmental issues. Implementation of these policies needs technical and financial assistance to bridge the gaps of incremental costs. And country's knowledge on adaptation in relation to each vulnerable sectors of the economy should also be substantially improved.

The Ministry of Environment, as the national focal point, was actively involved in the establishment of the Climate Change Secretariat, preparation of GHG inventory, implementation of the Clean Development Mechanism (CDM) and the Sri Lanka Carbon Fund etc., during the last decade in order to implement the convention and the Kyoto Protocol. This document presents the Second National Communication on Climate Change for Sri Lanka.

I take this opportunity to express the appreciation of this Ministry to all the experts who provided their generous contribution for the preparation of the Second National Communication on Climate Change. Also, I wish to extend my sincere gratitude to all state sector and non-state sector entities and individuals contributed to the document and staff of the Ministry of Environment, particularly the staff of the Climate Change Secretariat for their valuable contribution. Our special appreciation is extended to the Global Environmental Facility (GEF) and the United Nations Development Programme (UNDP) Country Office in Colombo for financial assistance provided for preparation of this document.

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The Ministry of Environment extends its deepest gratitude for all the team members for their valuable contribution for preparation of this Second National Communication on Climate Change.

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List of Acronyms

ADB	Asian Development Bank
AER	Agro-Ecological Regions
AIACC	Assessment of Impacts of and Adaptations to Climate Change
APEC	Asia-Pacific Economic Cooperation
APN	Asia Pacific Network
AWS	Automatic Weather System
AZ	Arid Zone
BAU	Business -As-Usual
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
CARP	Council for Agriculture Research Policy
CC	Climate Change
CCCS	Centre for Climate Change Studies
CCD	Climate Change Division
CCD	Coast Conservation Department
CCGT	Combined Cycle Gas Turbine
CCS	Climate Change Secretariat
CDM	Clean Development Mechanism
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CFL	Compact Fluorescent Lamp
CGCM	Canadian Global Coupled Model
CP	Central Province
CRI	Coconut Research Institute
CSIRO	Commonwealth Scientific and Industrial Research Organization
CV	Coefficient of Variation
CZ	Coastal Zone
CZMP	Coastal Zone Management Plan
DCS	Department of Census and Statistics
dm	dry matter
DMC	Disaster Management Centre
DNA	Designated National Authority
DOC	Degradable Organic Compound
DPF	Development Policy Framework
DS	Divisional Secretariat
DZ	Dry Zone

EEZ Exclusive Economic Zone
EF Energy Forum
EIA Environment Impact Assessment
EP Eastern Province
FD Forest Department
FIM First Inter-Monsoon
FSMP Forestry Sector Master Plan
GC General Circulation
GCM General Circulation Model
GCOS Global Climate Observing System
GDP Gross Domestic Product
GEF Global Environmental Facility
GHG Green House Gas
GIS Geographic Information System
GNP Gross National Product
GTS Global Telecommunication System
GWP Global Warming Potential
HadCM Hadley Centre Coupled Model
HLP *Haritha* (Green) Lanka Programme
IDA International Development Agency
IGCI Global Climate Change Institute
INC Initial National Communication
IOMAC Indian Ocean Marine Affairs Cooperation
IOR-ARC Indian Ocean Rim Association for Regional Cooperation
IPCC Intergovernmental Panel on Climate Change
ITCZ Inter-Tropical Convergence Zone
ITDG Intermediate Technology Development Group
ITI Industrial Technology Institute
IUCN International Union for Conservation of Nature
IWMI International Water Management Institute
IZ Intermediate Zone
JICA Japanese International Cooperative Agency
KP Kyoto Protocol
LA Local Authority
LNG Liquefied Natural Gas
LPG Liquefied Petroleum Gas
LTGE Long Term Generation Expansion

LUCF	Land-Use Change and Forestry
MC	Municipal Council
MCH	Maternal and Child Health
MD	Meteorology Department
MENR	Ministry of Environment and Natural Resources
MF&E	Ministry of Forestry & Environment
MOH	Medical Officer of Health
MOST	Ministry of Science and Technology
MSW	Municipal Solid Waste
NAP	National Action Plan
NARA	National Aquatic Research and Development Agency
NBRO	National Building Research Organization
NCP	North Central Province
NCPC	National Cleaner Production Centre
NCRE	Non-Conventional Renewable Energy
NCSD	National Council for Sustainable Development
NEM	North-East Monsoon
NEPS	National Energy Policy and Strategy
NERDC	National Energy Research and Development Centre
NG	Natural Gas
NGO	Non-Government Organization
NIES	National Institute for Environmental Studies (Japan)
NMVOC	Non-Methane Volatile Organic Compounds
NP	Northern Province
NPP	National Physical Plan
NPPD	National Physical Planning Department
NPPP	National Physical Planning Policy
NPV	Net Present Value
NRMC	Natural Resources Management Centre
NW	North West
NWP	North Western Province
ODS	Ozone Depleting Substance
OFC	Other Field Crops
OND	October, November and December
OOC	Ocean Observation Centre
OTC	Open Top Chamber
PC	Provincial Council

PFC	Per-Fluoro-Carbon
PV	Photo-Voltaic
R&D	Research & Development
RERED	Renewable Energy for Rural Economic Development
RF	Rain Fall
RIG	Revised IPCC Guidelines
RRDI	Rice Research and Development Institute
RRISL	Rubber Research Institute, Sri Lanka
RUE	Radiation Use Efficiency
SAARC	South Asian Association for Regional Cooperation
SACEP	South Asia Co-operative Environment Programme
SD	Sustainable Development
SDSM	Statistical Down-Scaling Model
SE	South East
SEA	Strategic Environmental Assessment
SGP	Sabaragamuwa Province
SIM	Second Inter-Monsoon
SLAAS	Sri Lanka Association for the Advancement of Science
SLSEA	Sri Lanka Sustainable Energy Authority
SME	Small and Medium Enterprise
SNC	Second National Communication
SP	Southern Province
SWB	Soil Water Balance
SWM	South-West Monsoon
TAR	Third Assessment Report
TNA	Technology Needs Assessment
TRI	Tea Research Institute
UC	Urban Council
UDA	Urban Development Authority
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UP	Uva Province
VET	Vehicle Emission Testing

WB	World Bank
WCD	Wildlife Conservation Department
WMO	World Meteorological Organization
WUE	Water Use Efficiency
WZ	Wet Zone

Units

G	Giga (10^9)
g	gramme
Gg	Gigagramme
Gm	gigametre
h	hecto (100)
h	hour
ha	hectare
J	Joule
k	kilo (1000)
kg	kilogramme
kha	kilohectare
km	kilometre
m	metre
M	mega (10^6)
m	milli (1/1000)
mg	milligramme
Mha	million hectare
Mkm	million kilometre
mm	millimetre
°C	degree Centigrade
P	Peta (10^12)
T	Tera (10^9)
t	tonne (1000 kg)
W	Watt
y	year

Chemical Symbols

$CaCO_3$	Calcium Carbonate
CaO	Calcium Oxide
CFC	Chlorofluorocarbon
CH_4	Methane
CO	Carbon Monoxide

CO_2	Carbon Dioxide
H_2	Hydrogen
HFC	Hydrofluorocarbon
N_2O	Nitrous Oxide
NMVOC	Non-Methane Volatile Organic Compounds
NO	Nitric Oxide
NOx	Oxides of Nitrogen
PFC	Perfluorocarbon
SO_2	Sulphur Dioxide
SF_6	Sulphur Hexafluoride

Executive Summary

Sri Lanka is an island nation in the Indian Ocean, located about 80 km to the southeast of the Indian sub-continent. It comprises a mainland of area 65,610 km^2 and a large number of small islands with only six having area more than 1,000 ha located off the northwest coast. The south-central part of the country is mountainous, while the rest of the country is mostly flat undulating land. The country has a coast line of about 1,585 km, comprising sandy beaches and sand dunes, and dotted with many lagoons, estuaries, marshes, mangroves and deltas. There are altogether 103 rivers spread around the country, with a total annual run-off of about 43 Gm^3.

The climate of the country depends largely on the monsoon wind pattern. The annual mean surface temperature has an average of about 27 °C in the lowlands and an annual mean temperature of about 15°C in the highlands. Based on the annual rainfall received, the country is divided In to three climatic zones - wet -, intermediate- and dry- zone. The wet-zone covering approximately the south-western quadrant, receives an annual rainfall in the range 2,500 - over 5,000 mm, while the dry-zone covering the north, eastern and most parts of the north-central provinces receives an annual rainfall below 1,750 mm. The intermediate-zone lying between the wet- and dry - zones receives annually rainfall between 1750 and 2500 mm. The southwest monsoon winds bring rainfall mainly to the wet-zone, while the northeast monsoon brings rainfall mainly to the dry- and intermediate- zones. The two inter-monsoon periods bring rain spread over the entire country.

There is plenty of water in the wet zone, with a shallow water table from which people could obtain their water supply. In the dry and intermediate zones, people depend on deep ground water sources for their personal needs as well as for agricultural and industrial purposes. Most of the cultivation of crops in the dry- and intermediate zones is carried out using water from irrigated schemes comprising both the ancient systems and the modern systems built over the last several decades. Only about 36% of the households have pipe-borne water supplies.

Sri Lanka follows a democratic system of governance headed by an Executive President, elected by the people once in 5 years. The country is divided into 9 provinces, and each province is divided into several districts. The system of governance consists of the Central Government with its cabinet of ministers and 9 Provincial Councils. The legislative body is the Parliament with 196 elected members and 29 appointed members selected out of national lists. Each Provincial Council is headed by a Governor appointed by the President and it has its own cabinet of ministers, which is chaired by a Chief Minister. The local administrative system operating in Sri Lanka comprises 12 Municipal Councils, 51 Urban Councils and 257 Divisional Councils.

The mid-year population estimated for 2009 has been 20.45 million, with a current growth rate of 1.0%. The disparity in the climatic conditions between the wet- and dry-zones has naturally demarcated the population distribution with a larger portion living in the wet zone, particularly in the western province. According to 2001 census, 72% of the population lived in rural areas, 22% in urban areas and 6% in plantation estates. It is estimated that the population will peak around 23 million during 2030-2040 depending on the growth rate.

The major crops and plantations grown in Sri Lanka are rice, tea, coconut, rubber, sugar cane, cinnamon, pepper, cashew and a variety of spices and seasonal crops. Out of 6.56 million ha of total land area, approximately 1.86 Mha constitutes cropland, out of which about 720 kha is under rice cultivation, while the plantation crops tea, rubber and coconut cover approximately 213 kha, 124 kha and 395 kha, respectively. Forests cover an extent approximately 2,000

kha including about 95 kha of planted forests. In Sri Lanka, rice and other seasonal crops are cultivated in two seasons – *Yala and Maha* which coincide with the two rainy seasons, south-west monsoon period and the second inter-monsoon period.

The country's economy is based mainly on the service sector which has contributed 59% to the GDP in 2009, with the industrial and agricultural sectors contributing 29% and 12%, respectively. The GDP (at current price) in 2009 has been Rs 4,825 billion (US$ 42 billion) with an average annual real growth rate of 6.4% during 2004 – 2008 period. The per capita GDP (current price) has grown from about US$ 838 in 2001 to more than US$ 2,000 by 2008. Sectors that have brought revenue to the country were industrial production, agriculture, fisheries, tourism and mineral exports including gem stones, among others.

Sri Lanka's present primary energy supply is based mainly on biomass (48%), petroleum oil (43%) and hydroelectricity (9%), with the total amounting to about 415 PJ. The Non-Conventional Renewable Energy sources are contributing only about 0.1%, while the contribution to the electricity grid is about 4%. The government plans to increase this ratio to 10% by 2015. Sri Lanka has no petroleum oil or coal. However, one coal power plant of 900 MW capacity is under construction and another (1,000 MW) is being planned to meet the future electricity needs. Hitherto, electricity generation was dependent on hydro-power (40%) and petroleum oil (60%). The total electricity consumption in 2008 has been 9,900 GWh and the per capita consumption has been 416 kWh with the grid supply penetrating to about 85% of the households.

Public transport systems are widely used and are available in all parts of the country, operated by both the government and private owners. Sri Lanka's railway lines cover a total distance of 1,150 km, extending to southern, northern, north-western and eastern parts of the country from the capital city which is on the western coast. Diesel operated vans are used widely for personal transport. Freight transport is done mostly by diesel driven trucks though there is potential to use railways. Waste disposal has been an issue in recent times with no properly designed sites for its disposal. Mandatory vehicle exhaust monitoring system is operating helping in the control of air pollution.

Sri Lanka gets affected by many extreme events annually including floods, landslides, droughts and occasional cyclones, causing much damage to life and property. Efforts are being made to minimize the damage through improved monitoring systems providing real time rainfall information from landslide prone areas and also improving mechanisms for information dissemination to people in threatened areas. The government has recently established a separate Ministry on Disaster Management to coordinate work on disaster relief and related work.

The government provides free health service as well as free education to its citizens and as a result has been able to maintain high life expectancy and high literacy rate among the people. The university as well as all tertiary level education is available without any fee to eligible students. There is, however, high competition for university admission.

Greenhouse Gas (GHG) Inventory

The National GHG Inventory was computed for the year 2000 using mostly the Revised 1996 IPCC Guidelines. In the absence of segregated information, Tier I methodology was used. Most of the activity data were taken from data published by government agencies such as the Sri Lanka Sustainable Energy Authority, Census and Statistics

Department and the Central Bank. Carbon Dioxide from fuel combustion has been the major source and it has shown a growth from 5447 Gg in 1994 to 10,430 Gg in 2000. The agriculture sector has shown a growth from 157 $GgCH_4$ in 1994 to 185 $GgCH_4$ in 2000. The land use change and forestry sector, on the other hand, has shown an emission of 27,882 $GgCO_2$ in 1994 while in 2000, has shown an uptake of 6,254 $GgCO_2$. The waste sector has shown a growth from 14 $GgCH_4$ to 97 $GgCH_4$ during this period.

Considering only the emissions, excluding the land-use change and forestry (LUCF) sector, CO_2 emissions have shown the highest contribution of 58%, followed by CH_4 and N_2O with contributions of 36% and 6%, respectively. If the removals from the LUCF sector are included, the corresponding emissions are 37%, 54% and 9%, respectively The table below gives a summary.

Summary of Emissions/Removals

Sector	CO_2 Gg	CO_2 Removals Gg	CH_4 $GgCO_{2eq}$	N_2O $GgCO_{2eq}$	Total $GgCO_{2eq}$ (Net)
Energy	10,430.0		881.4	251.1	11,562.5
Ind. Processes	492.4				492.4
Agriculture			3,887.9	821.5	4,709.4
LUCF-Emissions	10.3		35.1		45.4
Waste			2,033.2		2,033.2
Total-Emissions	**10,932.8**		**6,837.6**	**1,072.6**	**18,842.9**
LUCF-Removals		-6,254.0			-6,254.0
Total-Net	**10,932.8**	**-6,254.0**	**6,837.6**	**1,072.6**	**12,588.9**

In the Energy Sector, the total aggregate emission from fuel combustion has been 11,562 $GgCO_{2eq}$, comprising 10,430 Gg (90%) of CO_2, 881 $GgCO_{2eq}$ (8%) of CH_4 and 251 $GgCO_{2eq}$ (2%) of N_2O. Most of the CH_4 came from combustion of biomass. The aggregate comprised 3,075 $GgCO_{2eq}$ (27%) from the energy industry sub-sector, 955 $GgCO_{2eq}$ (8%) from the industrial sub-sector, 5,084 $GgCO_{2eq}$ (44%) from the transport sub-sector, 2,178 $GgCO_{2eq}$ (19%) from the household and commercial sub-sector and 269 $GgCO_{2eq}$ (2%) from the refinery use.

Sri Lanka's industrial production has been rather low and this is reflected by the relatively low emission of 492 $GgCO_2$ for the entire Industrial Processing sector. It comprises of 348 $GgCO_2$ (71%) from the cement industry, 78 $GgCO_2$ (16%) from the metal industry and 67 $GgCO_2$ (13%) from the mineral industry.

The agriculture sector has emitted a total of 4,709 $GgCO_{2eq}$ of CH_4 and N_2O gases. These comprised 1,253 $GgCO_{2eq}$ (27%) from enteric fermentation, 183 $GgCO_{2eq}$ (4%) from manure management, 2,466 $GgCO_{2eq}$ (52%) from rice cultivation, 760 $GgCO_{2eq}$ (16%) from agriculture soils and 48 $GgCO_{2eq}$ (1%) from residue burning.

In the Land Use Change and Forestry sector, there is a net uptake of CO_2 amounting to 6,254 $GgCO_2$ comprising 5,884 $GgCO_2$ from carbon stock change in woody biomass stocks and 370 $GgCO_2$ from soils. The emissions amounting to 45 $GgCO_{2eq}$ comprised 10 $GgCO_2$ from forest fires and 35 $GgCO_{2eq}$ from wetlands.

The Waste sector has contributed 2,033 $GgCO_{2eq}$ of CH_4 emissions comprising of 1,765 $GgCO_{2eq}$ from solid waste disposal sites and 268 $GgCO_{2eq}$ from waste water treatment plants.

The total CO_2 emission from fossil fuel combustion is 10,430 Gg while the total aggregate emission is 18,843 $GgCO_{2eq}$. with the uptake of 6,254 $GgCO_{2eq}$ from the land use change and forestry sector, the total net emission is 12,589 $GgCO_{2eq}$.

Impacts, Vulnerability and Adaptation

An analysis of the past climate in Sri Lanka was analyzed using temperature and rainfall data collected by the Meteorological Department. It was revealed that during the 40 year period 1961-2000, both the maximum and minimum temperatures at most stations have shown upward trends with rates ranging up to a maximum of 0.46 °C per decade in the case of maximum temperature and 0.27 °C per decade in the case of minimum temperature. On the other hand, the rainfall in all stations has shown decreasing trends with rates ranging from 1.5 mm/year to 19 mm/year, the high rates being shown in areas already receiving high rainfall.

The impact of global warming on the climate of Sri Lanka was assessed based on the IPCC Third Assessment Report projections. The software developed by the International Global Change Institute of University of Waikato, New Zealand was used for this purpose. Both the temperature rise and rainfall changes corresponding to different General Circulation Models and IPCC Emission Scenarios were obtained for different time frames. The temperature rise projected for 2100 was found to be within 1.1°C and 2.4°C, with a best estimate of 2.0°C, which is consistent with the values given by IPCC for the South Asia region for 2100. The temperature rise is more prominent during the south west monsoon period than in the north-east monsoon period.

While the temperature projections show the same trend for all models and seasons, the rainfall projections show a rather complex picture. The projections are seasonally dependent, with the south-west monsoon period showing increases in rainfall in areas already receiving high rainfall, and north-east monsoon period showing a less prominent change. Corresponding to a moderate emission scenario of A2, one model showed an increase in the annual rainfall up to 400 mm, while another model showed an increase up to 133 mm by 2100. A third model, on the other hand, showed a decrease in the annual rainfall down to 161 mm. This change in rainfall distribution has caused a shift in the demarcation between the dry and wet-zones, with a reduction in the area of the wet-zone.

The impact of climate change was considered in four sectors – agriculture, water resources, human health and coastal zone. Under agriculture, the crops of economic importance such as rice, tea, rubber, coconut and sugarcane were considered. Studies were carried out under controlled conditions for rice, tea and coconut to determine their response to CO_2 elevation all of which have shown positive responses. However, rice and coconut are expected to have lower yields under increased temperature and water stress. Rice will be further affected by increased salinity. Crop modeling studies were carried out on tea to determine its yield response to projected climate changes up to 2100. High-elevation tea yield is expected to improve while mid-elevation and low-elevation plantations are expected to have reduced yields. The country's tea industry as a whole is vulnerable to climate change.

The key adaptation option proposed for all crops is to develop varieties that are tolerant to increased temperatures and water deficits, and in the case of rice, to high salinity as well. Initiatives towards these have already been taken in view of the drought conditions that plague the cultivations regularly, but much more work need to be undertaken to meet

the future conditions. Other options that have been recommended are changes in cropping calendars and farmer education, adoption of soil and water conservation measures, provision of drip- and regular irrigation wherever possible. The importance of providing financial assistance to small-scale farmers to adopt recommended adaptation measures has been highlighted.

Under future climate change, it is projected that the country will receive more rain in areas where there is already a surplus of water, and less rain where there is a deficit of water. One adaptation measure against this that has been recommended is to collect the excess water received during the wet season in the wet zone, and transport this water to water-deficit dry areas, particularly to meet their requirements during the dry period. These proposals are already being considered though firm commitments are yet to be finalized. Currently, water needs of the people living in the dry areas are mostly met from ground water sources, both from shallow wells and deep aquifers. In order to meet the water demand in the dry zone, a system of reservoirs and canals have been built in ancient times and this has been recently augmented by diverting a river from the wet zone to the dry zone in the north-central and eastern parts of the country.

The increase in temperature and shortage of water will affect people's health in many ways; direct impacts due to heat stress, increased vector population, deaths and injuries caused by increasing extreme events and resulting spread of disease, illnesses brought about due to non-availability of clean water. Policy measures on improving the public health system and educating the people are among the adaptation measures suggested. Rainwater harvesting is another option that has been recommended.

One of the direct impacts on the coastal zone is its inundation due to sea level rise. High risk areas in the coastal zone are being mapped. It is expected that coastal erosion which is already causing damage will become severe. Intrusion of salinity into low lying agriculture land and water ways are expected to limit agricultural activities and usage of water, particularly where water is sourced for municipal water supplies from rivers at locations close to the sea. Relocation of coastal communities, water intakes, coastal highways and other infrastructure and strengthening the defense and port structures are some of the adaptation measures recommended.

In the long term, it has been proposed as an adaptation measure to shift the population from the present densely populated areas in the Western Province as well as from mountainous areas identified as environmentally fragile areas, to presently sparsely populated North-Central and Eastern Provinces, and to build up the future metropolitan cities in those provinces. It has also been proposed to relocate the industries away from the Western Province, enabling a more uniform distribution of resource utilization.

Mitigation Measures

The National GHG Inventory of 2000 shows that the highest CO_2 emission from fossil fuel combustion is from the road transport sub-sector with a contribution of 44%. Efforts were therefore made to identify initiatives to reduce emissions from this sub-sector first. An analysis of the vehicle fleet and their average distance traversed annually indicates that the main contribution to emissions come from the heavy trucks used in freight transport and buses. Currently, long distance freight transport is carried out using trucks and shifting this to railways could reduce emissions significantly. The number of vehicles entering the city could be reduced significantly by encouraging corporate executives who generally travel to work in their personal vehicles to attend to their work at home through networked IT facilities thus

avoiding commuting to office at least by 2 days a week.

According to the *Haritha* (Green) Lanka Programme (HLP), the government has decided that bio-fuels should be introduced blended with petroleum up to at least 10% by 2016. The average growth of fuel consumption in the transport sub-sector during 2000 – 2007 was found to be 3.8%, and hence a growth rate of 4% was assumed for the business-as-usual (BAU) scenario up to 2020. It is therefore suggested that considering the HLP target and other emission reducing initiatives, a 20% reduction from the transport sub-sector could be achieved by 2020, below the BAU case.

The second highest emitter of CO_2 from fossil fuel combustion is the power sub-sector, which has contributed 27% in 2000. According to the published future electricity generation plan of the Ceylon Electricity Board (CEB), Sri Lanka's CO_2 emission from this sub-sector will show a rapid growth in view of coal power becoming the main source of electricity in the near future. The government has also declared that at least 10% of the electricity supplied to the national grid should come from non-conventional renewable energy (NCRE) sources by 2015. The CEB has also announced a NCRE scenario through which it plans to increase the NCRE installations by about 600 MW by 2020. Currently, about 4% of the electricity generated comes from these sources and considering the large number of applications received from investors for NCRE project approvals, it is very likely that this target could be achieved, if not more. It is estimated that a 28% saving of CO_2 emissions between the BAU and the NCRE based scenario could be achieved by 2020 in the power sub sector.

The growth rate for combustion of oil in the industrial sub-sector during 2000 and 2007 was found to be 5.6%, and hence a BAU scenario was estimated assuming a growth rate of 6% up to 2020. The *Haritha* (Green) Lanka Programme adopted by the government has given several emission reduction targets for the industrial sub-sector based on substituting biomass for fuel oil, improving the plant efficiency and shifting to renewable energy. Based on these targets, it was assumed that in the industrial sub-sector, a saving of 25% could be achieved by 2015 and a 50% target by 2020.

Considering the proposed reductions in the transport, power and industry sub-sectors, the overall reduction of CO_2 emissions in the energy sector is estimated to be 27% by 2020 relative to the BAU scenario. In reality, the reductions could be even more, because the above targets did not include all the mitigation options that are available. While many initiatives have been identified for reducing emissions in the agriculture, land use & forestry and waste sectors, no effort was made to determine any emission reduction targets for these sectors, in view of the high uncertainties in estimating these emissions and the difficulties in monitoring the progress.

Resorting to organic farming to reduce nitrogen input to soils, better water management and no-tilling farming are some the mitigation measures recommended for agriculture. Increasing the tree crop stand in forests and home gardens is a cost-effective measure that has been recommended for increasing the carbon uptake in land-use sector. In the waste sector, several initiatives have been taken to reduce methane emissions through better management of solid waste that is presently disposed in open dumps. Many local authorities have already commenced compost plants using organic solid waste and engineered landfills which would reduce methane emissions.

Technology Transfer, Research and Systematic Observations

In response to the GEF call for proposal made in 2009 for the transfer of technologies, a proposal on bamboo processing technology was submitted by Sri Lanka and it is being considered. Several new technologies mainly in the energy sector for efficient utilization of biomass have been introduced. These included extracting thermal energy from agriculture residue and organic waste replacing oil, which have been introduced through initiatives taken by the private sector. GEF has approved a US $ 4 million grant, co-financed with UNDP and FAO, for the promotion of efficient biomass utilizations technologies under a 5 years programme commencing 2011 Many micro-hydro stand-alone power plants have been installed in mountainous areas to generate electricity, built with locally developed technologies. Technologies are being developed locally for producing bio-fuels and compressed biogas for use in the transport sector, but these have not yet gone into production due to many barriers.

Several technology-needs have been identified. Under energy, these include developing on-board gasification systems for use in passenger buses, synthesizing CO and H_2 present in syngas to produce liquid hydrocarbons for use as vehicle fuels, producing hydrogen from stand-alone wind power plants for use as fuel, clean biomass burning technologies, concentrated solar thermal technology, and technology for accommodating increased wind power. Under agriculture, there is an urgent need to develop capability to assess impacts on agriculture systems through crop modeling and breeding of crop varieties resistant to adverse climate conditions. Capability to quantify climate change impacts on vulnerable sectors and assessment of adaptation strategies needs to be developed. The capability to generate future climate change scenarios applicable to Sri Lanka based on the latest IPCC regional projections also needs to be developed.

A large number of short-term research studies were undertaken with funds provided by GEF under Enabling Activities Phase II covering climate variability, impact of climate change on crop yield, adaptation measures in agriculture, emissions from agriculture fields and waste, carbon sequestration in forests etc. In addition, several research studies were undertaken to determine the impact of temperature, rainfall and CO_2 elevation on rice, tea and coconut plantations. These studies need to be continued to assess the overall impact on country's agricultural productivity under future climate change scenarios using crop modeling. Studies were also undertaken to assess the overall climate change impact on agriculture in the wet zone and to develop a district-wise mapping of vulnerability with exposure to flooding, landslides, cyclones and droughts. A large number of areas in agriculture for undertaking further climate change related research have been identified.

Sri Lanka has been making systematic observations in meteorology for over 100 years, with the technology improved today to obtain real-time regular data on rainfall from landslide prone areas. In addition to meteorology observations, Sri Lanka makes regular observations on agro-meteorology, hydro-meteorology and ocean-related parameters. Sri Lanka exchanges these data with international data centers on a regular basis. However, there is a need to modernize the data collection and dissemination system using digital systems for easy recording and analysis.

Education, Training and Public Awareness

Sri Lanka's formal education system has included for several decades, environmental studies from the primary level in schools to post-graduate level in universities. More recently, their scope has been widened to include topics on climate change and even on ozone depletion. In several universities, post-graduate diploma and degree programmes with

climate change components are being offered. Research on climate change related topics have been undertaken for the dissertation for PhD degrees in some universities.

In the non-formal sector, many government organizations as well as non-government organizations have been conducting educational and training programmes on science of climate change, its impact on key areas such as agriculture, water resources, coastal zone and human health. These programmes were carried out mostly in schools for the benefit of students. Many public awareness programmes were carried out by government departments and institutions having a mandate to carry out climate change work. Public awareness programmes were also carried out by non-government organizations including media, both the print and electronic. Special awareness programmes were also carried out for government officers engaged in district administration and extension work in agriculture and development activities, apprising them of impacts of climate change in areas affecting the general public.

Capacity Building and Networking

Several programmes were carried out to build the capacity of government officers and researchers to undertake enabling activities for compliance with the UNFCCC. In 2002, funds were received by the Ministry of Environment from GEF under Enabling Activities Phase II Programme and these were utilized to build the capacity of a large number of young scientists working under several senior scientists in undertaking research and investigations for generating information on mitigation and adaptation to climate change. Funds from GEF were also received for a study on the Assessment of Impacts and Adaptation to Climate Change which provided opportunities to local scientists to build their capacity to undertake crop modeling studies for the purpose of projecting crop yields under future climate scenarios.

A Japanese assisted programme is being conducted at the Ministry to build the capacity of its officers and other interested parties in the formulation of projects for seeking CDM benefits. Several workshops were held for this purpose. The establishment of the Climate Change Secretariat within the Ministry of Environment in 2008 has enabled building of capacity of officers to undertake activities that would assist the country in conforming to the provisions in the UNFCCC, and implementing various decisions of its COPs. The Centre for Climate Change Studies established within the Department of Meteorology has helped in building the capacity of scientists in the public sector and universities in undertaking climate change related activities.

The National Meteorological Centre set up within the Department of Meteorology maintains a network linked to the Global Telecommunication System for global distribution and reception of meteorological data via its hub in New Delhi. The tide gauges maintained by the National Aquatic Resources Research and Development Agency are linked to a global network of sea level monitoring stations. Sri Lanka is a member of several information networks covering fields of environment (ENVINET), science and technology (SLSTINET), agriculture information (AGRINET), and education & research information (LEARNS). The government maintains the Lanka Government Network (LGN) with links to all ministries, departments and other public sector institutions. Currently it contains a limited quantity of climate change information, but has the potential to expand, which will enable a wider clientele to benefit.

Constraints and Gaps

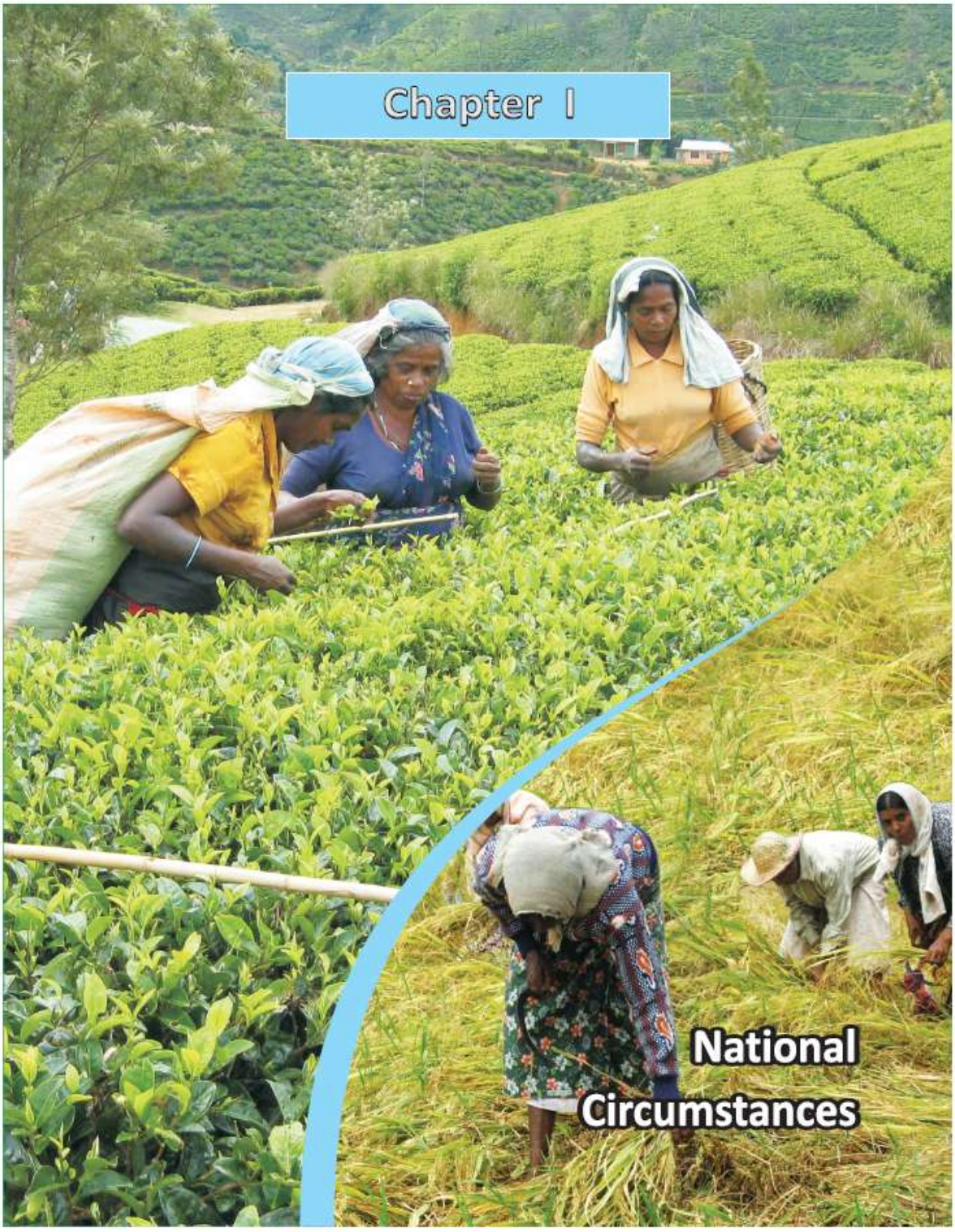
The preparation of the GHG Inventory was carried out using the Revised 1996 IPCC Guidelines. Due to lack of segregated data, the Tier I methodology was used and this has introduced many uncertainties. Though reliable activity data are available in the Energy Sector, the same is not true in other sectors. Many assumptions had to be made for activity data in both agriculture and land use change sectors, and this has made the uncertainties of emission estimates in these sectors appreciable. Even in the energy sector, there is uncertainty associated with the transport sub-sector in assigning fuel consumed by different categories of vehicles, if Tier II methodology were to be used for estimating non-CO_2 emissions.

In estimating the impacts of climate change on various sectors, no quantitative estimates were made except in one sector, and that was in tea. This is an impediment in quantifying the overall impact on the economy due to climate change. Though vulnerability assessment needs are to be assessed quantitatively with vulnerability rankings assigned to each sector, this procedure had not been followed in general. As a result, it was not possible to identify vulnerable areas that are most critical, as required in the Guidelines. Only qualitative assessments have been included.

Sri Lanka being subject to regular droughts annually has already introduced many initiatives to meet the challenge of water deficits and dry soils in agriculture and other sectors. Programmes for breeding of drought resistant varieties of crops, procedures for water and soil conservation and other adaptation measures are already in place. The government has already implemented large irrigation schemes to provide water to dry areas, and these would help in adapting to future situations. However, more work needs to be done in adapting to all aspects of climate change, which are yet to be assessed quantitatively for Sri Lanka. A strategy for adapting to climate change has been prepared with funding from the Asian Development Bank.

Funding Received for Climate Change Studies

Since preparation of the Initial National Communication on Climate Change which was submitted in 2000, the Ministry of Environment has received funds from GEF and several bilateral agencies to initiate studies on climate change and its impacts, and to build capacity to undertake work that would enable compliance with the UNFCCC. Altogether a sum of over US$ 1.5 million has been received by the Ministry for this purpose during this decade. In addition, several other ministries have received funds from multilateral agencies such as the World Bank, Asian Development Bank, Japan International Cooperative Agency and several UN affiliated organizations that have provided funding to these ministries to undertake various development projects that have a bearing on climate change. The areas for which such funding was received included meteorology, agriculture, irrigation, industries, power and energy. It is estimated that altogether a sum exceeding US$ 50 million has been disbursed for this purpose during the last decade.


Chapter I
National
Circumstances

National Circumstances

1.1 Geography

Sri Lanka is an island nation in the Indian Ocean, comprising a mainland and several small islands off the northern peninsular, located about 80 km southeast to the Indian Subcontinent. It lies between 5°55' and 9°50' North latitudes and between 79°42'and 81°53' East longitudes, with a maximum length of 435 km in N-S direction and maximum width of 240 km in E-W direction. It covers a total area of 65,610 km^2, including 62,705 km^2 of land area and 2,905 km^2 of inland water bodies (C&SD, 2009).

1.1.1 Land and Relief

On the basis of elevation and salient landforms, Sri Lanka is divided into five topographical regions (Vithanage, 1997).

1. The central highlands
2. The southwest lowlands
3. The east and southeast lowlands
4. The northern and north-central lowlands
5. The coastal fringe

The central highlands consist of the high mountain massif in the south to the transverse valley of the Mahaweli River. It constitutes high plains - Horton Plains, Moon Plains, Elk Plains, Kandapola Plains, and Ambewela Plains - and several high peaks - Pidurutalagala (2,524 m), Kirigalpotta (2,395 m), Totapola Kanda (2,357 m), Kudahagala (2,320 m) and the Adam's Peak (2,243 m). The peak wildernesses around the Adam's Peak and the Horton Plains have recently been declared as world heritage sites by the UNESCO.

The conspicuous topography of the southwest lowlands is the elongated parallel ridges running in the north-south direction, which are cut by the rivers flowing east to west originating from the central highlands. The east and southeast lowlands comprise undulating plains with isolated hills with flat tops. The north-central lowlands are somewhat similar to those in the east. The land over most of the country, other than the central highlands, is almost flat undulating with gentle slopes. (Fig. 1.1)

Fig. 1.1 Relief Map of Sri Lanka

Source: Wikipedia (2010)

The land above the 300 m contour, an extent of about 14,000 km^2, was declared to be environmentally very fragile area, being subject to heavy rainfall, land-slides and erosion. Most of this land, originally covered with rain forests, was opened up for monoculture tea plantations by the British in the 19th century and this has aggravated the situation.

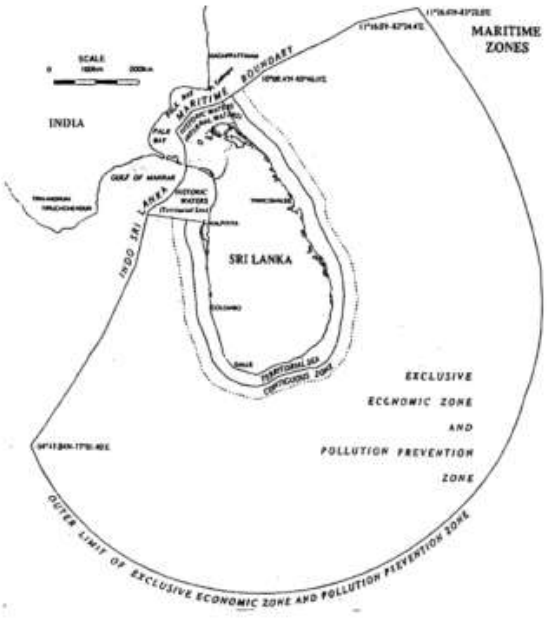
1.1.2 Coastal and Maritime Zone

The country's coastline is approximately 1585 km in length (CCD, 1990). The coastal fringe consists of estuaries, lagoons, marshes, sand dunes, spits, mangroves, off shore islands, deltas and associated features. On the seaward side of the coral reefs, and coastal and estuarine sea grass beds are found. Sri Lanka stands on the shallow Indian continence shelly which has a depth of only 70 m extending up to 19 km from the coast other than in the north and northeast where it merges with the continental shelf of the Indian peninsula. The continental shelf covers 26,000 km^2 or little less than half the land area of the country. Beyond this shelf, the sea bed drops to more than 900 m within 3 km. Within Sri Lanka's territorial waters are a large number of small islands, numbering about 113, but nearly half of which are below 100 ha in extent. There are only 6 major islands larger than 1,000 ha with the largest having an extent of 12,600 ha (Mannar Is.) and 5 others with extents between 1000 ha and 5000 ha, 4 of which are close to the northern peninsula and the other on the west coast at Kalpitiya (Vithanage, 1997).

In terms of the UN convention on the Law of the Sea, ratified by Sri Lanka in July 1994, the country is entitled to a total extent of approximately 489,000 km^2 of maritime waters. Comprising 437,000 km^2 exclusively economics zone (EEZ) and 51,250 km^2 maritime waters including Internal waters, Historic waters, Territorial sea, Contiguous zone and the EEZ. With a relatively small land area of 65,625 km^2, this gives a land to ocean ratio of 1:7.5, underlining the economic importance of the coastal zone in terms of coastal resources, economic returns and livelihoods. Fig. 1.2

In addition, according to a decision taken by the UN Third Conference on Law of the Sea, Sri Lanka would have rights for a considerable wider area than the EEZ, depending on the sediment depth around the country. This area covers a large extent of the southern part of the Bay of Bengal extending up to about 1.4 Mkm^2, going below even the equator (Wijeyananda, 1997). Sri Lanka has completed the necessary survey of the sea bed to determine the sediment depth, and filed its claim with the UN recently. According to the results of these studies Sri Lanka can claim an oceanic area almost equal to twenty-five times of its land area with thick sediment cover having a high potential of hydrocarbon accumulation (Tantrigoda, 2010).

Fig. 1.2 Map showing Sri Lanka's Exclusive Economic Zone



Source: Wijeyananda, 1997

The local administrative divisions bordering the coast cover approximately 19% of the land area and inhabited by 22% of the population (excluding Northern Province as no data were available). The

coastal zone (CZ) comprising these divisions have average widths in the range 3 - 15 km with widths higher than 10 km lying in the sparsely populated south-east and eastern parts.

With many of the major cities located on the coast, 65% of the urbanized land area is in the CZ, and also 17% of agricultural lands and 20% of home-gardens. The principal road and railway network connecting the coastal cities are located along the coastline. Some of the principal industries are located in the CZ including 80% of the tourist infra-structure. Thus the CZ forms a critical area both in terms of ecological and economic importance. In view of the high population and developed built-areas in the CZ, the damage caused by 2004 tsunami was severe in terms of both the loss of lives and infra-structure.

The coastline supports a highly productive marine ecosystem. The main ecosystems along the coast important for ecological processes and providing ecosystem system services are the mangroves, coral reefs and sea grass beds. During 2004 tsunami, it was observed that the areas covered with mangroves suffered a minimum damage to the coast line, which has prompted launching of programmes to increase mangrove cover along the coast line. A study carried out after the Tsunami showed that in the Eastern Province and Southern Province, the Tsunami waves have penetrated on an average 300 m interior from the coast with penetration up to even 1 km at certain places.

1.2 Climate

Sri Lanka's climate is characterized by the tropical monsoon system. The rainfall pattern is of primary significance in defining the island's climate. Daily observations of the key climatic parameters were carried out by the Department of Meteorology (DoM) at 18 stations out of 22 stations (4 being not accessible due to the civil conflict). Rainfall observations were supplemented by observations made by a large number of registered organizations.

1.2.1 Temperature

The annual mean surface air temperature of the island is in the range 20 °C - 30 °C, with an average of about 27°C. It shows a diurnal variation, with a maximum temperature attained early afternoon, and the minimum just after sunrise, which is in the range 5-10°C, depending on the elevation. There are considerable diurnal, seasonal and spatial variations in the temperature leading to important region-specific patterns.

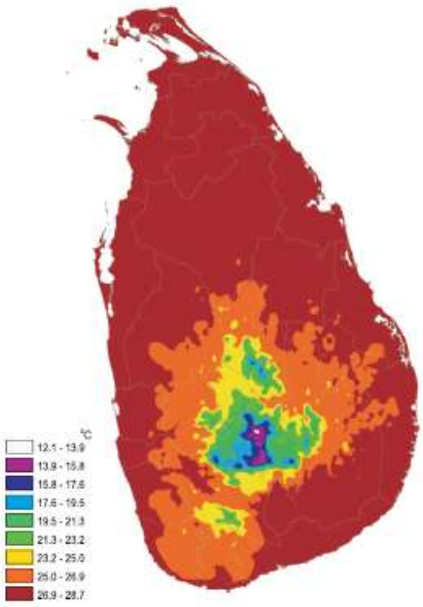
In the lowlands, the temperature rarely drops below 20°C, but it may exceed 30°C up to 35°C during prolonged droughts, particularly in the extreme north-west and south-east corners where the rain fall is a minimum. The mean annual temperature at higher elevations declines being governed by the adiabatic lapse rate, reaching a mean annual temperature of about 15°C at the high elevation station Nuwara Eliya.

In general, the following can be said about the temperature variations in Sri Lanka (MD, 2010):

- Number of warmer nights has increased
- Number of warmer days has increased
- Number of colder nights has decreased
- Number of colder days has decreased

The annual average mean temperature map constructed based on observations made at the 18 stations is shown in Figs. 1.3.

Fig. 1.3 Annual average mean temperature 1961-2000



Source: MD (2010)

1.2.2 Rainfall

The most important feature of the monsoon wind regime which controls the country's rainfall pattern is the seasonal alteration of atmospheric flow patterns, which is caused by the seasonally modulated excess heating of the Central Asian landmass in summer and the excess cooling in winter compared to the adjacent oceans (Mitra et al., 2002) Rainfall associated with the monsoon falls into the following two periods.

- Southwest Monsoon (SWM) period: May to September
- Northeast Monsoon (NEM) period: December to February

During the SWM, the southwestern lowlands and windward slopes of the central highlands receive 500 mm to 4000 mm of rainfall annually. The rest of the island receives less than 500mm during this period. During the NEM, the winds blow from the Central Asia across the Bay of Bengal to the directions of northeastern lowlands and central highlands. The rains generated from these winds are relatively low, being in the range 500-2500 mm received by eastern and northern plains and by the eastern sector of the central highlands where higher rainfall is received.

The southwesterly winds from the southern hemisphere and the northeasterly winds from the northern hemisphere converge over an area known as the Inter-Tropical Convergence Zone (ITCZ) causing large-scale convective activity. During SWM, ITCZ lies to the north of Sri Lanka, while during NEM, it lies to the south (Mitra et al., 2002). In between the two monsoons, ITCZ lies over Sri Lanka bringing in heavy rains resulting from the convective activity. These two periods are:

- First Inter-Monsoon (FIM) period: March to April
- Second Inter-Monsoon (SIM) period: October to November

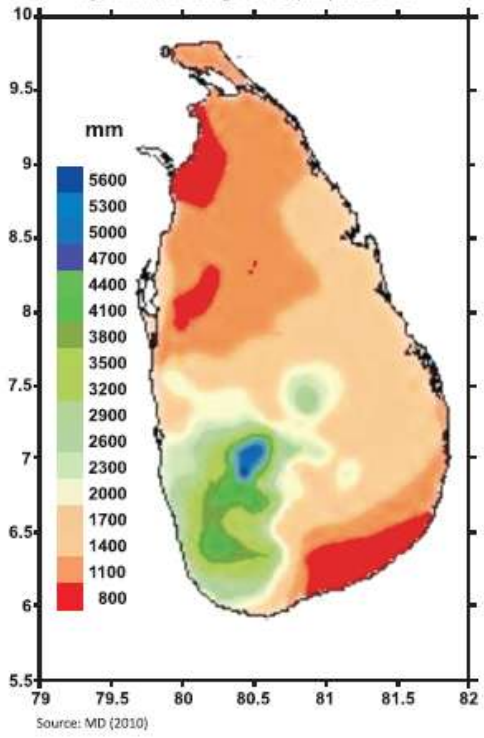
The amount of rainfall averaged over 1961-90 received in each of these 4 periods is shown in Table 1.1. While the monsoons bring rain either to SW part of the country or to NE, convective activity during the inter-monsoons bring rain to all parts of the country, with more rain spread over the country during the SIM than in the FIM. The annual rainfall received in the country averaged over the period 1961-2000 is shown in Fig.1.4. This clearly shows the demarcation of the wet zone covering the SW quadrant receiving rainfall in excess of 2500 mm a year. The annual average rainfall of 1860 mm received by the country is significant as it is used to determine the water balance in the country.

Table 1.1 Average rainfall during different rainfall seasons for 1961-1990

Season	Period	Average rainfall mm	% of annual Total rainfall	Coef. of variation %
FIM	March - April	268	14	27
SWM	May - Sept.	556	30	16
SIM	October - Nov.	557	30	23
NEM	Dec. - Feb.	479	26	41
Annual	Jan. - Dec.	1860	100	

Source: Meteorology Department

Fig. 1.4 Annual average rainfall (mm) 1961-2000



Source: MD (2010)

The cropping calendar adopted by farmers depends on this rainfall pattern. The first cropping season commences with the SWM rains and is referred to as the *Yala* season, while the second season commences with the SIM rains and is referred to as the *Maha* season. Since there is island-wide rains during SIM period, *Maha* cultivation is also practiced in all parts of the country.

1.2.3 Agro-ecological Regions

The country has been traditionally divided into two climatic zones - wet zone (WZ), and dry zone (DZ), mainly based on annual rainfall distribution up to fifties, but a Colombo Plan study on the country's land use, forestry, hydrometeorology and soils carried out during 1956-61 has resulted in re-demarcation of the climatic zones into three with a newly introduced intermediate zone (IZ) (Panabokke, 1996).

While the annual rainfall was the key parameter used in the new classification, the variation of the nature of other parameters such as soils, vegetation and rainfall frequency were also taken into consideration. In the revised system,

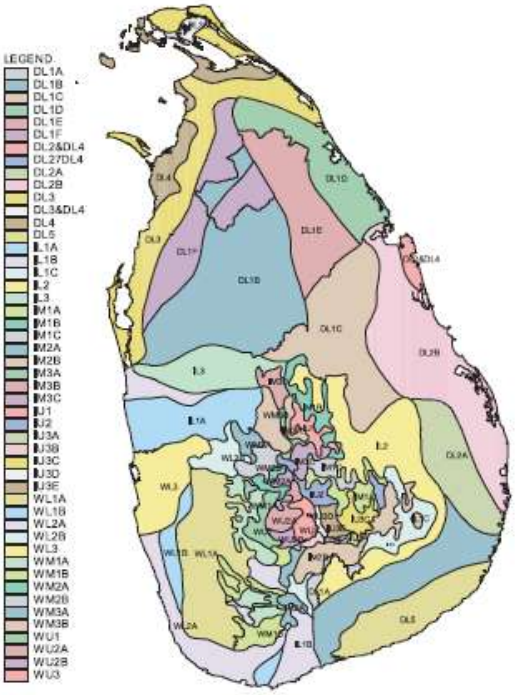
WZ receives relatively high mean annual rainfall over 2,500 mm, while DZ receives less than 1,750 mm and the IZ lying in between receives rainfall in the range 1,750 - 2,500 mm (Punyawardane, 2008). In addition, two relatively small regions lying at the extreme NW and SE ends of the country receiving below 100 mm of rainfall annually are referred to as Arid Zones (AZ). Both WZ and IZ fall on all three elevation ranges, while DZ and AZ fall only over the low-country.

The revised classification, however, lacked temperature information, which is important for crops such as tea. Since temperature is governed by the elevation according to adiabatic lapse rate of about -6.5°C/km, temperature variation was incorporated by including elevation variation into the system. In the new classification, elevation was divided into

three ranges low, mid and up-country. The mid-country lies between 300 and 900 m elevation and the other two below and above it, respectively. Each climatic/elevation zone was further sub-divided into several sub-regions based on several factors including annual rainfall, elevation, land use and soil characteristics. In respect of rainfall, rather than considering the annual value, the seasonality of rainfall and the 75% expectancy values of annual rainfall were incorporated (Panabokke, 1996). Each region is referred to as an Agro-Ecological Region (AER), and there are 10 such regions in the WZ, 9 in the IZ and 5 in the DZ.

With the availability of more spatial and temporal data, and advancement of Geographic Information System (GIS) technology, in 2002, the 24 AERs were further sub-divided into 46 agro-ecological sub-regions on an enhanced scale (Punyawardane, 2003). The demarcation of the island into these sub-regions is shown in Fig. 1.5. Each sub-region is denoted by a code. The three major climatic zones are indicated by the first upper case letter of the code (W, I and D). The second upper case letter of the code (L, M and U) denotes three categories of elevation. The numerical character in the third place of the code represents a more detailed moisture regime (rainfall and evaporation combined) with a degree of wetness on the scale of 1 to 5 where 1 being the most favorable. The lower case letter in the fourth place indicates a sub-region as determined by rainfall distribution and other physical environmental factors where degree of wetness decreases a > f.

Fig. 1.5 Revised Agro-Ecological Regions in Sri Lanka



Source: Punyawardane (2003)

1.3 Administrative Structure

Sri Lanka is a democratic, socialist republic and is a unitary state, governed by a central government and 9 Provincial Councils (PC). These were established in 1987 through an amendment to the constitution with a view to devolve power to all provinces in an equitable manner enabling self-governance in all local matters. This is one of the measures taken by the government in seeking a political solution to the civil conflict that plagued the country for nearly 30 years.

1.3.1 Central Government

The head of state is the President elected by the people once in six years. He is the Chief Executive as well as the Commander-In-Chief of the armed forces. The President is responsible to the Parliament, which is a unicameral 225-member legislature, comprising 196 elected members and 29 appointed members selected out of national lists. The President appoints and heads the cabinet of ministers composed of elected and appointed members of parliament. The President's deputy is the Prime Minister. The parliament has the authority to make all laws. The election of

members to the parliament is based on a district-wise proportional representation system since 1978, when the country adopted a new constitution which also gave executive powers to the President, doing away with the British parliamentary system that prevailed since independence from British rule in 1948.

For administrative purposes, the country is divided into nine provinces, each of which is divided further in to 2-4 administrative districts, depending on the population distribution. Seven provinces have been named according to their relative geographical position - Western Province (WP), Southern Province (SP), Northern Province (NP), Eastern Province (EP), North-Western Province (NWP), North-Central Province (NCP) and Central Province (CP). Two provinces have been named based on historical divisions - Sabaragamuwa Province (SGP) and Uva Province (UP). There is wide disparity between the development levels of the provinces, the highest being the WP while the lowest the UP.

The districts are named after each capital city. Each district is divided into several Divisions totaling 328, each of which is administered by a Divisional Secretariat (DS). Under each DS division, there are a large number of village level administrative divisions coming under a Village Officer (*Grama Niladari*). The officer is responsible to the government for the implementation of relevant rules and regulations at village level, collection of socio-economic information from the villagers and attending to complains with regard to minor offences among villagers.

1.3.2 Provincial Councils

The 13th amendment to the constitution adopted in 1987, established nine Provincial Councils with specific administrative powers devolved to them. Many subjects were devolved to the PCs while a few such as defense, security, immigration, communications and higher education were kept with the Central Government. Social infrastructure including schools and health services are administered by the PCs, though a few selected institutions were kept directly by the Central Government. Each PC is headed by a Governor appointed by the President and has its own cabinet of ministers, which is chaired by a Chief Minister. Members to the councils are elected once in 5 years.

1.3.3 Local Government

The local administrative system operating in Sri Lanka comprises 12 Municipal Councils, 51 Urban Councils and 257 Divisional Councils (Pradeshiya Sabha) to which people elect members once in 4 years. The maintenance of public utilities such as local roadways, community water supplies, recreation areas, public markets and regulation of construction activities as well as waste collection and disposal are among the responsibilities of the local bodies.

1.3.4 International Relations

Sri Lanka is a founder member of the Non-Aligned Movement and the Colombo Plan. It is also a member in several regional cooperative organizations including Asia-Pacific Economic Cooperation (APEC), the South Asian Association for Regional Cooperation (SAARC), the South Asia Co-operative Environment Programme (SACEP), the Indian Ocean Marine Affairs Cooperation (IOMAC), Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) and the Indian Ocean Rim Association for Regional Cooperation (IOR-ARC). Sri Lanka is a Party to about 35 UN multi-lateral agreements (MOE) (MENR, 2008a) and treaties and a member of most UN affiliated organizations.

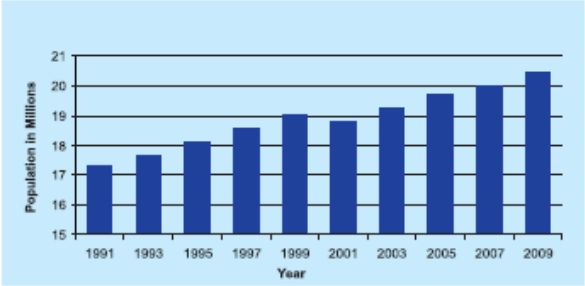
The Government of Sri Lanka, during the last decade, has submitted several environment related reports to international organizations. These included the State of the Environment submitted to SAARC (MENR, 2002a), Middle Path to Sustainable Development (SD) which is the National Report submitted to the World Summit on SD (MENR, 2002b), Caring for the Environment 2003-2007 - an Action Plan for SD (MENR, 2003), Caring for the Environment II - an Action Plan 2008-2012 (MENR, 2008b), which is a follow up to the previous report, 4th Country Report to the Convention on Biodiversity (MENR, 2009a) and Environment Outlook 2009 (MENR, 2009b) submitted to UNEP.

1.4 Population

The current population, its growth, distribution within the country and future projections are described in this section.

1.4.1 Current population and its growth

Fig. 1.6 Population growth during 1991 - 2009



Source: CBSL (2010a)

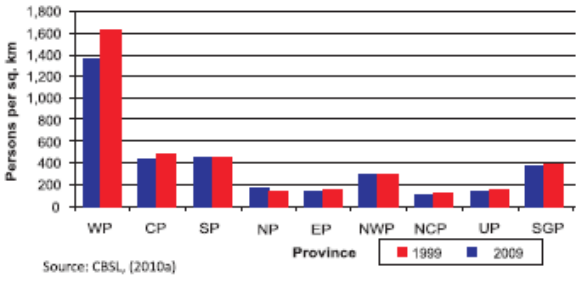
The last island-wide census was taken in 1981. Though a census was taken in 2001, it did not cover the NP and EP in view of the conflict situation, but the gaps were filled with projected values. The population growth during 1991 - 2009 is shown in Fig. 1.6 based on Central Bank statistics (CBSL, 2010a).

It is seen that there is a discontinuity in the trend in 2001, which could be attributed to the fact that population estimates prior to 2001 were projections based on 1981 census data while those beyond 2001 were projections based on 2001 census data which were subject to uncertainties because of the conflict situation in the North and East. With the displaced people returning to their homes since the end of the conflict, it is expected that the national census planned in 2011 will provide more island-wide accurate data. The average annual growth during the 16 year period is 0.93%.

1.4.2 Population Distribution

There have been two migration patterns in the country during the last 50 years. One is the influx of people in to the city from rural areas looking for better employment, while the other has been the migration of landless people from rural areas to new colonization schemes established in the NCP and EP. Yet, many socio-economic factors such as lack of infrastructure, schooling, housing, medical care, and the prevalence of malaria and adverse climatic conditions prevailing in the NCP and EP have seen the uneven population distribution pattern to continue showing a clear demarcation between the WZ and DZ with the highest density in the WP (Fig. 1.7).

Fig. 1.7 Distribution of population density among provinces in 1999 and 2009



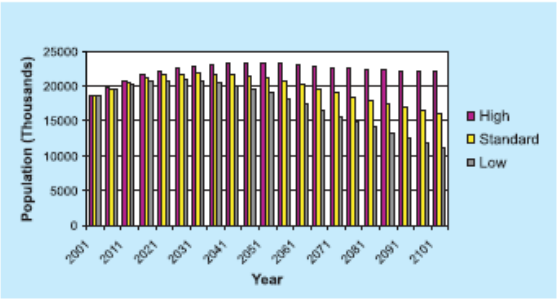
Source: CBSL, (2010a)

In 2009, Colombo district in WP has the highest population density of 3,729 per km^2, while Moneragala district in UP has the lowest density of 79 per km^2. According to 2001 census, 72% of the population lived in rural areas, 22% in urban areas and 6% in estates. The last category comprises the descendants from the Indian migrant labour brought down to work in British owned plantations or estates who still live within them and considered a separate socio-economic group.

1.4.3 Future Projections

Sri Lanka's future population is projected under three scenarios - high, standard and low, as shown in Fig. 1.8. The highest projected population is shown in the year 2046 as 23.3 million. The lowest projected population is shown in 2101 as 11.2 million. Sri Lanka's total population will continue to rise in the foreseeable future and reach stability for some time and a declining trend could occur thereafter. While the high scenario projects a decreasing rate of 0.08% while approaching 2100, the low scenario shows a higher decreasing rate of 0.75% for the same period.

Fig. 1.8 Population projections under three scenarios



Source: de Silva, (2007)

1.5 Water Resources

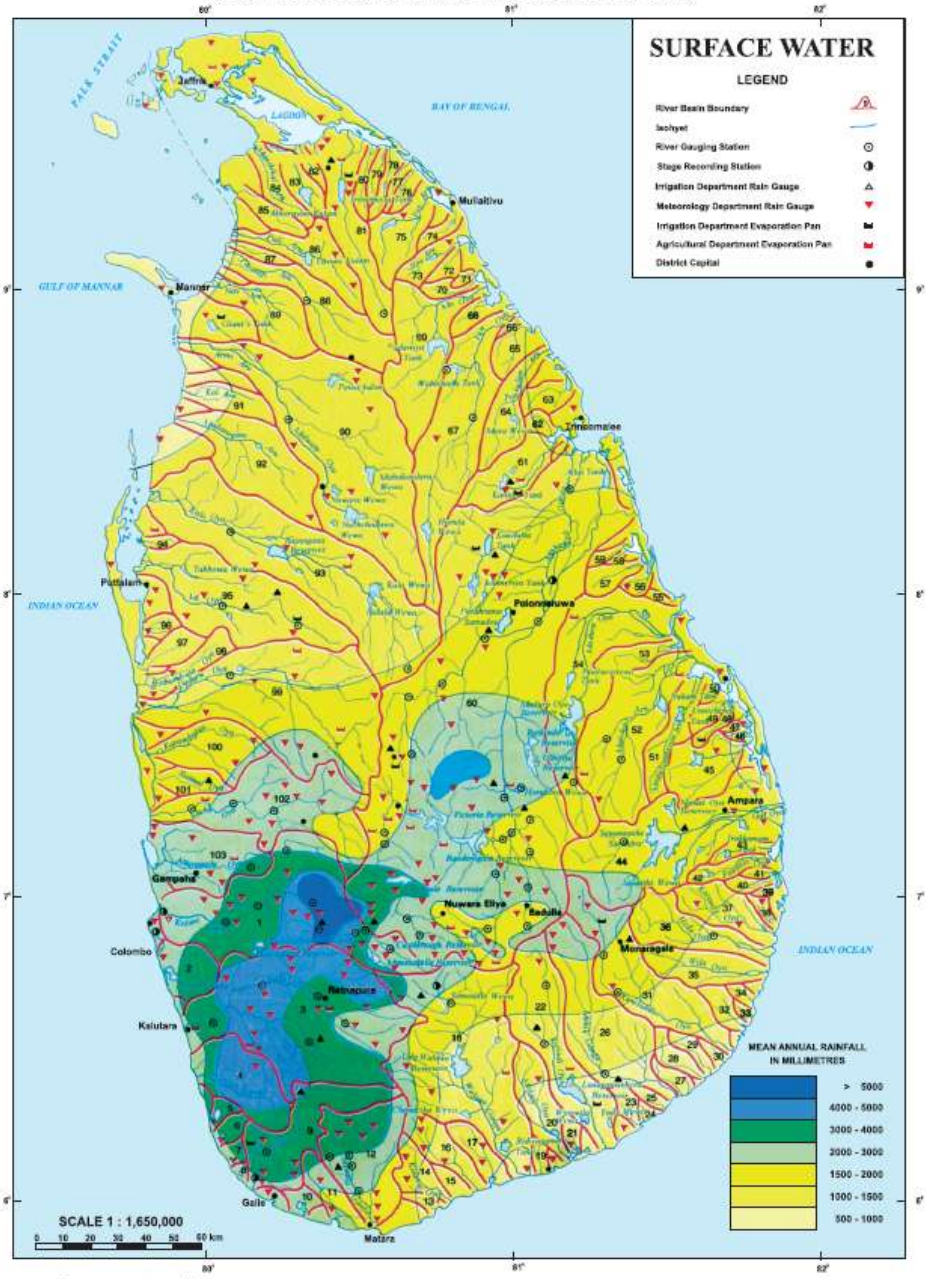
Being an island, Sri Lanka receives its water supply solely from rainfall, brought in from moisture-laden monsoonal winds flowing southwesterly and northeasterly directions during alternate seasons. Annual rainfall replenishes both the surface and most of ground water sources. Sri Lanka is generally considered to have adequate supplies of water though not everywhere all the time.

1.5.1 Surface Water

Sri Lanka has 103 rivers all of which, except the longest mahaweli river, flow radially mostly originating from the central mountains (see Fig. 1.9). The mean annual yield of the 103 river basins in the island is estimated to be 3.33 million ha.m, of which 1.36 million ha.m flow through the water deficit regions of the country. Mahaweli River's watershed covers an extent of 10,327 km^2. The river has a mean annual run-off of 9,000 Mm^3, which is approximately 20% of the total run-off of all the rivers in the island. Sri Lanka's rivers serve as the source of water for agriculture, industries and peoples' needs of sanitation and drinking where pipe-borne water is not available.

The mean annual rainfall received over the country for the period 1961-90 was 1,860 mm (see Table 1.1). This gives the average volume of fresh water received as 122 Gm^3. According to Madduma Bandara (2000), the average annual river flow has been estimated as 35% of the rainfall, which is equivalent to 43 Gm^3. Out of the balance 65% or 79 Gm^3, 20% or 16 Gm^3 seeps to the ground to replenish ground water sources. The remaining 63 Gm^3 is lost to the atmosphere through evaporation from soil and transpiration from vegetation. Water is extracted from rivers or wells for the benefit of man - sanitation, drinking, irrigation, hydro power - but this water goes back to the soil or waterways.

Fig. 1.9 The distribution of Sri Lanka's river system and their basins.



Source: www.google.com/fao.org

One of the main characteristics in the distribution of surface water is its excess in the WZ and deficit in the IZ and DZ. This characteristic is directly related to the differential rainfall pattern in the country. The availability of surface water resources is determined to a great extent by the evaporation rates in Sri Lanka, which are in the range 1,000-1,750 mm/year in the WZ as quoted by Madduma Bandara (2000). High temperature, prevailing dry winds and non-availability of a plant cover are the contributory factors in increasing high evaporation rates in the DZ to exceed 2,000 mm/year. When considering the amount of rainfall received by the DZ and AZ, it is clear that the high evaporation rates have increased the dryness to a considerable degree.

1.5.2 Ground Water

Sri Lanka's ground water supply is estimated to be around 7.25 Gm^3 per year, which is 15% of the surface water resource (MENR, 2003). According to Panabokke and Perera (2005) "the shallow karstic aquifer of the Jaffna peninsula is the most intensively used ground water resource in this country. The least utilized, yet adequately studied are the deep confined aquifers, which occur within the sedimentary limestone and sandstone formations of the northwest coastal plain. The shallow coastal sand aquifer that occurs on the coastal beaches and spits are intensively used and occupy a total extent of approximately 125,000 ha. The alluvial aquifers of this country constitute one of the most diversified forms in the tropical region, and occur in both coastal and inland flood plains, inland river valleys of varying size, and old buried river beds. These are fully used at present especially in the WZ.

It has now been recognized that the groundwater in the hard metamorphic rock in this country is found in the weathered rock zone, or the regolith, as well as in the deeper fracture zone of this hard rock region. This shallow regolith aquifer is mainly confined to a narrow belt along the inland valley systems of this undulating mantled plain landscape, and despite its low yield and transitivity, it has provided the basic minimum water needs for village settlements over several millennia. Recent developments in agro-well farming in the north central provinces of the country are wholly depended on this shallow ephemeral groundwater.

In Sri Lanka, groundwater resources are widely used for domestic, commercial and industrial purposes, small scale irrigation, water supply schemes and other purposes. About 80 percent of the rural domestic water supply needs are met from groundwater by means of dug wells and tube wells.

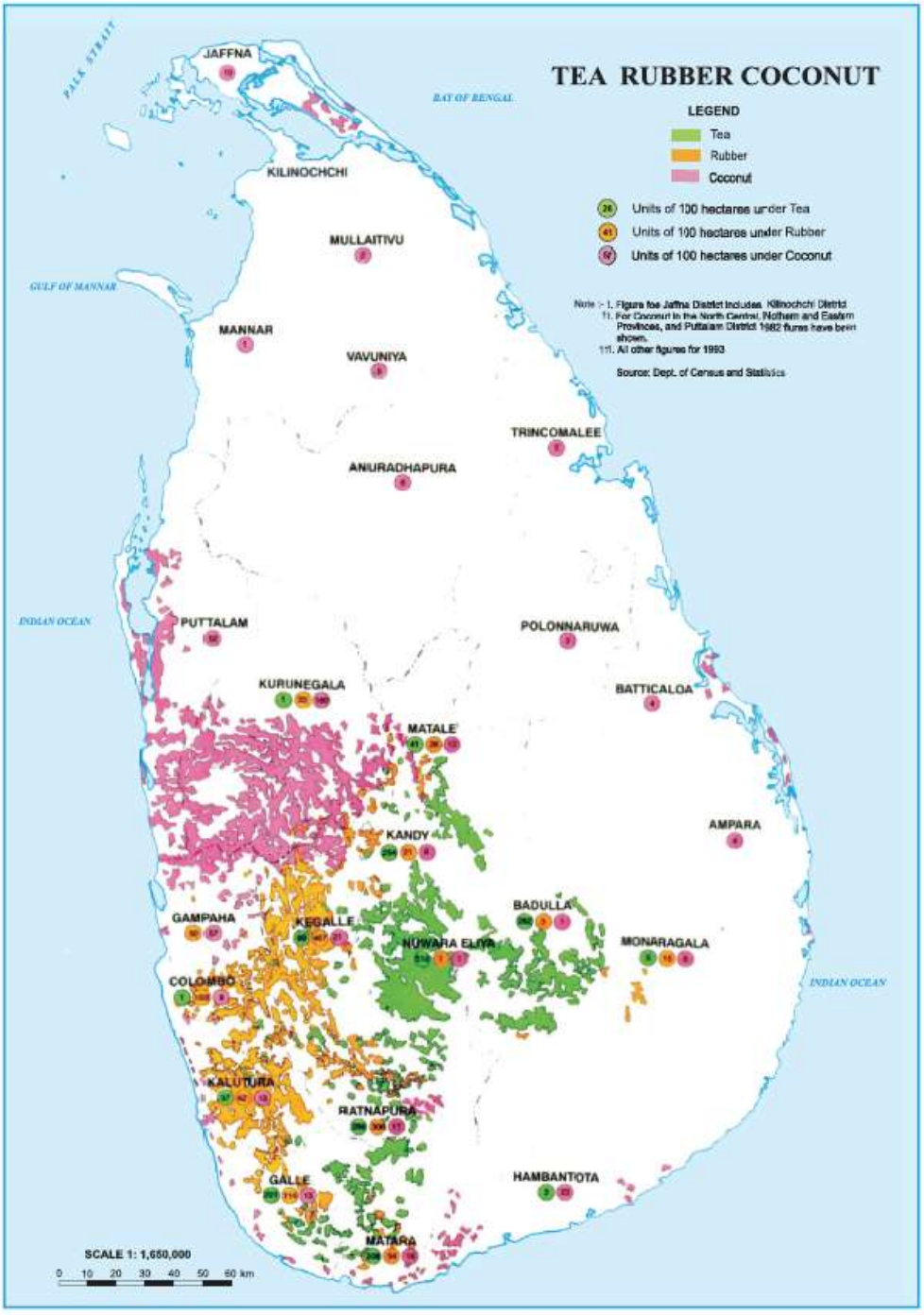
1.6 Agriculture

The last island-wise agricultural census, excluding the NCP and EP, was taken in 2002 (C&SD, 2008). The major crops and plantations grown in Sri Lanka are rice, tea, coconut, rubber, sugar cane, cinnamon, pepper, cashew and a variety of spices and seasonal crops. Out of 6.5 million ha of total land area, approximately 1.86 Mha constitutes cropland, out of which about 720 kha is under rice cultivation, while the plantation crops tea, rubber and coconut cover approximately 213 kha, 124 kha and 395 kha, respectively. The extents of these plantations are shown in Fig. 1.10. The minor crops occupy about 150 kha.

1.6.1 Cropping Seasons

In Sri Lanka, rice and other seasonal crops are cultivated in two seasons - *Yala and Maha* which coincide with the two rainy seasons. *Yala* season begins with the commencement of the SWM rains in the WZ, and rain-fed *Yala* cultivation is

Fig. 1.10 The distribution of land covered with tea, rubber and coconut plantations.



Soure: Arjuna Atlas (1997)

carried out mostly in the WZ. *Maha* season begins in the 4th quarter with the commencement of the SIM and ends during NEM period in the 1st quarter of the following year, with cultivation carried out in all three climatic zones because of the island-wide rainfall received during SIM. However, there is a wide variation of the actual days of sowing and harvesting in different parts of the country.

1.6.2 Rice Cultivation

Rice is grown mostly in the low- and mid-elevations, in all three climatic zones. It is cultivated in the two seasons - *Yala and Maha* - under both rain-fed and irrigated conditions. However, in each season only a fraction of the land that has been prepared for rice cultivation (referred to as *Asweddumised* land) is actually cultivated. Generally, *Maha* season covers a larger extent than *Yala*, in view of the fact that the commencement of the *Maha* season coincides with the SIM

Table 1.2 Rice extents sown and asweddumised during 2004-2008

Category	Estents sown and *asweddumised* in kha				
	2004	**2005**	**2006**	**2007**	**2008**
Sown *Maha*	520.7	580.6	591.3	525.4	581.6
Sown *Yala*	257.9	356.6	319.2	291.4	471.4
Total Sown/year	778.6	937.2	910.5	816.8	1053.0
Asweddumised	701.9	703.3	708.7	712.1	716.8
% Sown *Maha*	74.2	82.6	83.4	73.8	81.1
% Sown *Yala*	36.7	50.7	45.0	40.9	65.8

Source: C&SD. (2009)

period when the entire country receives substantial amount of rainfall. Table 1.2 gives the rice extents sown in each season during 2004-2008. It is seen that during *Maha*, 74-82 % of rice land is sown, while in *Yala*, only 37-65 % is sown.

Table 1.3 shows the seasonal production of rice over the last few years, which shows the correspondingly higher production in *Maha* season than in *Yala* season.

Table 1.3 Production of paddy (rice with husk) in the two seasons

Year	Production kt		
	Maha	*Yala*	Total
2005	2,012	1,233	3,245
2006	2,136	1,206	3,342
2007	1,973	1,158	3,131
2008	2,125	1,750	3,875
2009	2,384	1,266	3,650
Average	**2,126**	**1,323**	**3,449**

Source: C&SD. (2009)

Sometimes, farmers grow subsidiary crops in land not sown with rice in *Yala,* depending on the availability of water. In mid-elevations, terraced fields are a common sight in hill slopes, while in the low-land, rice fields occupy long stretches of valleys lying in between high ground. In the IZ and DZ, rice fields are irrigated with water stored in tanks built many centuries ago, as well as in recently built irrigation systems. On an average, 70% of rice extents receive water from either major or minor irrigation schemes while only 30% is rain-fed, resulting in a larger extent of rice being cultivated in the DZ than elsewhere.

1.6.3 Tea Cultivation

Tea is grown in 14 districts mostly located in the WZ and the balance in the IZ at all elevations. The census carried out in 2002 showed an extent of 212,700 ha being under tea, out of which the six districts - Nuwara Eliya (50 kha), Ratnapura

(38 kha), Badulla (31 kha), Galle (26 kha), Matara (24 kha) and Kandy (23 kha) covered 90% of the extent (C&SD 2008). Tea is a totally rain-fed crop very much sensitive to the temperature and rain fall. The productivity of tea land is thus dependent on rainfall and temperature. Spells of long droughts reduce the production severely.

The extent of tea held by small holders has increased to 44% by 2002. The majority of the small holders are in the low elevations, while in the high elevations, tea land is owned mostly by estates. The tea industry keeps records of its productions separately for three elevation categories - low grown, medium grown and high grown - the elevation ranges being below 610 m, 610-1,220 m, and above 1,220 m, respectively (CBSL, 2002). The elevation category is an important factor in the marketing of tea, as its flavor depends on the elevation and the region. Currently, about 90% of the tea production is exported bringing in annual revenue of more than Rs. 130 billion.

1.6.4 Rubber Cultivation

Rubber is grown in low- and mid-elevations covering WZ and IZ. The three districts - Kegalle (36 kha), Kalutara (30 kha) and Ratnapura (22 kha) - all in the WZ, covered over 75% of the total extent. The census taken in 2002 showed that small holders held 42% of the rubber land while it has been only 35% in 1982. The total extent also has reduced from 171,150 ha in 1982 to 116,500 ha in 2002, a 32% reduction. Of the three plantation crops, rubber is least affected by climatic variations. Rubber plantations are replanted generally in a 30 year cycle, and the timber is a source of fuel wood and is also utilized for furniture after treatment. The government has now decided to introduce rubber in the DZ districts and has already allocated land for that. Currently, only 40% of rubber is exported in the raw form, while the balance is used in making value added productions locally, some of which are exported.

1.6.5 Coconut Cultivation

Coconut is grown in all elevations except very high and in all three climatic zones in 23 districts. The major coconut growing areas, however, are in Kurunegala (134 kha), Puttalam (46 kha) and Gampaha (43 kha) districts, which are located in the lowland intermediate and wet zone. Plantations in these three districts cover about 57% of the total extent, which was 394,800 ha in 2002. It is a rain-fed crop dependent on rain fall and temperature. However, prolonged droughts could severely affect the coconut plants. In addition to being grown as a monoculture, it is widely grown in home gardens in all parts of the country. The productivity of coconut depends largely on the soil type. Coconut plantations are also susceptible to pest attacks. Most of the coconut production is consumed locally and only 14% is exported, which is mainly in the form of desiccated form and oil.

1.6.6 Other Crops

A wide range of subsidiary crops such as sugar cane, onions, cow pea, chillies, maize, soya bean, cassava, green gram, ground nut, gingerly, banana and vegetables are cultivated as seasonal crops covering a total extent of nearly 150,000 ha in 2009 (CBSL, 2009). In addition, perennial crops such as cinnamon, cloves, cardamom, pepper and cocoa are grown for both export and local market, covering a total extent of about 75,000 ha in 2009. Today, cinnamon from Sri Lanka meets about 75% of the global demand and its superior quality was known world-wide for centuries. The export of spices and other minor crop products has brought in annual revenue of over Rs. 17 billion in 2009.

1.7 Forests and Biodiversity

1.7.1 Forests

According to the survey carried out in 1999 the natural forest cover in the country was 22% of the country's land area. The total natural forest cover has shown a decrease from 2,046,600 ha in 1992 to 1,942,220 ha in 1999. The Forest Department (FD) manages 10,670 km^2 of land which amounts to 18% of island's natural habitats. The extent of land set apart for protection in the country is about 951,333 ha or about 14% of the island's total land area. Of this, the Wildlife Conservation Department (WCD) administers 8,618 km^2 or 12.5% and all are designated as protected areas. Table 1.4 gives the breakdown of different types of forests in the country in 1990 and 1999 which shows a 5% decline of forest cover during this period. A new forest inventory is being prepared by the FD using satellite imagery, and it is expected shortly.

According to the Report of the Forestry Sector Master Plan (FSMP) (MALF, 1995) timber is extracted from forests to meet various needs of man, including fuel-wood, furniture etc. FD has been engaged in reforestation as well as aforestation programmes resulting in the addition of several thousands of hectares of plantations annually. However, the extents added each year seem to have declined due to various reasons. Fig. 1.11 shows the distribution of forests in 1999.

Table 1.4 Classification of Natural Forests in Sri Lanka in 1992 and 1999

Forest Type	Extent (ha)	
	1992	1999
Montane Forest	3,108	3,100
Sub Montane Forest	68,838	65,792
Lowland Rain Forest	141,549	124,341
Moist Monsoon Forest	243,877	221,977
Dry Monsoon Forest	1,094,287	1,027,544
Riverine Forest	22,411	18,352
Mangroves	8,687	9,531
Sparse and Open Forest	463,843	471,583
Total – Natural Forests	**2,046,600**	**1,942,220**
Planted Forests	201,000	135,500
Total Forest Cover	**2,247,600**	**2,077,720**

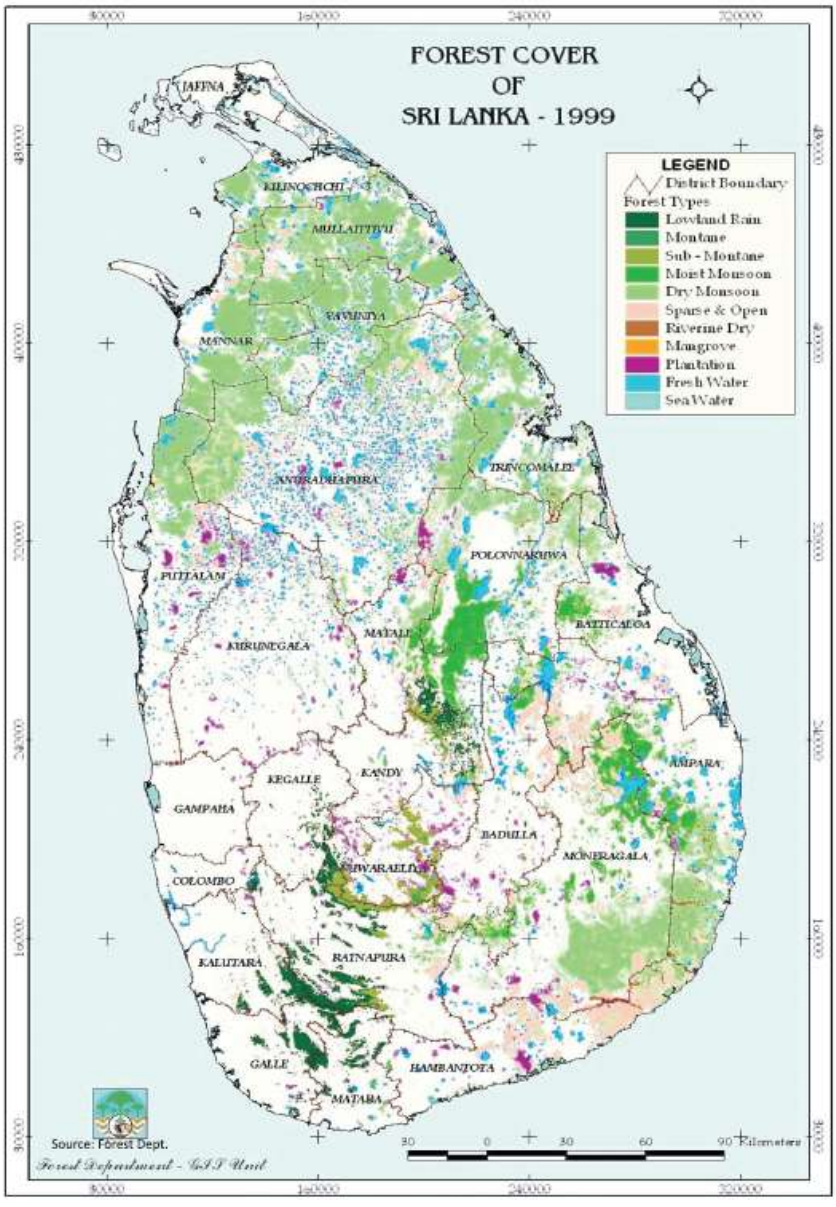
Source: Forest Dept (1999), C&SD. (1995), and C& SD (2003).

1.7.2 Biodiversity

Despite its small size, Sri Lanka exhibits a wide array of ecosystems with a remarkable diversity of species - considered to be the richest per unit area in the Asian region. Isolation for over 20 million years has also resulted in an exceptional degree of endemism among Sri Lanka's wild flora and fauna.

Presently, Sri Lanka has 677 species of indigenous vertebrate (excluding marine forms), of which 43% are endemic, with highest endemism among amphibians (85%), freshwater fishes (54%) and reptiles (50%), as reporter in the (MFNR, 2009a). "Similarly" the island is home to over 3000 angiosperms, of which a quarter comprises endemic species. Most invertebrate taxa in the island have been incompletely surveyed, but a rich diversity is apparent. Species diversity is also high in coastal and marine systems that sustain the food and ornamental fishery. The threats to Sri Lanka's biodiversity have been identified, chief among which are habitat loss and fragmentation, habitat degradation, over exploitation of biological resources, loss of traditional crop and livestock varieties and breeds, pollution, human - wildlife conflicts, a burgeoning spread of alien invasive species and increasing human population density.

Fig. 1.11 Distribution of different types of forest cover in 1999.



The 2008 IUCN global list of threatened species contains 534 species found within Sri Lanka, of which 119 are invertebrates, and 280 are plants. According to the 2007 Red List of Threatened Fauna and Flora of Sri Lanka, 223 species of vertebrates (amounting to 33% of all vertebrate species in the island), of which 62% were endemics, were found to be threatened; among them about 57 species of inland vertebrates assessed were Critically Endangered.

Although forest loss has occurred in all climatic regions, clearing of wet zone forests for plantation agriculture has had the most serious consequences. These forests that are the main repositories of the country's rich biodiversity, and much of the endemics, have continued to recede perceptibly due to the demand for land in the densely populated wet zone. They exist today as a series of small and fragmented forests located precariously in a sea of human settlements and monoculture holdings of tea and rubber. There is concern that most of these forests may now be too small and fragmented to maintain functional ecosystems and viable populations of fauna and flora in the long term. As a result, many of Sri Lanka's endemics are threatened with extinction in the foreseeable future.

Over exploitation of biological resources at levels exceeding the recuperative capacities of ecosystems and species; and the haphazard disposal of wastes and pollutants, loss of genetic diversity by the replacement of traditional varieties of livestock and crops with new high yielding varieties that show low resistant to pests and disease, threats to native species and ecosystems from alien invasive species, and increasing human-wildlife conflict that has already reached alarming proportions in the dry zone due to large scale human colonization of elephant habitats are other major threats to Sri Lanka's biodiversity. The socio-economic and ecological implications of biodiversity loss can be considerable and wide ranging, due to changes in forests and related ecosystems, inland wetlands, coastal and marine systems and impacts of such change on development activities, including tourism and trade.

1.8 Economy

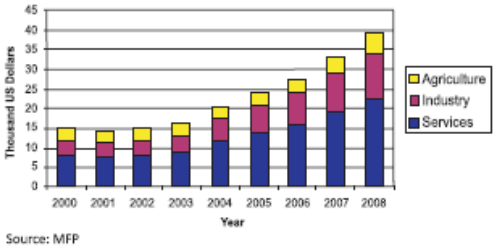
The current situation of the country's economy and the contribution from various sectors to its growth are described here.

1.8.1 Current Economy

Sri Lanka's (GDP) Gross Domestic Producer (at current price) in 2009 has been Rs 4,825 billion (US$ 42 billion) with an average annual real growth rate of 6.4% during 2004 - 2008 period (CBSL, 2009). The services sector has been the highest
contributor to GDP with 59%, followed by the industrial sector with 29% and the agricultural sector with 12% in 2009. The growth of GDP with sectoral contributions during the period 2000 - 2008 is shown in Fig. 1.12. Sri Lanka's economy is predominantly a small and medium enterprise economy where over 50 % of GDP is produced by this sector (MFP, 2008).

In 2009, all major sectors of the economy contributed positively to economy growth. However, there has been a slight decline in the growth rate compared to the previous year's. The delay in the monsoon rains the previous year had affected the agriculture, both the rice and plantation sectors including tea and coconut

Fig. 1.12 Sectoral Share in GDP

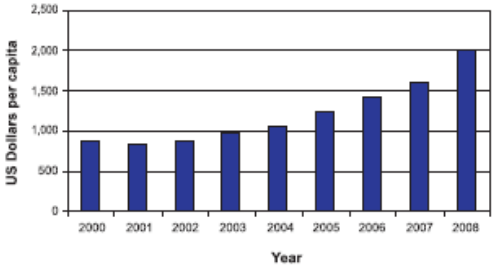


Source: MFP

De-regularisation, incentives for foreign investments, encouragement for private sector participation and increased competition have contributed to the expansion of the services sector, which has resulted in increased performance in transportation, communications, financial and banking services, trade and tourism. The per capita GDP (current price)

has grown from about US$ 800 in 2001 to more than US$ 2,000 by 2008, as shown in Fig. 1.13.

Fig. 1.13 Growth of GDP per capita (current price) during 2000 - 2008



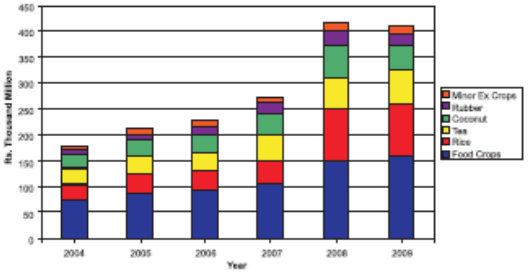
Source: CBSL (2010a)

1.8.2 Agricultural Production

The agricultural sector directly accounts for around one-fifth of national output, employs over one-third of the workforce and covers over one third the land extent. However, the agriculture contribution to GDP has declined from 20% in 2000 to 12% in 2008. In Sri Lanka, rice is the main crop, being the staple food. The next important are the three plantation crops - tea, rubber and coconut whose produce bring in a large share of the national revenue. Other food crops include a variety of legumes, cereals, vegetables grown mostly as seasonal crops.

Sri Lanka also cultivates many minor perennial crops whose produce is largely exported. These include spices such as cinnamon, cardamom, nutmeg, cloves and a variety of natural products having pharmaceu-tical value. Fig. 1.14 shows the growth of their production during 2004 - 2009.

Fig. 1.14 Growth of major agriculture production during 2004 - 2009

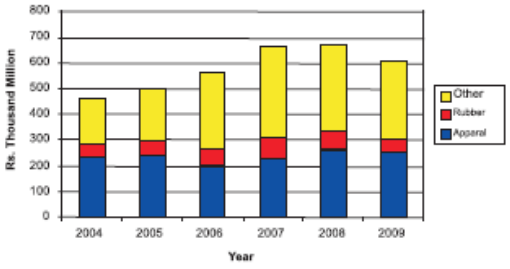


Source: CBSL (2010b)

1.8.3 Industrial Production

The apparel industry has been the main contributor to the manufacturing base in recent times while the manufacture of food and beverages, chemical and rubber-based goods have also made consistent contributions. Industrial exports are dominated by textiles and apparel, which contribute approximately 65% of industrial exports. Fig. 1.15 shows the growth of the industrial production since 2004.

Fig. 1.15 Growth of industrial production during 2004-2009



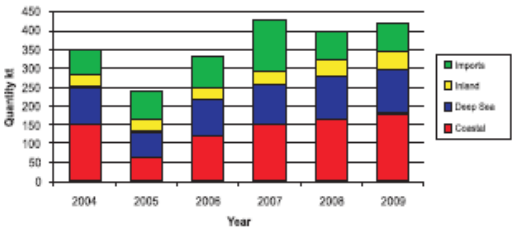
Source: CBSL (2010b)

The main contributions have come from apparels and rubber products. The current policy is for the government to serve only as a facilitator rather than as a direct producer, unlike several decades ago when the government directly got itself engaged in industrial activities. Most of the major industrial activities take place within the Free Trade Zones located in several parts of the country. A large number of industries commenced in the sixties and seventies are closed down today, as they were not economically viable and the sourcing of raw material also ran into problems.

1.8.4 Fisheries Production

The fisheries sector has produced about 320 kt in 2008 of which about 87% of the production has come from marine resources, contributing 1.6% to the National GDP. The fisheries sector is an important element in national food security, providing a source of affordable animal protein to the lower income groups. The Fisheries Industry provides employment to about 200,000 directly and another 200,000 indirectly, supporting livelihood to about 2.4 million. Fig. 1.16 shows the production and imports of fisheries products during 2004-2009. The export of fisheries products brings in revenue of about US$ 100 million annually.

Fig. 1.16 Growth of fisheries production and imports during 2004 - 2009



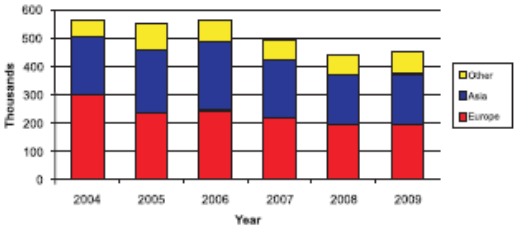
Source: CBSL (2010b)

1.8.5 Tourist Industry

Sri Lanka offers unique tourist attractions having a diversity of places of interest such as game parks, ancient ruins, mountain resorts, sandy beaches, wild life and other places of natural beauty all within a relatively small area. Fig. 1.17 shows the numbers of tourist arrivals during 2004-2009, which apparently has been negative presumably due to the global economic recession that prevailed in recent years and also due to the conflict situation in the country.

In 2009, the country has earned about Rs. 40 billion from tourism, which is about 20% of the export revenue of the country, and this has been generated from about 400,000 arrivals (CBSL, 2010b). This shows the potential of the tourism industry to improve the economy of the country. With the restoration of peace, the government has declared its intention to promote the industry and has called for investments to improve the necessary infrastructure.

Fig. 1.17 Tourist Arrivals during 2004-2009



Source: CBSL (2010b)

1.8.6 Socio-economic indicators

A set of socio-economic indicators for both 2001 and 2008 are given in Table 1.5.

A significant change in the demographic profile is the decline of the population growth from 1.2% to 1.0%, and the increase in the population density by 7%. The electricity generation has increased annually by 7%, while the per capita consumption has increased by 5.5% annually. The number of households connected to the national grid has increased from 73% to 86%. Another significant increase is the vehicle population which has been almost doubled up to 3.4 million. Similarly, the GDP has increased by more than a factor of 2, exceeding US$ 2000 per capita, bringing Sri Lanka into the category of middle income group.

Table 1.5 Key Socio-Economic Indicators

Socio-Economic Indicators	Unit	2001	2008
Mid-year population	million	18,797	20,217
Population growth rate	%	1.2	1.0
Population density	per km^2	300	322
Life expectancy at birth	years	71.7	74.1
Literacy rate	%	91.5	92.6
Poverty headcount index	%	22.7	17.4
Human development index	value	0.74	0.76
Households with tap water	%	(28)	36
Gross primary energy supply	PJ	378	415
Gross electricity generation	GWh	6,627	9,900
Non-fossil fuel factor	%	48	40
Households with electricity	%	73	83
Electricity consumption per capita	kWh/y	354	416
Motor vehicle population	million	1.706	3.391
Land telephones per capita	%	(5.1)	11
Mobile telephones per capita	%	(11)	55
Total Land Area	kha	6,562	6,562
Rice cultivation	kha	740	717
Tea plantations	kha	189	222
Rubber plantations	kha	157	122
Coconut plantations	kha	444	395
Subsidiary food crops	kha	200	201
Natural Forests	kha	1,942	n.a
Non-arable land	kha	1,025	1,025
Built-up land	kha	920	1,140
GDP (Current Market Prices)	US$ Bln	15.75	40.72
GDP per capita	US$	900	2,014
Agriculture Share	%	20.1	12.1
Industry Share	%	26.8	28.4
Services Share	%	53.1	59.5

Sources: C&SD 2003, C&SD 2009, C&SD 2010, CEB 2009n.a.: not available

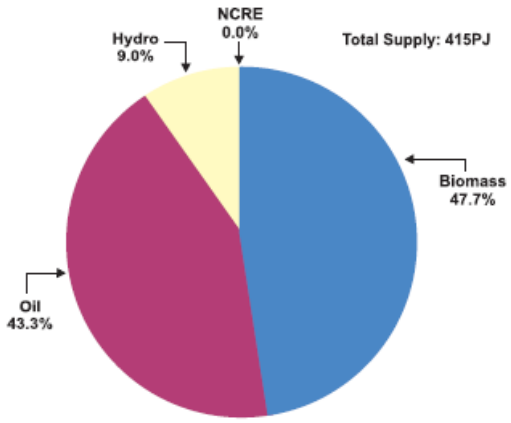
1.9 Energy

Under this topic, details of primary energy sources, petroleum imports, consumption of biomass, hydro power generation and non-conventional renewable energy (NCRE) sources will be discussed.

1.9.1 Primary Sources

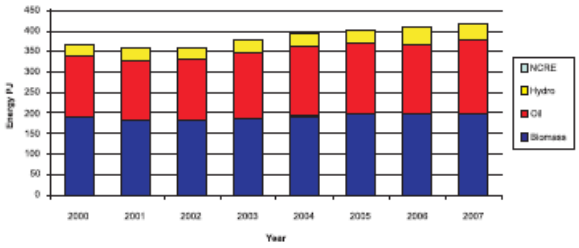
Sri Lanka's present primary energy supply is based mainly on biomass, petroleum oil and hydroelectricity. The composition of the primary energy supply in the country in 2007 is shown in Fig. 1.18, according to which, the total primary energy supply has been 415.5 PJ with contributions of 47.8% from biomass, 43.2% from petroleum, 8.9% from hydro and 0.1% from NCRE sources.

Fig. 1.18 Composition of Primary Energy Supply in 2007



Source: SLSEA 2008

Fig. 1.19 The primary energy share over the years 2000 to 2007



Source: SLSEA, 2008

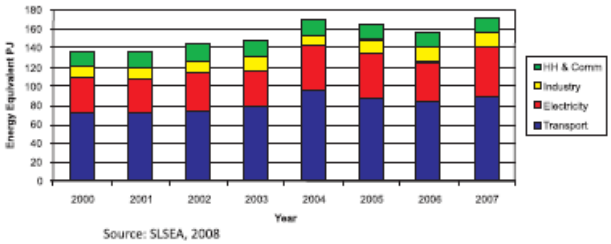
The growth of primary energy share during the years 2000 to 2007 is shown in Fig. 1.19. Both biomass and petroleum oil have shown a steady growth over the years. Despite the fact that the country has almost harnessed the maximum potential of large hydro, due to the growth of mini hydro power projects the total hydro power generation too has increased.

With the major supply coming from biomass which converts its energy content to useful energy at a very low rate around 10%, there is distortion in the total energy consumption of the country relative to others. In place of traditional use of biomass, had there been a more efficient way of extracting its energy, the total biomass consumption and in turn energy consumed would have been less than what was actually shown, and the country would have been ranked as a lower energy consuming country.

1.9.2 Petroleum Sources

The country has no fossil fuel deposits of its own and all its requirements are imported, though explorations are being carried out off-shore to look for deposits. Table 1.6 shows the amounts of petroleum oil imported both as crude oil and as refined products during the period 2005 - 2009. It also shows the refined products obtained from the crude oil. There has been an

Fig. 1.20 Sectoral consumption of petroleum oil during 2000 - 2007



Source: SLSEA, 2008

Table 1.6. Petroleum products imported and refined during 2005-2009

Imported Product	Products imported and refined (kt)				
	2005	2006	2007	2008	2009
Crude Oil	2,008	2151	1968	1853	2066
Refined Products	1823	1810	2314	2386	2154
Total Imports	**3,831**	**3961**	**4282**	**4239**	**4220**
Locally Refined					
Gasoline	161	193	163	164	179
Kerosene	142	144	97	111	83
Furnace Oil	624	766	772	731	778
Diesel	559	628	445	453	485
Aviation Fuel	114	131	171	154	179
Others	182	n.a	153	164	188
Total Refined	**1782**	**1862**	**1801**	**1777**	**1892**

Source: CBSL (2010a)n.a: not available

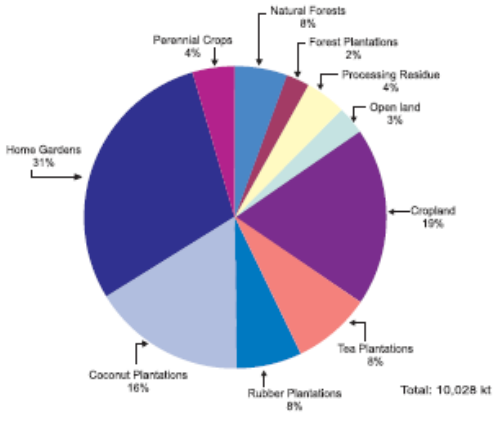
overall increase of 10% in oil imports during this period. Fig. 1.20 shows the consumption of petroleum products in electricity generation, transport, industry and domestic and commercial sectors during 2004-2007, as estimated in the Sri Lanka Energy Balance 2007 (SLSEA, 2008).

The highest consumption of fuel is in the transport sector, particularly in the sale of diesel oil. The petroleum oils are sold after taxing at different rates. Diesel oil consumed in heavy vehicles used for freight and public transport are taxed at low rates while gasoline consumed in private motor cars is taxed at high rates. On the other hand, kerosene used by the rural poor for lighting as well as fuel oil used in industries are sold at subsidized prices. Diesel oil and fuel oil are also used in thermal power plants which generate about 60% of the total electricity requirements of the country.

1.9.3 Biomass

Biomass, which meets about 48 % of the national energy consumption is supplied mostly through the informal sector, particularly for household cooking, small scale commercial and industrial applications. Biomass for these applications is sourced from home gardens, plantation litter, up-rootings for replanting of rubber, agriculture residue and forests. The records on such supplies are not maintained properly and therefore accurate data on biomass consumption in various sub-sectors are not available. For the purpose of energy balance calculations for 2007, only estimates of biomass consumption were made, which were about 8,400 kt for household and commercial sub-sector and 3,800 kt for the industry sub-sector, making the total consumption about 12,200 kt (SLSEA, 2008). However, in the FSMP developed in 1995(MALF, 1995), both these were projected for 2007 to be about 10,000 kt. Fig. 1.21 gives the breakdown of these sources.

Fig. 1.21 Sources of Fuel-wood projected for 2000 in 1996



Source : FSMP 1995

1.9.4 Large Hydro Power (>10 MW)

From late forties up to early nineties, hydro power has been the main source of electricity in the country. In 2008, however, only about 40% of electricity generation was from large hydro plants, the balance coming from petroleum oil. The current installed capacity of large hydro plants (>10 MW) since 2003 is 1,205 MW. A 150 MW plant is under construction while a further 211 MW of plants are planned. The annual generation capacities expected from these plants are 4,465 GWh and 1,313 GWh, respectively, making the total hydro power energy expected to be 5,778 GWh. (CEB, 2008). A master plan for the electricity supply in the country developed in late eighties by the CEB along with a team of German consultants found the total economic hydro energy potential available to be some 7,000 GWh/yr, with another 200 GWh/year of small plants (CEB and GTZ ,1989).

The sharing of water between power generation and irrigation for agriculture in more recently built hydro plants imposes some limitations on the maximum electricity that could be generated from them. Being sensitive to both rising temperature and rainfall variations, hydro power generation is very much vulnerable to climate change. Though the maximum potential of the current plants is 4465 GWh, the actual generation during 2003-2005 has been an average of only 3,256 GWh or 73% of the potential.

1.9.5 Non-Conventional Renewable Energy (NCRE)

Energy from non-conventional renewable sources has been introduced in Sri Lanka since 2000 beginning with a 3 MW wind power plant installed near the south-eastern coast. During 1997-2002, with funding provided by GEF through the World Bank, over 20,000 solar home systems and 35 community based mini-hydro systems with overall capacity of 350 MW were installed to supply electricity to rural population away from the national grid. Another 31 MW of grid-connected mini-hydro systems were also installed under the project. A second project carried out in 2002-2007 funded jointly by GEF and World Bank provided solar home systems to over 105,000 households and installed 127 community based mini-hydro systems with overall capacity of 1,226 MW benefitting 4,728 households (RERED, 2010). The project also funded the installation of 105.2 MW of grid-connected mini-hydro systems. The situation with regard to the supplying of electricity through NCRE resources is given in Table 1.7, according to which the contribution from NCRE sources is about 4%.

Table 1.7 Electricity supplied by NCRE sources in 2007

Category		No. of Projects	Total Installed Capacity (MW)	Energy Generated (MWh)
Grid-connected	Small Hydro Plants	61	112.9	344,000
	Biomass Plants	2	2.0	1,100
	Wind Power Plants	1	3.0	2,270
	Solar PV Systems	1	0.018	33
	Sub-Total	**65**	**117.92**	**347,403**
Off-Grid	Small Hydro Plants	227	4.73	9.57
	Solar PV Systems	128,527	5.80	6.27
	Wind Systems	25	3.0	5.75
	Sub-Total (Ex PV)	**252**	**7.73**	**21.59**
Total		**317**	**125.65**	**347,425**

Source: SLSEA, 2008

According to the National Energy Policy and Strategies in Sri Lanka (MP & E, 1994), Sri Lanka will endeavour to increase the contribution of NCRE sources connected to the national grid by 10% by 2015. With the government encouragement for the private sector to participate in NCRE projects, several projects have been completed and more under construction or given permits by the Sustainable Energy Authority set up for that purpose. The status of NCRE projects as of October 2010 is shown in Table 1.8.

Table 1.8 NCRE Projects commissioned/under construction/approved

Category	No. of Projects	Capacity Range (MW)	Total Capacity (MW)
Small Hydro Plants	279	0.1-10	519
Biomass/Week Plants	32	0.2-10	228
Wind Power Plants	28	0.8-10	246

Source: SLSEA (2010)

Among the major NCRE projects that have been commissioned are a biomass plant of 10 MW capacity and a wind power plant of 10 MW capacity. Also, work on the construction of a solar PV project of capacity 900 kW at the SE arid zone has commenced with Korean and Japanese assistance. It is expected to supply 560 MWh of energy to the national grid, saving 360 t of CO_2 emission annually. By the end of October 2010, a total of 83 small power projects with capacity 218.7 MW have been connected to the grid. Another 107 projects are under construction with an aggregate capacity of 314.3 MW. Construction work is yet to begin on 153 projects for which provisional approval has been granted and these have a total capacity of 461.3 MW.

According to a USAID assisted study, the wind power potential available country-wide was estimated to be in the region of 24,000 MW (SWERA, 2010), but economically feasible and easily accessible capacity was estimated to be about 1,800 MW (ESMAP, 2003). This includes sites in the southeastern, northwestern and northern coastal regions where already several wind energy plants have been installed or planned.

The electricity utilities have recently introduced net-metering system enabling the corporate sector to participate in the generation of electricity in an environmentally friendly manner and contribute to national development. Several companies have installed large PV systems within their premises to feed the excess electricity generated to the national grid. Though it is not economically competitive, they do so as part of their corporate social responsibility and to improve their carbon foot-print. It is expected that with the possible price reduction of PV panels in the future, more consumers will opt to generate their own electricity on their roof top and sell any excess to the grid.

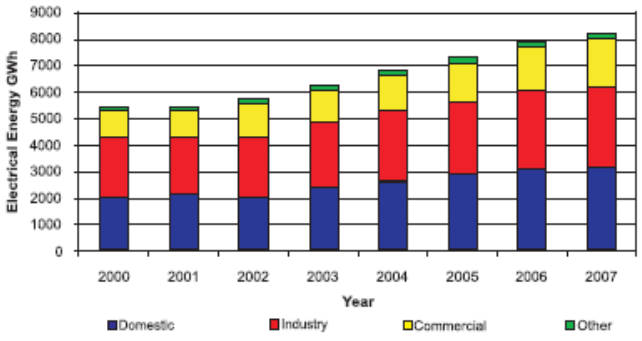
1.9.6 Electricity Consumption

Sri Lanka's annual demand in electricity has been 8,417 GWh in 2008 with the peak capacity demand of 1,922 MW (CBSL,2010a) occurring between the lighting hours of 6.00 pm to 10.00 pm (SLSEA,2008). Fig. 1.22 shows the sectoral consumption of electricity during 2000 - 2007, according to which the domestic sector has been the highest consumer. There is an increase in the number of domestic sector consumers as a percentage of the total number of households and the increase in the per capita consumption for the same period. The former has increased by 38% from 60% to 83% between 2000 and 2008, while the per capita electricity consumption has increased by 18% from 352 kWh to 416 kWh during the same period. Still, these figures are far below the 2005 global average (2,600 kWh) or even the Asian average (1,400 kWh).

1.10 Transportation

Sri Lankans depend heavily on public transport systems, comprising buses and trains, while sea and air transport are also used to a limited extent. These are described here.

Fig. 1.22 Sectoral consumption of electricity during 2000-2007



Source: SLSEA, 2008

1.10.1 Road Transport

Sri Lanka has nearly 12,000 km of major highways and about 16,000 km of minor roads (CBSL, 2010a). The country does not have a single expressway, though one is under construction. The domestic passenger transport system uses personally owned vehicles including cars, vans and motor cycles and hired vehicles including three-wheelers, while public transport comprises buses and railways. Domestic freight movement depends mainly on road while railway also contributes. Boat services are available mainly to transport passengers across ferries, particularly in the NP and EP.

The vehicle population is concentrated in the WP where 28% of the people live. The average ownership of vehicles is 108 per 1000 persons, a high value among developing countries. The registered vehicle population during the period 2006 - 2009 is given in Table 1.9.

Table 1.9 Vehicle (licensed) population growth during 2006-2009

Category	Vehicles with valid revenue license			
	2006	2007	2008	2009
Buses	16,808	15,819	15,230	12,243
Coaches	23,436	25,107	23,867	23,500
Vans	171,518	180,923	171,209	175,384
Cars	225,710	252,027	256,835	250,943
Land vehicles	87,650	92,028	75,302	65,974
Lorries	161,814	182,045	172,424	180,739
Motor Cycles	981,294	1,126,831	1,100,097	1,150,966
3-Wheelers	290,964	342,286	343,965	372,626
Others	3,336	5,737	4,194	12,733
Total	**1,962,520**	**2,222,803**	**2,163,123**	**2,245,108**

Source: CBSL (2010a)

The highest growth is among 3-wheelers and motor cycles. Gasoline has a higher tax than diesel and hence costs more, resulting in the use of a larger number of diesel operated vans even for personal transport. In 2007, 505 kt of gasoline, 1,302.9 kt of diesel and 3.9 kt of LPG have been consumed by vehicles.

1.10.2 Railways

Sri Lanka has about 1450 km of railway track, most of which is limited to a single wide-gauge track. Only short stretches from the city on the three main lines have been converted to double track. These include stretches up to Rambukkana

on the main line, up to Kalutara South on the coastal line and up to Ja-Ela on the Puttalam line. The effective railway fleet of Sri Lanka consists of about 200 diesel electric locomotives and 46 diesel power sets. Work on the reconstruction of the northern railway line beyond Vavuniya which was destroyed during the civil conflict has commenced. A new railway line is being laid as an extension to the Southern line taking it up to Kataragama. Several new extensions to the railways are being planned under the National Physical Plan drawn up to 2030 (NPPD, 2006). The total number of passenger-kilometres carried by the railways annually has been 4,680 million in 2008.(CBSL, 2010a)

1.10.3 Sea Transport

Sea transport handles the bulk of the freight in both imports and exports. A small amount of local sea freight includes transport to the northern and eastern regions of the country. The country has one major sea port and several minor ports. The Port of Colombo which is the main marine center for navigation in Sri Lanka handles most of the international marine transport. Lying close to the main shipping route from Suez to South- and Far-East, Colombo port serves both as a container hub and a bunkering station in addition to serving the country as its main exporting and importing port. Two smaller ports in Galle and Trincomalee also handle some coastal shipping and fishing boats. A large number of fisheries harbours have been built near almost every coastal city to serve the fishing community. A deep inland port has been constructed in Hambantota, a town close to the southern most point having the potential to service the main shipping routes to South-East and Far-East. The port services showed a significant growth since 2006.

1.10.4 Civil Aviation

Sri Lanka has one international airport and 13 domestic airports. There are two national carriers operating on international and regional routes. The civil aviation sector has shown a healthy growth in 2006. The total ordinary passenger handling at the Katunayake International Airport has increased by 12% while the total cargo handling has increased by 7% in 2006. In 2008, nearly 3 million passengers were carried by the principal airline, and 90,000 tonnes of freight carried. Work on a second international airport has commenced in the southern district close to Hambantota. A few private sector organizations operate the local air transport, which includes both passenger and freight transport.

1.11 Waste Sector

The present situation with regard to generation and disposal of solid waste, industrial effluents and air pollution is described in this section.

1.11.1 Solid Waste

Currently, Sri Lanka generates about 6,400 tonnes of solid waste per day of which about 2,500 tonnes are collected by local authorities. The waste from residential, public markets and other commercial services is mainly organic in origin, with smaller amounts of hazardous waste. The current Municipal Solid Waste (MSW) generation in major cities is on an average approximately 0.80 kg per capita per day. It is estimated that the urban MSW generation will increase up to 1 kg per capita per day by year 2025. The study further estimated that the per capita per day waste quantity was 0.60 kg in Urban Councils and 0.40 kg in Divisional Councils (Pradeshiya Sabhas) (MENR, 2009) Of the MSW generated, only 10-40% is collected and the rest remains either piled up or dumped in low lands. Waste collection practice in local authority areas differs greatly. Current trend is to privatize the collection and disposal of waste in most of MCs and UCs.

Open dumping accounts for more than 85%. There are four main dumps more than 5m deep in the WP, one a wetland bordering a waterway. In addition, there are 19 shallow dumps mainly serving the Pradeshiya Sabhas.

On the other hand, waste disposed from industrial establishments and hospitals comprise largely of hazardous materials. Such waste include inorganic acids and alkaline, zinc bearing wastes, heavy metal waste, waste oil derived from motor vehicles, solvent wastes from paint industries, dyes from the garment industries, asbestos plastic and resin wastes and chemical wastes from pharmaceuticals. A 1996 study provided an estimate of an annual collection of 40,600 tonnes of hazardous waste (MENR, 2005).

1.11.2 Industrial Effluents

The government has gazetted many years ago the standards for effluents discharged to waterways from industries. It is mandatory for any industry to comply with these standards and install waste water treatment plants to bring the pollution levels below the maximum permitted levels. The government also considered over a decade ago the feasibility of setting up two central waste water treatment facilities, one in the north and the other in the south of the city. However, the matter was not pursued because of the lack of interest among the industrialists.

1.11.3 Air Pollution

Though ambient air quality standards have been gazetted for many years, standards for emissions from industries and power plants have not been gazetted yet. However, these standards which are in the draft form are being utilized by many, particularly in Environment Impact Assessment (EIA) studies. Measurements of air quality at a station within the city show that the concentration of certain pollutants such as sulphur dioxide and suspended particulate matter exceeds the maximum permissible levels during certain periods. The government has recently introduced mandatory vehicle emission testing and issuing certificates as a measure for reducing air pollution. The government has also decided to expand the ambient air quality monitoring stations to cover a wider part of the country from its solitary station in Colombo.

1.12 Extreme Events

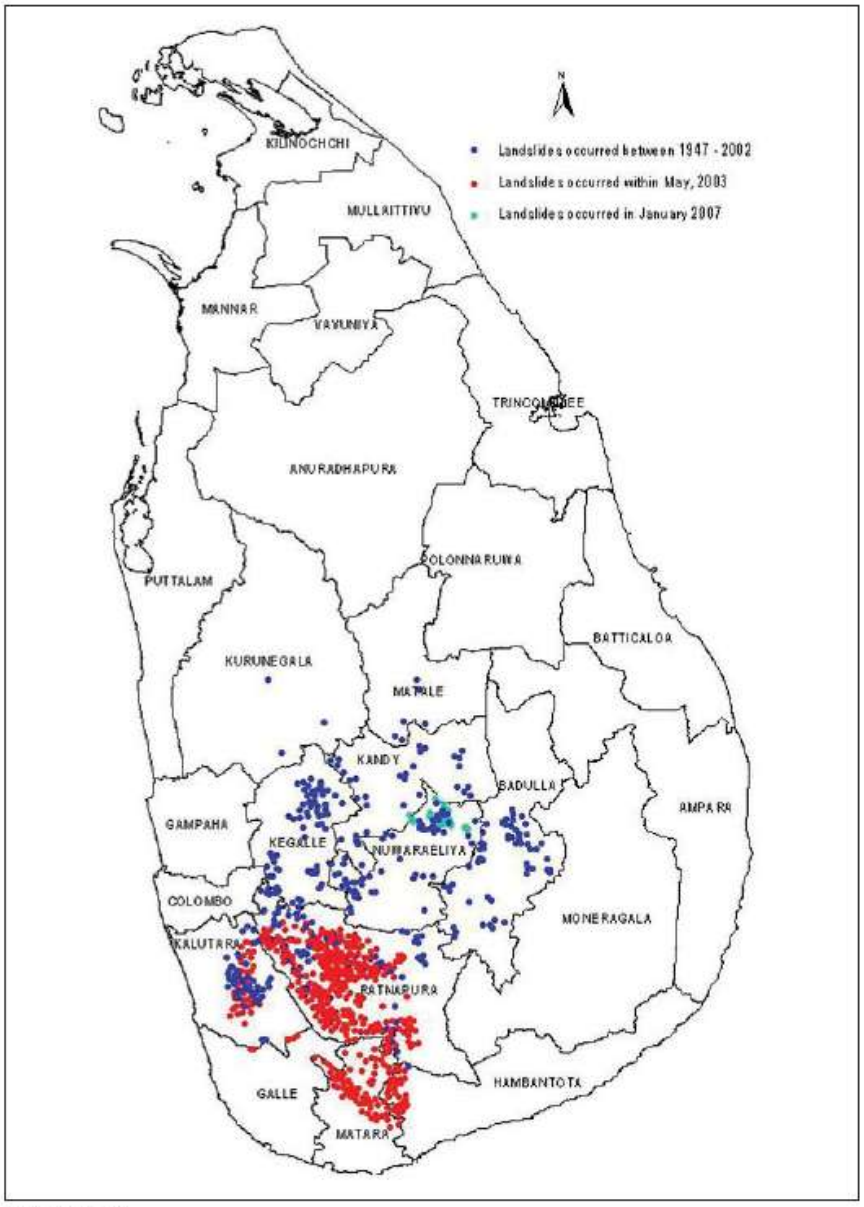
In Sri Lanka, many people suffer annually due to natural disasters such as floods, droughts and landslides, and occasionally due to cyclonic storms. The Meteorology Department collects real time weather information through its automatic weather monitoring station network and issue adversaries and early warnings, particularly to people in vulnerable areas. In order to alert the people and minimize the damage caused by these extreme events and to provide relief, the government has recently set up a Ministry of Disaster Management.

1.12.1 Land Slides

Almost in every rainy season, Sri Lanka experiences at least a few cases of landslides. The occurrences of landslides depend on several factors including climatological, geological, geomorphological and anthropogenic factors. The spatial distribution of landslides that have occurred in our country between 1869 and 2010 is shown in Fig. 1.23.

According to data collected, 700 events of landslides had taken place since 1951 within the administrative districts of Ratnapura, Kegalle, Nuwara Eliya, Kandy, Matale, Badulla, Kalutara, Galle, Matara and Hambantota. These have caused

Fig. 1.23 Distribution of landslides in Sri Lanka



Source: NBRO 2010

420 deaths, damages to over 100 houses, 30 instances of damages to highways and railways. Most of these have been identified as due to human intervention. The number of landslides that have been occurred within the 10 year period between the years 2001 - 2010, numbering about 600, compared to nearly 100 that had taken place during the 50 year period between years 1951 - 2000, compels us to anticipate drastically higher number of landslides within the next 40 years.

1.12.2 Floods

Intense rainfall received in upper catchments causes floods in downstream river basins when the rivers cannot hold the flow of water. Flooding also takes place in lowlands when intense rainfall causes the inflow to exceed the outflow. In Sri Lanka, intense rainfall occurs whenever there are disturbances in the upper atmosphere or depressions in pressure generally occurring over the Bay of Bengal. Sometimes cyclonic conditions prevailing over the Bay of Bengal also brings about heavy rainfall, with or without stormy conditions within the country. During 1974-2007, major flooding has taken place on 2,300 occasions in 13 districts, causing 442 deaths, affecting over 5 million people. Occurrence of flash floods following high intense rainfall in urban areas due to their poor drainage systems is becoming a regular feature. The worst floods in the city occurred in 1992 and 2010 when even the House of Parliament was submerged in flood water.

1.12.3 Cyclonic Storms

The occurrence of cyclones is not a common phenomenon in Sri Lanka, but past experiences show that there had been at least 5 major cyclones during the last 50 years accompanied with flash floods resulting from high intensity short duration rainfall. Generally these cyclones originate in the Bay of Bengal and the landfall occurs across the east coast. The districts in the EP, NCP and NP namely, Ampara, Batticaloa, Trincomalee, Jaffna, Mullativu, Vavuniya, Mannar, Anuradhapura and Polonnaruwa were affected by these cyclones.

Cyclones have affected Sri Lanka mostly in the months of November and December. During the period from 1974 to 2000 the worst affected cyclone was in 1978 which crossed the northcentral part of the country causing 740 deaths. Floods that followed caused serious damage to 23 % of the island affecting nearly a million people in the districts of Batticaloa, Polonnaruwa, Amapara, Anuradhapura and Mannar. More recently in May 2010, "Layla" cyclone crossed Jaffna, Mannar and Anuradhapura districts, affecting 148,718 families consisting of 629,347 persons and causing 26 deaths. 983 houses were fully damaged and 3,662 houses damaged partially.

1.12.4 Droughts

Generally, drought is a regular event in certain parts of the country. In the *Maha* season, the country is less likely to experience drought conditions except in the extreme northwestern and southeastern regions, while in the *Yala* season, the entire dry zone is highly vulnerable to drought conditions, whereas there is only a slim chance of drought conditions in the wet zone (Chitranarayana and Punyawardana, 2008). However, island-wide droughts could occur occasionally, such as in 2001 and 2004, causing severe damage to crops and hardships to people for want of water even for drinking. Even in areas supplied with pipe-borne water, availability of water is restricted during the day. During prolonged droughts, where water intakes to municipal water supplies are located in rivers close to the sea, salinity increases due to intrusion of sea water upstream. During the 20 year period 1985-2004, there had been over 1400 reports of droughts, affecting over 8 million people and 280,000 ha of cropland, mainly in the DZ.

1.13 Social Infrastructure

Under this section, country's health services and the education system will be discussed.

1.13.1 Health Services

The government hospitals, managed both by the Central Government and the eight Provincial Councils, provide 95% of in-patient care. In addition, major Municipalities provide services of a limited nature. The government provides this service free of charge to the public spending Rs. 71 billion or 1.5% of GDP in 2009 (CBSL, 2010b).

The Central Dispensaries, Maternity Homes, Rural Hospitals, Peripheral Units and District hospitals are primary care institutions. The base and Provincial hospitals are secondary care institutions and provide specialized services. The base hospitals are situated in large towns and administered by the respective Provincial Ministers of Health. The Provincial hospitals provide a wide range of specialties and also possess well-equipped laboratories to provide an efficient service.

With regard to Preventive Health Services Sri Lanka has a good record in the provision of preventive health services. The island is divided in to 252 Medical Officers of Health (MOH) and services are delivered through a team of field officers. The National Expanded Programme of Immunization seeks to control vaccine-preventable diseases namely Tuberculosis, Diphtheria, Tetanus, Poliomyelitis, Measles, Hepatitis B and Rubella.

Altogether, there are over 500 government hospitals with nearly 69,000 beds (3 in 1000), served by over 13,000 doctors (1 in 1,500) and about 25,000 qualified nurses (1 in 800). Sri Lanka has low mortality and low fertility rates. The female life expectation is 76.6 years while male life expectancy is 68.1 years.

1.13.2 Education System

The government provides free education for all children from the kindergarten up to university level. There are over 10,000 schools out of which about 100 are privately owned. The student population is about 4.1 million with a student to teacher ratio of about 20. The government expenditure on general education in 2009 has been Rs. 100 billion or 2.1% of GDP (CBSL, 2010b).

The free access to education has resulted in achieving a literacy rate of 90% this decade. There is, however, marked disparity between the literacy of the estate population (76%) and that of the rest (92.5%). There is high retention rate up to the primary level (98%) while it has declined to about 60% at the Grade 10 level. There is very stiff competition for admission to universities. In 2008, about 130,000 students became eligible for admission, though only about 20,000 were admitted.

The country has 15 universities, all state-run, with a total student population of about 66,000 currently. Generally, only about 75% of the students complete the courses and graduate. Out of those who graduate, approximately 40% are in liberal arts, 20% each in science and management and 10% each in medicine and engineering. A large number of students who fail to secure university admission either seek admission in foreign universities or follow degree courses offered by private institutes enabling them to obtain degrees from foreign universities. These students also have the opportunity of obtaining a degree from the Open University through distance education and also external degree from

national universities.

Of the students who fail to get admission to universities, about 40,000 secure admission to Technical Colleges, Colleges of Education or Colleges of Technology. The rest follow various vocational courses offered by the public sector and private sector organizations which enable them to secure employment both locally and overseas.

1.14 Development Policies and Priorities

As required by the UNFCCC, some information on the government priority areas for development and disaster recoveries are given here.

1.14.1 Recovery from the Civil Conflict and Tsunami

Sri Lanka emerged last year (2009) from a civil conflict that lasted for nearly three decades in the Northern and Eastern provinces. The conflict left these two provinces, which covered 30% of the country's land area and 57% of the coastline, completely devastated - both the people's lives and the physical infrastructure. A large number of people were left homeless and another large number was found missing or killed in the conflict while many houses were damaged and townships particularly in the North were totally destroyed (CBSL, 2010b).

The tsunami that occurred on the 26th of December 2004 also took a heavy toll on the country. It severely destroyed the coastal belt of the Northern and Eastern provinces as well as the Southern and Western provinces. The tsunami took people unawares and left behind widespread destruction. This has resulted in a loss of nearly 31,000 lives, 4,000 reported missing, and displacement of over 550,000 people with nearly 1,000 children becoming orphans or separated from their parents (CBSL, 2005). There was severe damage to homes and infrastructure worth over US$ 1 billion, and to people's livelihoods, ecosystems and coastal infrastructure.

Both the civil conflict and the tsunami caused total or severe damage to housing and private property, transport infrastructure, fisheries and harbours, hotels, restaurants, hospitals, schools, water and electricity supplies, highways, railways, telecommunications and the environment. The government's highest priority is now to focus on rebuilding both the Northern and Eastern and tsunami affected areas and bring them in line with the development efforts of the rest of the island (MFP, 2008).

The government has announced a comprehensive programme for the development of the Northern Province (NP) and Eastern Province (EP). Accordingly, it primarily aims at resettlement of displaced people and rehabilitation and reconstruction of economic infrastructure to restore livelihoods and basic needs such as water supply, sanitation, electricity, health and education facilities etc. and the creation of income generating activities in the provinces. A total sum of nearly Rs. 300 billion has been allocated by the government for the rehabilitation of the Northern Province during the 2-year period 2010 - 2012 (CBSL, 2010b).

The reconstruction of the rail track and highways connecting North and South, schools, hospitals, government offices and houses are envisaged in this plan. The rehabilitation of the displaced children, women and youth in the area, and the rehabilitation of the former rebel group members towards making them useful citizens in society is also a priority. The resettlement of several hundreds of persons internally displaced due to the conflict has now been almost totally completed after de-mining the area except for a few tens of thousands. The establishment of government

administration and infrastructure facilities including public transport, hospitals, schools etc. within the NP and EP is also progressing well.

1.14.2 National Strategy for Sustainable Development

In pursuant to the commitments under the World Summit on Sustainable Development, the government had developed Sri Lanka Strategy for Sustainable Development, in 2008 (MENR, 2008b) with a vision of achieving sustained economic growth that is socially equitable and ecologically sound, with peace and stability. The Government in 2009 established the National Council for Sustainable Development (NCSD) with a view to address the issues and challenges of long term sustainability of the development process and thereby sustainable development. A National Action Plan (NAP) for Haritha (Green) Lanka Programme (HLP) was developed for this purpose by a high level committee of ministry secretaries facilitated by the Ministry of Environment. The NAP/HLP includes short medium and long-term targets spanning the period 2009-2016 performance indicators (NCSD 2009).

The HLP had 10 broad mission areas which are:

- Clean Air - Everywhere,
- Saving the Fauna, Flora and Ecosystems,
- Meeting the Challenges of Climate Change,
- Wise Use of the Coastal Belt and the Sea Around,
- Responsible Use of the Land Resources,
- Doing Away with the Dumps,
- Water for All and Always,
- Green Cities for Health and Prosperity,
- Greening the Industries,
- Knowledge for Right Choices

1.14.3 Development Policies and Projections

The Department of National Planning had formulated a Development Policy Framework (DPF) outlining a Vision for the Future with projections of the performance of key economic sectors up to 2020 (DNP, 2010). It has taken into consideration the development that had taken place in the country during the period 2005 - 2009 as demonstrated by various socio-economic indicators such as real economic growth (6%), per capita income (from US$ 1000 to US$ 2000), access to telecommunication (from 23% to 86%) and reduction of unemployment (from 7.4% to 5.0) and poverty (from 15.7% to 7.6%), as well as improvements in other social infrastructure indicators.

Policy directions have been made for undertaking further development in key sectors such as agriculture, plantations, fisheries, livestock, irrigation, energy, transport, and industry among others, and projections made for targets to be achieved by 2015 and 2020. These are to be attained through rapid economic growth and a change in the structure of the economy to a modern, environmentally friendly and well connected rural-urban economy that can create better - remunerated employment opportunities, with the ultimate goal of achieving a better quality of life for people in all strata of the society.

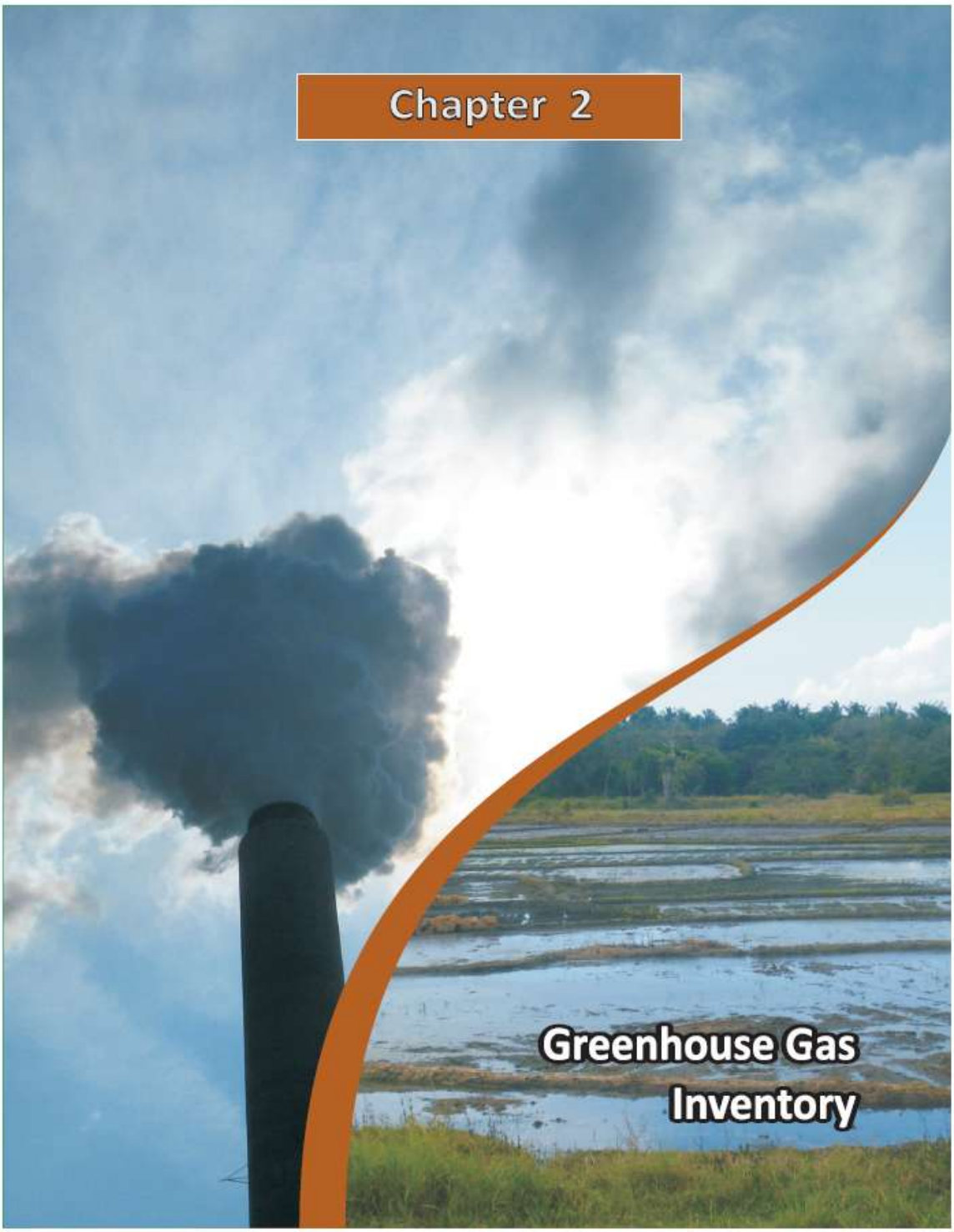
1.15 Institutional Arrangements for preparation of Second National Communication

The Ministry of Environment is the national focal point for UNFCCC. The Ministry established a Climate Change Secretariat (CCS) within the Ministry to serve as a node for the implementation of UNFCCC decisions including the preparation of the GHG Inventory and the country's National Communications. It also serves as the National Designated Authority (DNA) for the CDM under the Kyoto Protocol (KP). The CCS is headed by a Director under the direct supervision and guidance of the Additional Secretary of Ministry of Environment and the Secretary of Ministry of Environment.

The objectives of the CCS are to:

- Provide a platform to address climate change issues at the national level for incorporation into the development process.
- Function as the form of dedicated institutional mechanism to undertake climate change responses including development of relevant policies and programmes.
- Liaise with sectoral agencies at national and sub-national levels for identifying priorities and developing mechanisms to implement national policies on climate change.
- Facilitate undertaking climate change related research and dissemination of research results to initiate policy reforms and actions.
- Establish a mechanism to monitor impacts of national responses to climate change.
- Liaise with the UNFCCC Secretariat and be responsible for preparing documentation in connection with Sri Lanka's participation at meetings of COP and other climate change related meetings.
- Serve as Secretariat for the Designated National Authority (DNA) for the approval of CDM projects.

The preparation of the Second National Communication was coordinated by the Climate Change Secretariat by establishing a SNC Project Management Unit. Thematic Working Groups consisting of experts from relevant ministries, institutions and agencies of both government and non-government led by a Thematic Consultants, were appointed on each of the following thematic areas: National Circumstances, Greenhouse Gas Inventory, Vulnerability and Adaptation, Mitigation, Technology Transfer, Research & Systematic Observations, and Education, Training, Public Awareness & Networking and Socio-Economic Impacts of Climate Change, to prepare the respective thematic reports. A separate National Consultant and a Thematic Group was appointed for compile the final report based on the individual thematic reports. The final report was produced through expensive deliberations of all the key stakeholders related to Climate Change through workshops, working group meetings & individual consultations where necessary.



Chapter 2

Greenhouse Gas Inventory

National Greenhouse Gas Inventory

Sri Lanka has submitted its Initial National Greenhouse Gas (GHG) Inventory for 1994, and is required to submit the Second National GHG Inventory for 2000, prepared generally in accordance with the Revised 1996 IPCC Guidelines (RIG, 1996) for National Greenhouse Gas Inventories (IPCC, 1997). The GHGs of concern are primarily carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). They are also required to report the emissions of precursor gases such as carbon monoxide (CO), oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOC), and in addition the emissions of sulphur dioxide (SO_2). Non-Annex I Parties are also encouraged to include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) in the inventory.

2.1 Introduction to GHG Emissions

2.1.1 Sources of GHGs

The GHGs are produced mainly during the combustion of fossil fuels for generation of energy, both thermal and motive. Fuels such as coal, petroleum oil and natural gas are burnt to drive turbines to generate electricity, or operate boilers in industry or run vehicles. The main GHG emitted from these combustion processes is CO_2. Refinery operations as well as fuel storage and handling also cause non-combustion emissions referred to as Fugitive Emissions. Various industrial processes could cause the emission of CO_2, CH_4, N_2O and NMVOC. Agricultural activities such as rice cultivation, ruminant animal rearing and animal waste management contribute to emission of CH_4 and N_2O. Burning of crop residues after harvesting and forest fires result in the emission of CO_2, CO, CH_4 and NO_x. Land use changes and soil disturbances cause the emission of CO_2, while changes in woody biomass stocks results in the emission or absorption of CO_2. Application of nitrogen fertilizers in agricultural land causes the emission of N_2O. Disposal of solid waste both in sanitary land-fills and open dumps as well as waste water treatment facilities results in the emission of CH_4.

2.1.2 Summary of GHG Emissions

Table 2.1 gives the summary of emissions from each of the above sources estimated for 2000. The CO_2 Equivalent values of CH_4 and N_2O were calculated using the Global Warming Potential (GWP) values reported in IPCC Second Assessment Report (SAR) corresponding to a 100 year time frame for each of these two gases, viz. 21 and 310, respectively.

Table 2.1 Summary of GHG Emissions/Removals during 2000

Sector	CO_2 Gg	CO_2 Removals Gg	CH_4 $GgCO_{2eq}$	N_2O $GgCO_{2eq}$	Total $GgCO_{2eq}$ (Net)
Energy	10,430.01		881.37	251.10	11,562.48
Ind. Processes	492.40				492.40
Agriculture			3,887.94	821.50	4,709.44
LUCF-Emissions	10.34		35.07		45.41
Waste			2,033.22		2,033.22
Total-Emissions	10,932.75		6,837.60	1,072.60	18,842.95
LUCF-Removals		-6,253.99			- 6,253.99
Total-Net	**10,932.75**	**-6,253.99**	**6,837.60**	**1,072.60**	**12,588.96**

The total CO_2 emission from fossil fuel combustion is 10,430 Gg while the total aggregate emission is 18,843 $GgCO_{2eq}$ which comprises 61.4% from the energy sector, 25.0% from the agriculture sector, 10.8% from the waste sector, 2.6% from the industry sector and 0.2% from the land use change and forestry sector as shown in Table 2.1. With the uptake of 6,254 $GgCO_{2eq}$ from the land use change and forestry sector, the total net emission is 12,589 $GgCO_{2eq}$.

2.2 Energy Sector

Emissions from fossil fuel combustion in electricity generation, refinery operations, industrial, transport, and household and commercial sub-sectors are presented in this section. The necessary data for these estimates were extracted from the Energy Balance Statement for 2000, prepared by the Sri Lanka Sustainable Energy Authority (SLSEA, 2010).

2.2.1 Emissions from Electricity Generation

The emissions in this sub-sector are generated during the combustion of a variety of fuels in thermal power plants which use different motive power sources to drive the alternators. These sources included residual-oil and auto-diesel fired compression-ignited internal combustion engines (diesel engines), fuel-oil fired boiler-driven steam turbines and auto-diesel and naphtha fired simple as well as combined cycle gas turbines (CCGT).

The CO_2 emission for each fuel type is determined using their oxidation rates and the total fuel consumed in the power sector and the carbon emission rates given in the RIG (1996) for each fuel type. Tier 1 method was used to calculate their non-CO_2 emissions, using the emission factors given in the IPCC Guidelines, in the absence of the specific emission factors of the generators. Table 2.2 gives these emissions.

Table 2.2 GHG and other Emissions from Electricity Generation Processes

Fuel		Emissions (Gg)						
Type	Amount*kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
HFO	498.80	1535.58	0.06	0.01	0.30	4.01	0.10	29.93
Diesel	481.59	1530.25	0.06	0.01	0.31	4.17	0.10	2.89
Total		**3065.84**	**0.12**	**0.02**	**0.61**	**8.18**	**0.20**	**32.82**

*Source: SLSEA (2008)

The total emissions from this sector is 3,076 $GgCO_{2eq}$, comprising 3,066 Gg of CO_2 emissions, 3 $GgCO_{2eq}$ of CH_4 and 7 $GgCO_{2eq}$ of N_2O.

2.2.2 Emissions from Refinery Operations

During refinery operations, fuels are consumed in both combustion processes and non-combustion processes. The latter is included under Fugitive Emissions.

Emissions from Combustion Processes

Emissions caused during combustion processes were calculated using Tier I Emission Factors given in respect of industries. The emissions are given in Table 2.3.

Table 2.3 GHG and other Emissions from Refinery Processes

Fuel		Emissions (Gg)						
Type	Amount* kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
LPG	45.40	134.12	0.00	0.00	0.02	0.43	0.01	0.00
Gasoline	0.89	2.74	0.00	0.00	0.00	0.01	0.00	0.00
Naphtha	0.12	0.39	0.00	0.00	0.00	0.00	0.00	0.00
Kerosene	0.60	1.91	0.00	0.00	0.00	0.01	0.00	0.00
AV Gas	1.35	4.26	0.00	0.00	0.00	0.01	0.00	0.00
Diesel	6.56	20.84	0.00	0.00	0.00	0.06	0.00	0.00
Fuel Oil	33.78	103.99	0.01	0.00	0.01	0.26	0.01	1.94
Total		**268.25**	**0.01**	**0.00**	**0.03**	**0.78**	**0.02**	**1.94**

*Source: SLSEA (2008)

Fugitive Emissions

Fugitive Emissions generated during refinery operations are calculated using Emission Factors given in RIG (1996) (Table 1.65) and the total amount of crude oil refined, which was 2348.9 Gg in 2000. These emissions are given in Table 2.4.

Table 2.4 Fugitive Emissions from Refinery Processes

	Fuel	Emissions (Gg)						
Fuel	Amount*kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Crude Oil	2348.9		0.10		0.22	0.14	1.46	2.20

*Source: SLSEA, 2008

The total CO_2 equivalent emissions from this sub-sector is 2.1 $GgCO_{2eq}$., comprising 2.1 $GgCO_{2eq}$ of CH_4.

2.2.3 Emissions from Industry

Energy for industrial purposes is generated from several sources – biomass, petroleum oils, and electricity. However, electricity for industries is not considered here as it has already been considered under energy industry. Biomass is used in tea and rubber factories, bakeries, tile and brick industries and other small scale industries. Petroleum oil is used for operating boilers, ovens and furnaces. Table 2.5 gives the amounts of different fuels used in the industrial sub-sector in 2000, and the emissions.

Table 2.5 GHG and Other Emissions from Industry in 2000

Fuel Type	Amount* kt	Emissions (Gg)						
		CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
LPG	14.75	43.57	0.00	0.00	0.01	0.14	0.00	0.00
Kerosene	5.19	16.53	0.00	0.00	0.00	0.05	0.00	0.00
Diesel	35.90	114.07	0.00	0.00	0.02	0.31	0.01	0.22
Fuel Oil	216.94	667.86	0.02	0.01	0.09	1.74	0.04	13.02
Bagasse	264.80	(659.89)	0.13	0.02	16.95	0.42	0.21	0.16
Biomass	2978.78	(5011.73)	2.14	0.18	97.39	4.62	3.82	11.92
Total		**842.03**	**2.29**	**0.21**	**114.46**	**7.28**	**4.09**	**25.32**
Co_2 from BM		**(5,671.62)**						

*Source: SLSEA (2008)

The total CO_2 equivalent emissions from this sub-sector is 955 $GgCO_{2eq}$., comprising 842 Gg of CO_2 emissions, 48 $GgCO_{2eq}$ of CH_4 and 65 $GgCO_{2eq}$ of N_2O.

2.2.4 Emissions from Transport Sector

Road Transport

There has been a rapid increase in the vehicle population between 1994 and 2000, and a corresponding increase in fuel consumption and GHG emissions. The active vehicle population has increased from 790,000 in 1994 to 1,163,000 in 2000, showing a 47% increase (MENR, 2004). The gasoline and diesel sales which were 184 kt and 782 kt, respectively in 1994, were 224 kt and 1,175 kt in 2000, showing a 22% increase in gasoline and 50% increase in diesel sales during this period. Calculation of emissions from vehicles requires information on the amounts of fuel consumed by specific categories of vehicles during a year. This information is not available readily. Sometimes, transport models are used to estimate such information, but there are uncertainties in such estimates. Hence, in the present estimates, Tier I method, in which a single emission factor is used for the entire fleet of vehicles in respect of a given type of fuel, was used. Table 2.6 gives the amounts of fuel used in the road transport sector and the quantities of GHGs and other gases emitted by the entire fleet of vehicles.

Table 2.6 Emissions from Road Transport Sub-sector in 2000

Fuel		Emissions (Gg)						
Type	Amount kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
LPG	6.86	20.27	0.02	0.00	0.13	0.19	0.00	0.00
Gasoline	224.38	689.72	0.20	0.01	80.42	6.03	15.08	0.45
Diesel	1175.15	3734.04	0.25	0.03	50.92	40.74	10.18	7.05
Total		**4444.03**	**0.47**	**0.04**	**131.47**	**46.96**	**25.26**	**7.50**

*Source: SLSEA (2008)

The total CO_2 equivalent emissions from this sub-sector is 4,466 $GgCO_{2eq}$, comprising 4,444 Gg of Co_2 emissions, 10 $GgCO_{2eq}$ of CH_4 and 12 $GgCO_{2eq}$ of N_2O.

Railway Transport

The railway transport system has not changed significantly during the period 1994 to 2000. The railway engines are entirely of diesel-electric driven types. Table 2.7 gives the amount of fuel consumed in 2000, and the emissions of GHGs and other gases, calculated using Tier I emission factors.

Table 2.7 Emissions from Railway Transport Sub-sector in 2000

Fuel		Emissions (Gg)						
Type	Amount*kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Coal	0.10	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Diesel	25.25	80.23	0.01	0.00	1.09	1.31	0.22	0.15
Total		**80.46**	**0.01**	**0.00**	**1.09**	**1.31**	**0.22**	**0.15**

*Source: SLSEA (2008)

The total CO_2 equivalent emissions from this sub-sector is 80.8 Gg CO_{2eq} comprising 80.5 Gg of CO_2 emissions, 0.1 Gg CO_{2eq} of CH_4 and 0.2 Gg CO_{2eq} of N_2O.

Air Transport

Two types of fuel are used in aviation: aviation gasoline (Av. gas) and aviation turbine (Avtur). Table 2.8 gives their consumption in 2000 and emissions of GHGs and other gases calculated using Tier I emission factors.

Table 2.8 Emissions from Aviation Transport Sub-sector in 2000

Fuel		Emissions (Gg)						
Type	Amount*kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Av Gas	0.13	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Av Tur	157.32	496.59	0.00	0.01	0.70	2.10	0.35	0.16
Total		**496.99**	**0.00**	**0.01**	**0.70**	**2.10**	**0.35**	**0.16**

*Source: SLSEA (2008)

The total CO_2 equivalent emissions from this sub-sector is 501.5 $GgCO_{2eq}$, comprising 497.0 Gg of CO_2 emissions 0.1 $GgCO_{2eq}$ of CH_4 and 4.4 Gg CO_{2eq} of N_2O.

Sea Transport

Though Sri Lanka is an island state, sea transport is confined mainly to fisheries and naval activities. Passenger transport exists only at ferries to cross rivers and for transport to islands in the North. Table 2.9 gives their fuel consumption in 2000 and emissions. These, however, could be underestimates, since it is possible for the fishing boat operators to have obtained their fuel supplies, particularly diesel, from road-side fuel outlets which have been included under road transport category.

Table 2.9 Emissions from Sea Transport Sub-sector in 2000

Fuel	Amount* Gg	CO_2 Gg	CH_4 Gg	N_2O Gg	CO Gg	NOx Gg	NMVOC Gg	SO_2 Gg
Diesel	9.70	30.82	0.00	0.00	0.42	0.63	0.08	0.06
Fuel Oil	1.91	5.88	0.00	0.00	0.08	0.12	0.02	0.11
Total		**36.70**	**0.00**	**0.00**	**0.50**	**0.75**	**0.10**	**0.17**

*Source: SLSEA (2008)

Summary of Emissions from the Transport Sector

Table 2.10 gives the summary of the emissions from the Transport sector calculated using Tier I emission factors

Table 2.10 Emissions of GHG and other gases from the Transport Sector

Sub-sector	Emissions (Gg)						
	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Road Transport	4444.03	0.47	0.04	131.47	46.96	25.26	7.50
Railway Transport	80.46	0.01	0.00	1.09	1.31	0.22	0.15
Air Transport	496.99	0.00	0.01	0.70	2.10	0.35	0.16
Sea Transport	36.70	0.00	0.00	0.50	0.75	0.10	0.17
Total	**5058.19**	**0.48**	**0.05**	**133.76**	**51.13**	**25.93**	**7.98**

*Source: SLSEA (2008)

The total CO_2 equivalent emissions from this sub-sector is 5,084 $GgCO_{2eq}$., comprising 5,058 Gg of CO_2 emissions, 10 $GgCO_{2eq}$ of CH_4 and 16 $GgCO_{2eq}$ of N_2O.

2.2.5 Household and Commercial Sector

According to the 2001 National Census taken in 18 districts (excluding the conflict area), Sri Lanka had 4.05 million households, out of which 80% used firewood for cooking, 14.8% used LPG, and 3.1% used kerosene (C&SD, 2001). Further, nationally 63.6% of households used electricity for lighting, which varied from 85% in urban areas to 38% in estate areas. The rest of the households used kerosene for lighting. The Sri Lanka Energy Balance 2000 gives the LPG, kerosene and biomass consumption figures in the household and commercial sector in 2000 as 122.71 kt, 225.79 kt and 9,609 kt, respectively. However, in the Energy Balance (SLSEA, 2008) statement, the biomass consumption in households and commercial sector for 2000 has been revised to 8,350 kt. Table 2.11 gives the emissions from this sector based on these consumption figures calculated using Tier I emission factors.

Table 2.11 Emissions from Household and Commercial Sector in 2000

Fuel		Emissions (Gg)						
Type	Amount*kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
LPG	122.71	367.47	0.03	0.00	0.29	0.29	0.03	0.00
Kerosene	225.79	708.86	0.10	0.01	0.20	1.01	0.05	0.23
Diesel	10.83	34.41	0.00	0.00	0.01	0.05	0.00	0.06
Fuel Oil	27.60	84.97	0.01	0.00	0.02	0.11	0.01	1.66
Biomass	8,350.00	(14,048.68)	38.83	0.52	647.13	12.94	77.66	33.40
Charcoal	0.09	(0.21)	0.00	0.00	0.00	0.02	0.00	0.00
Total		**1,195.71**	**38.97**	**0.53**	**647.65**	**14.41**	**77.74**	**35.35**

Source: SLSEA (2008)

The total CO_2 equivalent emissions from this sub-sector is 2,177 $GgCO_{2eq}$, comprising 1,196 Gg of CO_2 emissions, 818 $GgCO_{2eq}$ of CH_4 and 163 $GgCO_{2eq}$ of N_2O.

2.2.6 International Bunkering

Sri Lanka's international airport and the main harbour provide bunkering facilities to a large number of international flights and ships crossing the Indian Ocean. Table 2.12 gives the fuels supplied to air planes in 2000 and their emissions.

Table 2.12 Emissions from Bunkering to International Aviation in 2000

Fuel		Emissions (Gg)						
Type	Amount*kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Avtur	102.09	322.26	0.00	0.01	0.46	1.37	0.23	0.10

Source: SLSEA (2008)

The total CO_2 equivalent emissions from this sub-sector is 325 $GgCO_{2eq}$, comprising 322 Gg of CO_2 emissions, 0.1 $GgCO_{2eq}$ of CH_4 and 3 $GgCO_{2eq}$ of N_2O.

Table 2.13 gives the fuel supplied to ships in 2000 and their emissions.

Table 2.13 Emissions from Bunkering to International Shipping in 2000

Fuel		Emissions (Gg)						
Type	Amount*kt	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Diesel	44.49	141.37	0.01	0.00	1.93	2.89	0.39	0.27
Fuel Oil	120.32	370.42	0.02	0.00	4.84	7.25	0.97	7.22
Total		**511.78**	**0.03**	**0.00**	**6.77**	**10.15**	**1.36**	**7.49**

*Source: SLSEA (2008)

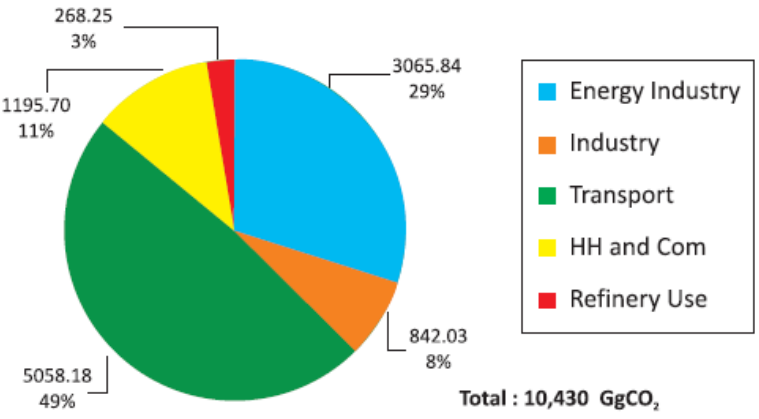
The total CO_2 equivalent emissions from this sub-sector is 514 $GgCO_{2eq}$, comprising 512 Gg of CO_2 emissions, 1 $GgCO_{2eq}$ of CH_4 and 1 $GgCO_{2eq}$ of N_2O.

2.2.7 Summary – Energy Sector

Table 2.14 gives the summary of the emissions from the Energy Sector for 2000.

	Emissions (Gg)						
Sector	**CO_2**	**CH_4**	**N_2O**	**CO**	**NOx**	**NMVOC**	**SO_2**
Total Energy	**10,430.01**	**41.97**	**0.81**	**896.73**	**81.92**	**109.44**	**105.60**
A. Fuel Combustion	10.430.01	41.87	0.81	896.51	81.78	107.98	103.40
1. Energy Industry	3,065.84	0.12	0.02	0.61	8.18	0.20	32.82
2. Industry	842.03	2.29	0.21	114.46	7.28	4.09	25.31
3. Transport	5,058.19	0.48	0.05	133.76	51.13	25.93	7.98
4. Household & Comm	1,195.70	38.97	0.53	647.65	14.41	77.74	35.35
5. Refinery	268.25	0.01	0.00	0.03	0.78	0.02	1.94
B. Fugitive Emissions		0.10		0.22	0.14	1.46	2.20
Memo Items							
International Bunkers	843.03	0.04	0.01	7.22	11.51	1.58	7.59
CO_2 from Biomass	**19,720.30**						

Fig. 2.1 CO_2 Emissions from the Sub-Sectors within the Energy Sector



2.3 Industrial Processes

Sri Lanka's industrial production in 2000 has been rather at a low level compared to that in most other countries in the region, with a share in the GDP of only 27% from manufacturing industries (CBSL, 2010a). The key industries contributing to GHG emissions were cement manufacture, lime production for construction industry, and industries using $CaCO_3$ containing material and soda ash. These are described below.

2.3.1 Cement Manufacture

Of the three cement plants in Sri Lanka, only two were operating in 2000 jointly producing 698 kt of cement (Holcim 2010). In the manufacture of cement, when limestone ($CaCO_3$) is heated, lime (CaO) is produced releasing CO_2 into the atmosphere. Lime, reacting with silica containing material, produces an intermediate product, clinker, from which cement is produced after grinding it and mixing with a little gypsum. The CO_2 and SO_2 emitted are determined using the emission factor 0.4985t CO_2 per tonne of cement and 0.3 $kgSO_2$, respectively, as given in the RIG (1996), which yields 347.95 $GgCO_2$ and 0.209 $GgSO_2$.

2.3.2 Lime Production

Quick lime (CaO) is produced when $CaCO_3$ containing material such as calcite, corals, or dolomite is burnt, in the process releasing CO_2 into the atmosphere. Lime is a material used in the construction industry and is produced mainly from dolomite, as the use of corals is banned. Table 2.15 gives the CO_2 emitted from this process, calculated using IPCC emission factors.

Table 2.15 Emissions during lime production in 2000

Material Burnt*	Quantity kt	EF tCO_2/t*	$GgCO_2$ emitted
Calcite	3.781	0.79	2.99
Dolomite	19.875	0.91	18.09
Total			**21.08**

Source: GS&MG (2001) t represents the tonnes of lime produced

2.3.3 Calcite and Dolomite Use

Both calcite and dolomite, which are additives used in the ceramic, glass, and other industries, contain $CaCO_3$. During the manufacturing process, CO_2 is released. The amounts released are calculated using rates given by IPCC Guild lines, and these are given in Table 2.16. The purity factor of booth materials is assumed to be 100%.

Table 2.16 Emissions during lime consumption in 2000

Material Added[1]	Quantity kt	EF tCO_2/t	$GgCO_2$ emitted
Calcite	4,320	0.440	1.90
Dolomite	12,526	0.477	5.98
Total			**7.88**

2.3.4 Soda Ash Use

Soda ash is used in various industrial applications; but the requirements are all imported as there is no local production. The amount imported in 2000 was 91,162 t according to Customs records. Using the IPCC default emission factor of 415 kg/t, the amount of CO_2 emitted from soda ash use was estimated as 37.83 Gg.

2.3.5 Asphalt Production and Use

GHGs are emitted during asphalt manufacture for use both as roofing sheets and in road paving. Table 2.17 gives the GHG emissions from these operations.

Table 2.17 Emissions from asphalt manufacture and use in 2000

Operation	Quantity kt	Emissions (Gg)			
		CO	NOx	NMVOC	SO_2
Roofing Sheets	0.468	0	0	0	0
Mixing Plant	44.010	0.002	0.004	0.000	0.005
Road Paving	44.010			14.083	
Total		**0.00**	**0.00**	**14.08**	**0.01**

2.3.6 Glass Manufacture

In 2000, Sri Lanka has produced 541,800 numbers of glass bottles (GS&MB 2001). Assuming an average weight of 0.5 kg per bottle, and an emission factor for NMVOC of 4.5 kg/tonne of glass produced, its emission in 2000 was estimated as 1.22 t NMVOC.

2.3.7 Metal and Paper Industries

Sri Lanka's metal industry comprised only the rolling of steel products which amounted to 48,537 tonnes in 2000. The process emits CO_2, CO, NOx, NMVOC and SO_2. Only Co_2 emission is significant (i.e 1.6 tCO_2/t) while the rest of the emissions are low. (i.e 35-45 g/t) Paper rolling too produces similar emissions. The emissions from both processes are given in Table 2.18

Table 2.18 Emissions from steel and paper rolling in 2000

Operation	Quantity kt	Emissions (Gg)				
		CO_2	CO	NOx	NMVOC	SO_2
Steel Rolling	48.537	77.659	0.0	0.002	0.001	0.002
Paper Rolling	6.785		0.038	0.010	0.025	0.047
Total		**77.659**	**0.038**	**0.012**	**0.026**	**0.049**

2.3.8 Food and Beverages

The preparation of food and beverages causes emission of NMVOC during fermentation and mixing processes. The amounts of items produced in 2000 and their emissions are given in Table 2.19. Emissions were calculated using the emission factors given in IPCC Guidelines.

Table 2.19 Emissions of NMVOC during preparation of food and beverage items in 2000

Item	Unit	Production	Emission Factor	NMVOC Emission Gg
Beer	hL	919,992	35 g/hL	0.03
Spirits/Arrack	hL	2,527,363	15 kg/hL	37.91
Bread	t	49,458	8 kg/t	0.440
Cakes & Biscuits	t	30,441	1 kg/t	0.03
Meat, Fish & Poultry	t	400,160	0.3 kg/t	0.12
Sugar	t	64,310	10 kg/t	0.64
Margarine	t	13,250	10 kg/t	0.13
Animal Feed	t	120,650	1 kg/t	0.12
Total				**39.38**

2.3.9 Summary Industrial Processes

Table 2.20 gives the summary of emissions from the Industrial Sector for 2000.

Table 2.20 Summary Emissions from the Industrial Sector

Sub-Sector	Emissions (Gg)				
	CO_2	CO	NOx	NMVOC	SO_2
Total Industrial Processes	**492.40**	**0.04**	**0.02**	**53.49**	**0.26**
A. Cement Manufacture	347.95				0.209
B. Lime Prod & Use	28.96				
C. Soda Ash Use	37.83				
D. Asphalt Use		0.002	0.004	14.083	0.005
E. Glass Manufacture				0.001	
F. Steel Rolling	77.66		0.002	0.001	0.002
G. Paper Rolling		0.038	0.010	0.025	0.048
H. Food and Beverage				39.38	

2.4 Solvents

Sri Lanka has been manufacturing surface coatings and also importing substantial amounts of solvents and surface coatings which contribute to NMVOC emissions. Of these, the amount of solvents imported in 2000 was 4.1 kt and locally produced as a byproduct in the petroleum refinery was 68.5 kt (ECF 2002). The amount of NMVOC emitted was estimated assuming all this quantity was evaporated. The estimated emission was 72.6 kt NMVOC.

2.5 Agriculture

GHG emissions from livestock, and rice cultivation, agricultural soil and agriculture residue burning were considered under agriculture.

2.5.1 Livestock Emissions

Livestock emissions fall into two categories: methane emission by ruminant animals, and emissions from manure management systems. These emissions were calculated using Tier I method given in RIG (1996). The country's animal population was counted at the Agriculture Census taken in 2002 and the total number was found to exceed 1.3 million. The animal population values were taken from this census data, assuming that there was no significant difference in populations between 2000 and 2002.

Enteric Fermentation

Enteric emission depends on several factors including animal feed, weight, age etc. Tier I method gives a single emission factor for each type of ruminant animal except in the case of cattle, where two factors are given, one for dairy cattle (46 kg/head) and the other for non-dairy cattle (25 kg/head). The division of cattle population as dairy and non-dairy was taken as 43% dairy and 57% non-dairy, based on 2003 population figures given in Census and Statistics Publication (C&SD 2003). The emissions calculated are given in Table 2.21. The total CH_4 emission is 59.68 $GgCH_4$, which is equivalent to 1,253.3 $GgCO_{2eq}$.

Table 2.21 Methane emissions from ruminant animals in 2002.

Category	Population	CH_4 Emission Gg
Dairy Cattle	517,621	23.81
Non-Dairy Cattle	686,149	17.15
Buffalo	303,231	16.68
Goats	404,917	2.02
Swine	81,106	0.02
Total		**59.68**

Methane Emissions from Manure Management

Methane is produced when organic substances present in manure decompose in an anaerobic environment. The production of methane is temperature dependent. The IPCC Tier I method specifies three emission factors for use with manure collected under three ambient temperature conditions – cool (<15 °C), temperate (15-25 °C), or warm (>25°C). In the Nuwara Eliya District with an average elevation of more than 1,500 m, the temperature is in the range 15-25 °C, and hence, animal-rearing in this district is considered to be under temperate category, and the other districts are considered under the warm category.

Table 2.22 gives the animal population in Nuwara Eliya District and in the rest of the country, and the amounts of methane emitted from manure under these two categories. The total CH_4 emission is 6.92 $GgCH_4$, which is equivalent to 145.3 $GgCO_{2eq}$.

Table 2.22 Methane emission from manure management in 2002

Category	Population in warm districts	Population in temperate district	CH_4 emission Gg
Dairy Cattle	506,207	11,414	3.09
Non-Diary	671,019	15,130	1.37
Buffalo	299,797	3,434	1.52
Swine	80,667	439	0.49
Goats	398,395	6,522	0.09
Poultry	15,530,173	179,605	0.36
Total			**6.92**

N_2O Emissions from Manure Management

Since cattle and buffaloes are mostly free grazing, the manure (dung and urine) is directly deposited on soil (without storage or treatment). The N_2O emissions from cattle and buffaloes are given in the following section. The total N_2O

emissions from manure management in poultry and swine were estimated using the country specific activity data and default emission factors (IPCC 1997, 2000), Default nitrogen excretion rates from IPCC (1997) were used with half of the value considered for the young population (IPCC 2000). Emission factor for poultry manure with bedding (0.02 kg N_2O-N/Kg N excreted) was considered for poultry and average for solid storage, dry lot, pasture/range/paddock (each 0.02 kg N_2O-N/Kg N excreted) was considered for swine. Considering the poultry population raised for both eggs and meat and the swine population raised for both breeding and fattening (according to the population statistics from Census of Statistics in Sri Lanka), it was assumed that 74 and 77 percent of the manure produced by poultry and swine, respectively, is managed. The estimated total emission is 0.12 Gg N_2O, which is equivalent to 37.2 $GgCO_{2Eq}$.

2.5.2 Rice Cultivation

Rice cultivation covers approximately 12% of the total land area of the island or about 750,000 ha. Sri Lanka has two cropping seasons – *Yala* and *Maha*, to coincide with the two rainy seasons, induced by the two wind regimes – SW and NE monsoons. Generally, more land is brought under cultivation in *Maha* than in *Yala*. Extents of rice land cultivated in the two seasons during the 3 year period 1998/99 – 2001/2 were averaged to obtain the extent cultivated in 2000. Statistics on extents of land irrigated from major and minor schemes as well as rain-fed extents are available. Table 2.23 gives the 3-year averaged extents harvested in each season under rain-fed and irrigated conditions.

Table 2.23 3-year Averaged Extents of rice harvested from rain-fed and irrigated fields

Water Supply	*Maha* ha	*Yala* ha
Rain-fed	146,208	54,819
Irrigated	365,664	256,280
Total	**511,872**	**311,099**

Even with irrigated water, fields are supplied with water only intermittently. Hence these extents were scaled down by a factor of 0.5 as recommended in IPCC Guidelines for both seasons under irrigated conditions. It was assumed that under rain-fed conditions in both *Maha* and *Yala* seasons, drought conditions could set in and therefore, a scaling factor of 0.4 was applied to rain-fed extents harvested. Methane emission from rice fields has been measured in Sri Lanka on two occasions, one at a mid-elevation WZ station (Namaratne, 1998) and the other at a low-elevation IZ station (Sirisena, 2004), obtaining seasonal values of 31.5 g/m^2 and 27.6 g/m^2, respectively. Hence, an average value of 30 g/m^2 may be taken for the country, though it may not be exactly valid as it represents only two locations. The other alternative is to use the value of 10 g/m^2 recommended for India in RIG (1996) which also has given the globally recommended value of 20 g/m^2 (RIG Table 4.13). The Indian measurements, however, extend over a wide range of values going up to 46 g/m^2 for Assam and 29 g/m^2 for Calcutta (Gupta et al., 2004). Hence, the base value of 30 g/m^2 was used in the present calculations. The methane emissions from rice fields calculated as described above is 117.43 $GgCH_4$, as shown in Table 2.24. This is equivalent to 2,466 $GgCO_{2eq}$.

Table 2.24 Methane emissions from rice fields in 2000

Water Regime	Extent* ha	Scaled down Emission Factor g/m^2	CH_4 Emission Gg
Intermittent Flooding	621,944	15	93.31
Drought Prone	201,027	12	24.12
Total	**822,971**		**117.43**

*Source: C&SD (2003)

2.5.3 Crop Residue Burning

Seasonal crops such as rice, maize, and sugarcane leave residues after harvesting, part of which are generally burnt on site, causing emission of a variety of GHGs. The amounts of residue generated were estimated using data obtained in the Agricultural Census of 2002 and conversion factors given in RIG (1996). The non-CO_2 gases emitted were estimated using emission factors given in 1996 and 2006 IPCC Guidelines, assuming 20% of residue is burnt and the results are given in Table 2.25. These give a CO_2 equivalent emission of 26 $GgCO_{2eq}$.

Table 2.25 Emissions from Crop Residue Burninig in 2000

Crop	Residue production Gg	CH_4 Gg	CO Gg	N_2O Gg	Nox Gg
Rice	3170.16	1.06	22.32	0.05	1.71
Maize	64.2	0.01	0.11	0.01	0.01
Blackgram	13.53	0.00	0.02	0.00	0.00
Cowpea	36.25	0.00	0.06	0.00	0.00
Gingerly	10.07	0.00	0.02	0.00	0.00
Greengram	27.4	0.00	0.05	0.00	0.00
Ground nuts	15.18	0.00	0.03	0.00	0.00
Ground nuts (Husks)	3.30	0.00	0.01	0.00	0.00
Kurakkan	8.23	0.00	0.01	0.00	0.00
Manioc	126.3	0.01	0.21	0.01	0.01
Sweet Potatoes	25.99	0.00	0.04	0.00	0.00
Ginger	4.40	0.00	0.01	0.00	0.00
Turmeric	3.64	0.00	0.01	0.00	0.00
Sugarcane	303.31	0.03	0.53	0.01	0.01
Total		**1.11**	**23.43**	**0.08**	**1.74**

2.5.4 N_2O Emissions from Managed Soils

Nitrous oxide emissions from managed soils include both direct and indirect emission

Direct Emissions

The direct emissions include those from nitrogen (N) input on managed organic soils, and direct emissions from urine and dung inputs from grazing animals. Direct emissions from managed organic soils and the urine and dung deposited on pasture, range and paddock, were estimated according to the IPCC methodology. The direct emissions are given in Table 2.26. The estimated N_2O emission of 1.63 Gg is equivalent to 505.3 $GgCO_{2eq}$

Table 2.26 Direct N_2O emissions from managed soil

Source/emission category	N_2O Gg
Direct emissions	
N inputs to managed soils	
Synthetic fertilizers	1.380
Organic amendments	0.064
Crop residues	0.158
Mineralized soil organic matter	0.011
Managed organic soils	0.002
Grazed soils (pasture, range and paddock)	0.011
Total direct emissions	**1.626**

Indirect Emissions

Indirect emissions include the N_2O emissions from atmospheric deposition of N volatilized from managed soils (from N inputs), and emissions due to any N leached/runoff from managed soils, as shown in Table 2.27. The total indirect N_2O emission is equivalent to 255.13 $GgCO_{2eq}$.

Table 2.27 Indirect emission of N_2O from agriculture land.

Source	N_2O Gg
Indirect emissions	
Atmospheric deposition of volatilized N from managed soils	
Synthetic fertilizers	0.243
Organic amendments	0.013
Grazed soils (pasture, range and paddock)	0.002
Leaching/runoff from managed soils	
Synthetic fertilizers	0.546
Organic amendments	0.014
Grazed soils (pasture, range and paddock)	0.002
Crop residues	0.001
Mineralized soil organic matter	0.002
Total indirect emissions	**0.823**

2.5.5 Summary - Agriculture Sector

Table 2.28 gives the summary of emissions from the Agriculture Sector.

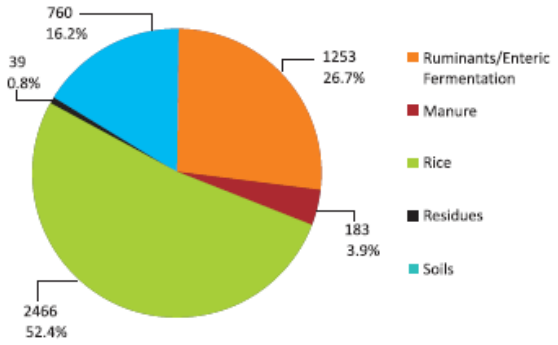
Table 2.28 Non-CO_2 Emissions from the Agriculture Sector 2000

Source	Emissions (Gg)			
	CH_4	N_2O	CO	NOx
Enteric Fermentation	59.68			
Manure Management	6.92	0.12		
Rice Cultivation	117.43			
Crop Residue Burning	1.11	0.08	23.43	1.74
Direct Emissions from Soils		1.63		
Indirect Emission from Soils		0.82		
Total	**185.14**	**2.65**	**23.43**	**1.74**

The total CO_2 equivalent emissions from this sub-sector is 4,709 $GgCO_{2eq}$, comprising 3,888 $GgCO_{2eq}$ of CH_4 and 821 $GgCO_{2eq}$ of N_2O.

Fig. 2.2 shows the composition of aggregate emissions from the agriculture sector in $GgCO_{2eq}$ values. The highest is from rice fields contributing 52.4%, while contributions from enteric fermentation, soils, manure management and residue burning have been 26.7%, 16.2%, 3.9 % and 0.8%, respectively.

Fig. 2.2 Emissions from sub-sectors under agriculture sector in $GgCO_{2eq}$.



2.6 Land Use Change and Forestry (LUCF) Sector

Under this sector, the Revised 1996 IPCC Guidelines (RIG 1996) require emissions or removals of CO_2 from the following land-use and forestry activities be reported.

- Changes in forest and other woody biomass stocks including harvesting, forest plantations, community plantations etc;
- Forest and grassland conversions (conversion of forests and grassland to pastures, cropland, and other managed uses);
- Abandonment of croplands, pastures, plantation forests or other managed lands, and
- Changes in soil carbon

According to RIG (1996), undisturbed natural forests free of anthropogenic activities and are in equilibrium are excluded from inventory calculations. Under managed forests, the reforestation and afforestation activities undertaken by Forest Department (FD) have been included. The three plantation crops - tea, coconut, and rubber which cover about 11% of the entire land extent, serve both as sources and sinks, as they are harvested regularly. Changes in carbon stocks in these crops as well as in home gardens are reported. However, no estimates have been made on forest land converted to grassland or on abandonment of cropland, as no such activities have been identified for 2000. Some of the estimates reported here are however, based on IPCC 2006 Guidelines (Lokupitiya, 2008).

2.6.1 Changes in forest and other woody biomass stocks

Changes in forest biomass stocks

The FD has conducted reforestation and afforestation programmes and only these have been included under changes in biomass stocks. Forest plantations less than 20 years old were considered as land converted to forestlands. Enrichment plantation areas since 1980 were added as the forestland remaining forestland younger than 20 years. In estimating the change in living biomass carbon stocks, Tier 2, gain-loss method (IPCC 2003, IPCC 2006) was used for both natural and plantation forests. The fraction of carbon in biomass was assumed to be 0.47, based on the past studies and new IPCC (2006) guidelines. In estimating annual carbon gain in forest plantations, country-specific mean

annual increment rates (solid volume over bark; m^3 s.o.b. ha^{-1}) for different age classes of each plantation type were extracted from the yield tables based on site-level measurements (MLLD, 1986). Country-specific wood densities (Vivekananda, 1978) and root: shoot ratios (Ranasinghe et al., 1991) were used based on the data availability. In cases where country-specific wood densities, biomass expansion factors, and root: shoot ratios were not available (to expand the merchantable wood volume to total biomass in both above- and below-ground), appropriate values given by IPCC (2003, 2006) were used. For the forestland remaining forestland less than 20 years (i.e. enrichment areas), the mean annual aboveground biomass increment rates were extracted from Muthuwatte and Chemin (2003). Although a land use change matrix could not be drawn for the country due to lack of specific land use change information, specific areas under the forestland remaining forestland, and land converted to forestland could be determined based on the data available. Table 2.29 provides the estimated carbon gain in forest plantations (2,551 Gg CO_2 yr^{-1}), including the carbon gain in living biomass (1,784.19 Gg) and litter (766.51 Gg).

Table 2.29 Carbon gain in forest plantations in 2000

Type of Stock	Gg CO_2 yr^{-1}*
Carbon Gain in different forest categories	
Land converted to forest plantations in the dry and intermediate zones	- 907.38
Land converted to forest plantation in the wet zone	- 876.81
CO_2 gain from biomass stock change	**-1784.19**
Carbon stock change in litter	-766.51
Total CO_2 stock change in forest plantations	**-2,550.70**
* '-' Indicates uptake/removals, and '+' denoted with no sign indicates emission to the atmosphere	

Carbon loss in timber removal

Since there was a scarcity of disaggregated data for timber and fuel wood volumes removed from the forest plantations and natural forests, extrapolated wood volumes for the inventory year according to the Forestry Sector Master Plan (FSMP) were used in estimating the carbon removed in timber and fuel wood.

In estimating the carbon loss in wood removal or felling, the methodology suggested in the IPCC good practice guidance was used (IPCC, 2003). Timber volumes removed from the plantations and natural forests were extracted from the extrapolated volumes given in the FSMP for the inventory year, according to which the average timber volumes removed from plantations and natural forests in 2000 were 158,333 m^3 and 8,700 m^3, respectively. For plantations, a weighted density was estimated using the country- and species- specific growing stock, area, and wood density information; the weighted density thus estimated (0.55 tonnes dry matter (d.m.) m-3) was used in calculating the biomass expansion factor (3.08) for converting the extracted volumes to total aboveground biomass and for calculating the timber biomass (and carbon) removal. The fraction of

Table 2.30 Carbon lost due to removal of trees from plantations

Source of biomass	Gg CO_2 yr^{-1}
Carbon lost due to felling in Plantations	416.76
Carbon lost due to felling Natural forests	20.58
Total CO_2 lost due to timber removal	**437.34**

biomass left to decay was assumed to be 10 percent, based on expert opinion. For natural forests, a weighted density of 0.5 t d m m^{-3} was estimated based on the country-specific growing stocks, areas, and densities relevant to different forest types, and a biomass expansion factor of 3.05 was used in calculating the timber removal (437.34 Gg), as given in Table 2.30.

Carbon loss in fuel-wood removal

In Sri Lanka, fuel-wood constitutes nearly 50 percent of the total energy consumption. About 24 percent of the fuel-wood used in the domestic sector and about 38 percent used in the industrial sector come from natural forests (Bandaratilake, 2001). The average fuelwood removed from plantations and natural forests in 2,000 were 288,333 and 633,900 tonnes, respectively (MLAF, 1995). Since the fuel wood removal from natural and plantation forests corresponding to the inventory year was given in the FSMP as tonnes(bm), it was converted to tonnes(dm), assuming a moisture level of 15 percent, and a biomass expansion factor of 3.4. The estimated carbon removal in fuel-wood was 4,593.12 Gg, as given in Table 2.31.

Table 2.31 Carbon lost due to removal of fuel-wood

Source of biomass removal	Gg CO_2 yr^{-1}
Carbon lost due to fuel-wood sourcing from Plantations	1436.02
Carbon lost due to fuel-wood sourcing from Natural forests	3157.10
Carbon lost due to fuel-wood sourcing	**4,593.12**

Carbon stock change in the biomass of perennial woody crops

Carbon gain in the perennial woody crops was estimated using the same methodology as for the forests. Data for the perennial woody crops belonging to different age classes were obtained from the Department of Census and Statistics. This information was further supplemented with the data from the annual reports of Central Bank of Sri Lanka and literature on country specific studies. Annual biomass growth rates corresponding to different age classes were obtained from the country (Hettiarachchi and Mohotti, 2008) or the default values from IPCC (2003; 2006).

Since there is a low level of wood removal from specific perennial crops, the extrapolated removal rates according to the FSMP (MLAF, 1995) were used for perennial crops other than tea, rubber, and coconut. For tea, rubber, and coconut, the harvest removal (both as timber and fuel wood) rates based on country specific studies were used. In calculating the carbon loss in wood removal from tea plantations, a country specific biomass expansion factor (BEF2) of 3.08 was derived (IPCC 2003), considering 61.8 tonnes biomass ha^{-1}. For rubber, an estimated country-specific wood density of 0.63 tonnes dry matter m^{-3} was used. For all the perennial crops without country specific information, a wood

Table 2.32 Carbon stock change in the biomass of perennial woody crops in 2000

Description	Gg CO_2/yr
Tea, rubber, and coconut	
Carbon gain	- 17,772.41
Carbon loss	9,186.78
Carbon stock change	-8,585.63
Other perennial crop plantations	
Carbon gain	-854.94
Carbon loss	1,186.54
Carbon stock change	331.61
Total biomass carbon stock change in all perennial crops	**-8,254.02**
* '-' Indicates uptake/removals, and '+' (denoted with no sign) indicates emission to the at mosphere	

density of 0.5 tonnes dry matter m^{-3} was assumed, with a biomass expansion factor of 3.4 [i.e. the average value for the tropical broadleaf forests according to IPCC (2003, 2006)], and a carbon fraction of 0.47 in the biomass removed. Assuming that there is no net biomass change in annual croplands, biomass carbon stock changes were calculated only for the perennial woody croplands as shown in Table 2.32.

Carbon Change in Home Gardens

Carbon stock changes in home gardens, an agro-forestry system providing food, timber, medicine and spices were estimated separately from the perennial cropland. The total area under Home Gardens in 2000 was estimated at 877,400 ha. Home gardens constitute a well developed agro-forestry system that extends throughout the country, supplying 41 percent of the saw-logs and 26 percent of the biofuel demand in the country (Ariyadasa 2002a).

Since home gardens have rich diversity of tree species in a large area extent (~6 times the extent of forest plantations) with a high annual carbon gain, and a high rate of wood removal as both timber and fuel wood compared to forests (timber supply is about 6-8 times, and fuel wood supply is more than 10 times, compared to forest plantations), The annual net carbon gain in biomass is relatively low. Carbon gains and losses in home gardens were estimated using the same methodology as for the forest plantations. A wood density of 0.57 was assumed, and the timber volume removed was estimated at a rate of 0.95 m^3 sawlogs and 0.5 m^3 of poles $ha^{-1}yr^{-1}$. The resulting carbon gain is 109.33 $GgCO_2/yr$, as shown in Table 2.33. This difference, however, is not significant, considering the uncertainties in the gain and loss values.

Table 2.33 – Annual carbon stock change in home gardens in 2000.

Activity	CO_2 Gg/yr
CO_2 gain in live biomass	
Home gardens in the dry and intermediate zones	-7818.65
Home gardens in the wet zone	-9009.68
Total CO_2 gain	-16828.33
CO_2 loss	
Carbon losses due to felling	2508.83
Carbon losses as fuel wood	14210.17
Total CO_2 loss	16719.00
Carbon stock change (as CO_2) in live biomass	**-109.33**

Summary of Carbon Change in Woody Biomass

A summary of the carbon change in woody biomass in forest plantations, perennial cropland, and home gardens as estimated above is given in Table 2.34.

Table 2.34 Summary of carbon changes in woody biomass

Description	$GgCO_2$ / yr
CO_2 gain in forest plantations	-2,550.70
CO_2 lost due to timber removal	437.34
CO_2 lost from fuel-wood removal	4,593.12
CO_2 stock change in all perennial crops	-8,254.02
CO_2 stock change in home gardens	-109.33
Net CO_2 stock changes	**-5,883.59**

2.6.2 Carbon stock change in soils

The soil carbon stock change was estimated only for the land converted to forestland. It was assumed that the land that got converted to forestland was initially abandoned/degraded land, and the system had been low input and highly

managed prior to establishing the plantations. High input (without manure) was assumed for the inventory year, considering the dead biomass and litter accumulation on plantation forest soils; but this was further modified using an adjustment factor (0.95) to reflect any biomass removal in fuel-wood gathering and other purposes. A period of 20 years was assumed as the transition period to forestland.

Tier 1 methodology was used, with updated emission factors from IPCC 2006. Carbon stock changes in mineral soils were estimated with these values. Due to lack of information on the managed organic soils (12-20 percent or more organic matter by mass; IPCC, 2006) in forests, mineral soil carbon stock changes were estimated separately for the land converted to forestland in different climatic zones. Forest soil is a net carbon sink of 636.85 Gg CO_2 yr^{-1}, as given in Table 2.35.

Table 2.35 Carbon stock changes in forest soils in Sri Lanka

Source of soils	Gg CO_2 yr^{-1}
Soil carbon stock change in dry and intermediate zones	285.99
Soil carbon stock change in wet zone	350.86
Total carbon stock change in mineral soil	**636.85**

Carbon stock change in crop soils

Cropland mineral soils

This was estimated using a default inventory period of 20 years (IPCC 1997; 2003; 2006), and the annual cropland areas at the beginning and end of the inventory period (i.e.1980 and 2000). According to the estimates based on the district wise data from the Department of Census and Statistics, there was an overall 3 percent reduction (from 989126 ha to 958176 ha) of the total annual cropland, including paddy land, by the end of the inventory period. About 19 percent of the specific crop areas had been abandoned (since 1980) or converted to other land uses, and 17 percent of the specific crop area had been newly added by 2000. Thus the total cropland area of 1980 not in cultivation by 2000 was 189764 ha, and the extent of extra land added to cropland by 2000 (i.e. land converted to croplands) compared to 1980, was 169225 ha. Since the total land converted to forestland between 1980 and 2000 was 77036 ha, it was assumed that this 'new' forestland came from part of the cropland area prior to the beginning of the 20-year inventory period.

Carbon stock changes in cropland converted to forestland were estimated above under forest soils. The remainder of the uncultivated cropland (compared to 1980) by 2000 must have got converted to another land use than forest, for which no data were available. Due to lack of national statistics on changes in management practices and carbon/organic inputs in the cropland remaining cropland, carbon stock change estimates were made only for the land converted to cropland. It was assumed that the land which got converted for cropland was native forestland originally (IPCC, 1996). The default IPCC methodology, stock change factors and reference carbon stocks (IPCC, 2006), and country specific activity data were used. The cropland soils under annual crops were a net source of CO_2, emitting 38.78 $GgCO_2$, as shown in Table 2.36.

Table 2.36 Annual carbon stock changes in cropland soils

Source	Area ha	Amount $GgCO_2$/Yr
Mineral soil carbon stock change		
Paddy land (New land)		
Dry and intermediate zones	145,861	-15.08
Wet Zone	11,846	-1.56
Other Annual Crops	11,518	55.42
Net Exchange in Mineral Soil		**38.78**
Emission from Organic Soil	**80**	**5.87**
Total Emission from crop Soils		**44.65**

Cropland Organic Soils

The Tier 1 methodology given by IPCC (2003, 2006) was used. Since natural wetland areas and rice paddies are excluded from this category, the area of cultivated crop area (with other crops) in organic soils in Sri Lanka is relatively low (about 80 ha in Muthurajawela and Negombo lagoon area based on the available information). Thus considering an emission factor of 20 tonnes C ha^{-1} yr^{-1} (IPCC, 2003), the total emissions of cultivated organic soils was estimated at 5.87 Gg CO_2. The total emissions from both mineral and organic soils are 44.65 $GgCO_2$, as shown in Table 2.35.

Emissions from Lime and Urea applications on Managed soils

Lime and urea applied on soils release CO_2 as a result of dissolution and break down processes within soil. The default methodology (IPCC, 2006) was used in estimating the emissions from liming and urea fertilization. The data for dolomite and urea applied on different crop types in 2000 were extracted from the National Fertilizer Secretariat, Statistics division of the Agriculture Department, and the Tea Research Institute. the total amounts of dolomite and urea were 6,900 t and 297,700 t, respectively. The CO_2 emissions were estimated using an emission factor of 0.13 (i.e. the fraction of carbon in dolomite; IPCC, 1997 a, b, c; 2006) for dolomite and an emission factor of 0.2 (i.e. the carbon fraction in urea; IPCC, 2006) for urea, and the results are shown in Table 2.37.

Table 2.37 CO_2 Emissions from application of lime and urea on Soil

Substance	Consumption kt	C fraction	CO_2 Emission Gg
Dolomite	6.9	0.13	3.29
Urea	297.7	0.2	218.51
Total			**221.80**

The total CO_2 emissions from lime application on cropland soils were estimated to be 3.29 Gg CO_2, while the emission from urea fertilization was estimated at 218.51 Gg CO_2, making the total emissions from soils as 221.80 $GgCO_2$.

Summary of emissions from carbon stock changes in soil

Table 2.38 Summary of carbon stock changes in soils

Description	$GgCO_2/yr$
Stock change in forest soil	-636.85
Emission from crop soils	44.65
Emissions from lime and urea on cropland soils	221.80
Net CO_2 emissions from soil	**-370.4**

2.6.3 Emissions from Forest Fires

Carbon Loss

The carbon loss in forest fires was estimated in this section. Although there is no significant threat to natural vegetation from forest fires, fire hazard is significant in forest plantations, especially in pine and eucalyptus plantations (Ariyadasa 2002b). Since these fires are mostly short-term, surface fires, no change in the belowground biomass was assumed from fire. An average area of 310.5 ha was considered to be affected by fire during the inventory year (Ariyadasa 2002b). The fraction of biomass lost in fire was assumed to be 0.1 (i.e. Fraction left on the forest to decay was

considered as 0.9 (IPCC 2003). The average aboveground biomass of land areas affected by fire during the inventory year (B_w in eq. 3.2.9) was estimated using country-specific data (estimated at 193.25 tonnes ha^{-1} using the data for eucalyptus and pine from Ranasinghe etal. (1991) and Khadka (2005), respectively. The carbon loss due to forest fires was 10.34 $GgCO_2$/yr.

Non-CO_2 Emissions

Under this, non-CO_2 emissions due to forest fires (mostly surface fires, as described above) were estimated. Overall emissions from forest fires include CO_2 and other GHGs resulting from incomplete combustion of the fuel. Out of these non-CO_2 GHGs, CH_4, CO, N_2O, and NO_x were estimated. Total carbon released in forest fires was used in estimating the non-CO_2 emissions (Table 2.39). In estimating CO and CH_4 emissions, carbon released in fire [2.82 Gg C yr^{-1},(i.e. C in 10.34 Gg CO_2) as given previously] was multiplied by the relevant emission ratios, and mass conversion factors corresponding to each gas, as given by the IPCC (1997 a, b, c; 2003). For N_2O and NO_x emissions, nitrogen released was estimated by multiplying the carbon released by a Nitrogen-Carbon ratio of 0.01 (i.e. N released was 0.028 Gg C yr^{-1}); then this value was multiplied by the corresponding emission ratios (IPCC, 2003) and mass conversion factors (IPCC, 1997; 2003). The results are given in Table 2.39.

Table 2.39 - Non-CO_2 emissions due to forest fires in 2000

Greenhouse gas	Emission ratio	Mass conversion factor	Emission Gg yr^{-1}
CH_4	0.012	16/12	0.045
CO	0.06	28/12	0.395
N_2O	0.007	44/28	0.000
NO_x	0.121	46/14	0.011

2.6.4 Grasslands

Due to lack of information on the extents of the land converted to grasslands and grasslands remaining grasslands, all grasslands were considered as grasslands remaining grasslands, and assumed to be in stability, with the dead wood and litter stocks are in equilibrium; thus following the Tier 1 methodology, carbon stock changes in biomass and dead organic matter were not estimated (IPCC, 2006). Since the area under both forests and grasslands/savannas were considered together under forest fires (as the data were not available separately for forests and grasslands), burning of grasslands/savannas were not estimated here, to avoid double accounting.

2.6.5 Emissions from Wetlands

According to Ramsar definition, the wetlands in Sri Lanka can be categorized as inland natural freshwater wetlands, marine and salt water wetlands, or man-made wetlands (Kotagama and Bambaradeniya 2006). In this section, only the emissions from managed and man-made wetlands that are relevant to anthropogenic activities are considered. The country's total peat-land area is 2500 ha, while Muthurajawela, the largest peat deposit in the country extends over 2000 ha (Dahanayake et al., 1991). Off-site emissions from horticultural (non-energy) use of peat were not considered in this analysis, as the use of peat in horticulture is not a common practice in Sri Lanka. Peat extraction for

any other use is a rare occurrence in the country, as well. Thus on-site CO_2 and non-CO_2 emissions from managed peatlands due to peat extraction were not estimated.

Human impacted flooded land areas include the tanks and reservoirs used for irrigation, hydroelectricity, etc. Only were considered using an emission factor of 0.095 $kgCH_4$/ha/day. The total area under major irrigation reservoirs (each >200 ha) was estimated to be 7820 ha (Kotagama and Bambaradeniya 2006). The annual extent of the land converted to flooded land, (i.e. the area under seasonal/minor irrigation tanks) was found to be 52,250 ha (Kotagama and Bambaradeniya 2006). Table 2.40 gives the amount of CH_4 emitted annually from these man-made reservoirs as 1.62 $GgCH_4$, which is equivalent to 34 $GgCO_{2eq}$.

Table 2.40 Emissions from Flooded Land

Activity	Area ha	$GgCH_4$
Flooded Land remaining flooded	7,820	0.27
Land converted to Flooded Land	52,250	1.35
Total		**1.62**

2.6.6 Summary - Land Use Change and Forestry Sector

Table 2.41 Emissions/Removals of GHG in the Land-use and Forestry Sector

Activity	Emissions CO_2 (Gg)	Removals CO_2 (Gg)	CH_4 Gg
Carbon stock change in woody biomass		5,883.59	
Carbon stock change in soils		370.4	
Emissions from forest fires	10.34		0.05
Emissions from flooded land/tanks			1.62
Total	**10.34**	**6,253.99**	**1.67**

2.7 Waste Sector

In the Western Province where the population is the highest, daily collection of solid waste is estimated to be about 6,400 t/day. These are disposed mostly in open dump yards. Some efforts are being taken to sort recyclable substances and covert the organic component into compost. A few proposals had been made to set up waste to energy projects, but these have still not taken off the ground.

2.7.1 Solid waste disposal

The Ministry of Forestry and Environment has compiled a list of the amounts of solid waste generated in all local bodies in the country in 1998, according to which the waste generated within all Municipal and Urban Councils has been 1,937 t/day. This amount was desegregated into Colombo city and its suburb MC where the characteristics of waste collection are different to the rest. This yields an annual generation of 719.1 kt after applying a correction factor of 1.017 to account for the population difference between 1998 and 2000. The desegregated data on degradable organic component (DOC), disposal factor, dissimilate factor were assumed. The values for the "rest" category were based on IPCC Guidelines while the other two were specific to the locations as reported. These data yield a CH_4 emission of 84.1 Gg for 2000, as shown in Table 2.42.

Table 2.42 Methane Emission from Municipal Solid Waste

Area	MSW collected t/day*	MSW collected kt/yr	Disposal Factor	DOC Factor	Dissimilate Factor	CH_4 emitted Gg
Colombo MC	643	238.7	0.9	0.83	0.2	35.66
Dehiwala-Mt Lavinia MC	176	65.3	0.9	0.94	0.2	11.05
Rest	1118	415.0	0.6	0.75	0.2	37.35
Total	**1937**	**719.0**				**84.06**

*Source: MENR (2002)

2.7.2 Waste water treatment

It is mandatory for large industries to treat their waste water before releasing them into waterways, and some industries are practicing it. Table 2.43 gives the amount of waste water generated in 2000 from the major industries.

Table 2.43 – Waste water treatment at selected industries

Industry	Wastewater Generation rate(m^3/ t of product)	Biodegradable Organic Component (kg COD / m^3 of wastewater)
Canneries	26	0.25
Beer	5	17
Meat Processing	18	0.25
Dairy Products	2.8	1.5
Sugar	15	98
Soft Drinks	2.5	0.25
Paper	44	3
Petroleum Refining	3	0.35
Rubber	22.7	0.25

The estimated quantities of CH_4 generated from both domestic and commercial sector waste water generation activities are given in Table 2.44, which gives a CH_4 emission of 12.76 $GgCH_4$, which is equivalent to 268 $GgCO_{2eq}$

Table 2.44 Methane emission from wastewater treatment in 2000

Activity	Amount of waste water tCOD/BOD	Recovery	Emission $GgCH_4$
Industrial treatment	107,680	0	4.85
Domestic and Commercial	79,144	0	7.91
Total			**12.76**

2.7.3 Summary Waste sector emissions

Table 2.45 Summary of Methane Emissions from Waste Sector

Source	Emission	
	$GgCH_4$	$GgCO_{2eq}$
Municipal solid waste	84.06	1,765.2
Domestic and Commercial wastewater	7.91	166.1
Industry	4.85	101.8
Total	**96.82**	**2,033.1**

2.8 Overall summary of GHG emissions and removals.

The overall summary of emissions and removals of all GHG and precursor gases from all sectors is given in Table 2.46, in the format given in Table 1 of Annex B to the Decision 17 of COP 8. There have been no records of any imports of HFCs or PCFs or SF_6 to the country in 2000. Thus, Table 2 of Annex B to the Decision 17 of COP 8 is not given here.

Table 2.46. National greenhouse gas inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases

Greenhouse gas category	CO_2 Emissions Gg	CO_2 Removals Gg	CH_4 Gg	N_2O Gg	CO Gg	NOx Gg	NMVOC Gg	SO_2 Gg
Total emissions and removals	**10,932.75**	**6,253.99**	**325.60**	**3.46**	**920.59**	**83.68**	**235.54**	**105.86**
1. Energy	**10,430.01**		**41.97**	**0.81**	**896.73**	**81.92**	**109.44**	**105.60**
A. Fuel combustion	10,430.01		41.87	0.81	896.51	81.78	107.98	103.40
1. Energy Industries	3,065.84		0.12	0.02	0.61	8.18	0.20	32.82
2. Industries	842.03		2.29	0.21	114.46	7.28	4.09	25.31
3. Transport	5,058.19		0.48	0.05	113.76	51.13	25.93	7.98
4. Household and Comm.	1,195.70		38.97	0.53	647.65	14.41	77.74	35.35
5. Refinery Use	268.25		0.01	0.00	0.03	0.78	0.02	1.94
B. Fugitive Emissions			0.10		0.22	0.14	1.46	2.20
1. Oil and Gaseous			0.10		0.22	0.14	1.46	2.20
2. Industrial Processes	**492.40**	**NA**	**NA**	**NE**	**0.04**	**0.01**	**53.49**	**0.26**
A. Cement Manufacture	347.95				NE	NE	NO	0.21
B. Mineral Industries	66.79		NO		NO	NO	NO	NO
C. Chemical Industries	NA		NA	NA	NA	NA	14.08	NA
D. Metal Industries	77.66		NO	NE	NE	NE	NE	NO
E. Other (Food & Paper)	NE			NE	0.04	0.01	39.41	0.05
3. Solvents and other products	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**72.60**	**NA**
4. Agriculture			**185.14**	**2.65**	**23.42**	**1.74**	**NE**	**NA**
A. Enteric Fermentation			59.68					
B. Manure Management			6.92	0.12			NE	
C. Rice Cultivation			117.43				NE	
D. Agricultural Soils			NE	2.45			NE	
E. Burning Savannah			NE	NE	NE	NE	NE	
F. Burning Agri. Residues			1.11	0.08	23.42	1.74	NE	
G. Other			NO	NO	NO	NO	NO	
5. Land-use change and forestry	**10.34**	**6,253.99**	**1.67**		**0.40**	**0.01**	**NA**	**NA**
A. Changes in woody biomass stocks	NE	5,883.59						
B. Forest and grassland conversion	10.34	NO	0.05	0.0	0.40	0.01		
C. CO_2 emission and removal from soil	NE	370.4						
D. Other – Emissions from flooded land	NE	NA	1.62		NE	NO		
6. Waste			**96.82**	**NE**	**NE**	**NE**	**NE**	**NO**
A. Solid waste disposal in land			84.06		NE		NE	
B. Waste water handling			12.76	NE	NE	NE	NE	
C. Waste incineration					NO	NO	NO	NO
Memo items								
International bunkers	**834.03**		**0.03**	**0.01**	**7.22**	**11.52**	**1.58**	**7.59**
CO_2 emissions from biomass	**19,720.30**							

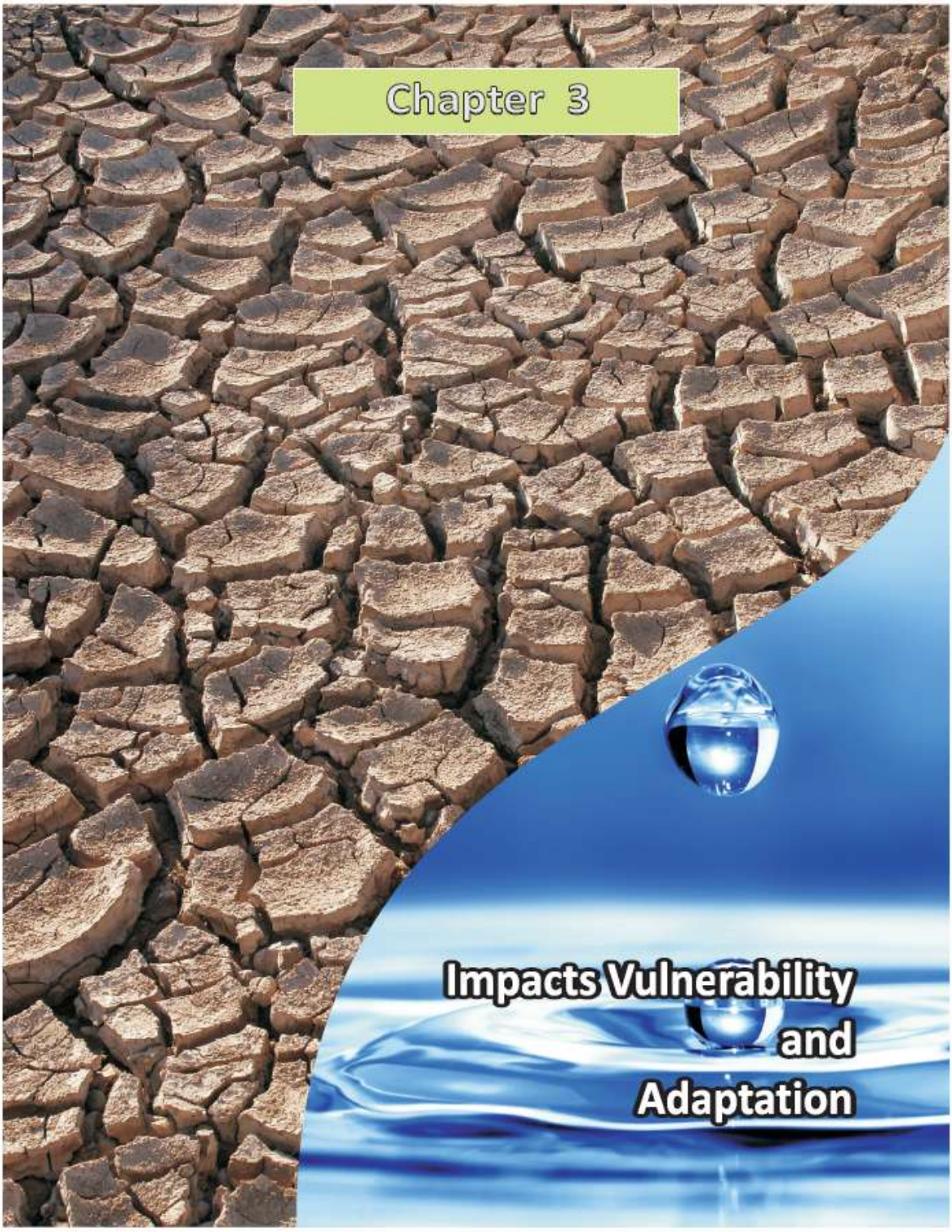
NO - Not Occurring; NE - Not Estimated; NA - Not Applicable; IE - Included Elsewhere; C - Confidential
1. Energy - CO2 removals; if no sub categories there can't be main value, hence shaded

2.9 Aggregated Emissions

The aggregated emissions are calculated using Global Warming Potential values applicable to 100 year time horizon reported in the IPCC Second Assessment Report (SAR). For the three main GHGs, these are 1 for CO_2, 21 for CH_4 and 310 for N_2O. A summary of the Inventory expressed in CO_2 Equivalent values is given in Table 2.47.

Table 2.47 Aggregate Inventory of GHG Emissions and Removals

Sector	CO_2 Gg	CO_2 Removals Gg	CH_4 Gg	CH_4 $GgCO_{2eq}$	N_2O Gg	N_2O $GgCO_{2eq}$	Total $GgCO_{2eq}$ (Net)
Energy	10,430.01		41.97	881.37	0.81	251.10	11,562.48
Ind. Processes	492.40						**492.40**
Agriculture			185.14	3,887.94	2.65	821.50	4,709.44
LUCF-Emissions	10.34		1.67	35.07			**45.41**
Waste			96.82	2,033.22			2033.22
Total-Emissions	**10,932.75**		**325.60**	**6,837.60**	**3.46**	**1,072.60**	**18,842.95**
LUCF-Removals		-6,253.99					-6,253.99
Total-Net	**10,932.75**	**-6,253.99**		**6,837.60**		**1,072.60**	**12,588.96**


Chapter 3
Impacts Vulnerability and Adaptation

Impacts, Vulnerability and Adaptation

An important aspect of climate change studies is to determine its impact on the country's vulnerable sectors, assess vulnerabilities and decide on adaptation measures. In this Chapter, these aspects will be considered in respect of agriculture,p water resources, human health and the coastal zone. In most cases, vulnerability has been assessed qualitatively based on adverse impacts only without considering the adaptive capacity of the affected people. Whatever adaptation measures that had been carried out in various sectors, were undertaken to meet the threats of recurring droughts. In most sectors, only recommendations for adaptation were given rather than describe any actual measures taken. The Chapter will commence with a discussion on climate change trends and future climate projections as applicable to Sri Lanka.

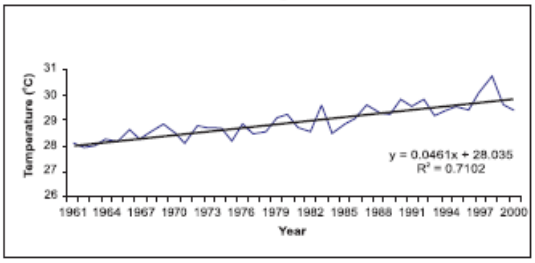
3.1 Trends in Present Climate

Sri Lanka has been collecting climate data from 1861 at 22 meteorological stations located in all districts of the country. The data on temperature and rainfall have been analyzed by the Meteorological Department (MD) to determine their trends over the period 1901-2000, using data taken from 18 meteorological stations, excluding data from the stations in Northern and Eastern Provinces which were not functioning throughout.

3.1.1 Temperature Analysis

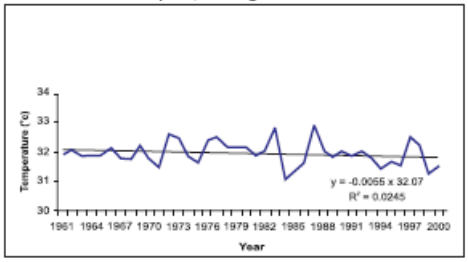
For the purpose of this report, temperature (maximum and minimum) and rainfall data were analyzed for the 40-year period from 1961 to 2000. During this 40 year period, an increasing trend in annual maximum temperatures with rates up to 0.046 °C per year was seen at all stations except at Nuwara-Eliya and Ratnapura which showed decreasing trends. The highest rate of temperature increase of 0.046 °C per year was observed at Badulla, while the highest decreasing rate of -0.005°C per year was observed at Ratnapura. These two trends are shown in Figs. 3.1 and 3.2, respectively.

Fig. 3.1 Annual mean maximum temperature trend at Badulla, during 1961 - 2000



Source: MD (2010)

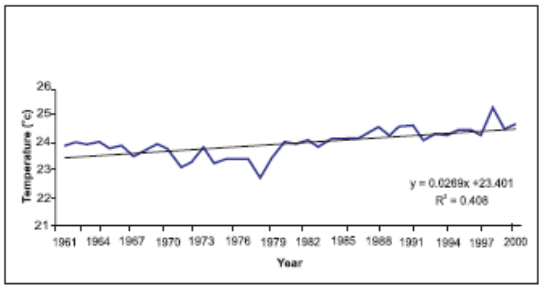
Fig. 3.2 Annual mean maximum temperature trend at Ratnapura, during 1961 - 2000



Source: MD(2010)

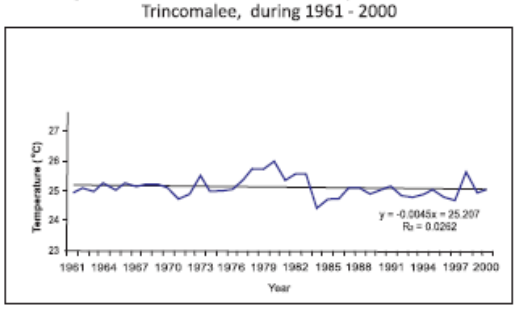
During the same period, increasing trends in annual mean minimum temperatures were observed at all stations except at Trincomalee, where a slight decreasing trend was seen. The highest rate of increase of 0.0269 °C per year was observed at Ratmalana while a rate of decrease of -0.0045 °C per year was observed at Trincomalee. These two trends are shown in Figs. 3.3 and 3.4. respectively.

Fig. 3.3 Annual mean minimum temperature trend at Ratmalana, during 1961 - 2000



Source: MD(2010)

Fig. 3.4 Annual mean minimum temperature trend at Trincomalee, during 1961 - 2000

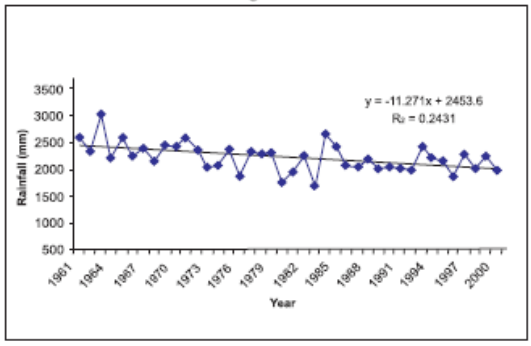


Source: MD(2010)

3.1.2 Rainfall Analysis

A decreasing trend of 9.46 mm per year was observed in annual mean rainfall over the whole country from 1961-2000 time period (Fig. 3.5). As a dense data base is available in rainfall, district - wise rainfall data were analyzed which shows considerable differences in trends among them. The highest decreasing rate of 19.06 mm/year was observed at Kalutara district and the lowest rate was observed at Jaffna (1.55 mm per year). Comparative rates in decreasing trends can be seen at Gampaha (15.94 mm per year) and Galle (15.32 mm per year) districts as well.

Fig. 3.5 Annual average rainfall trend in Sri Lanka during 1961 - 2000



Source: MD (2010)

Analysis of climate data clearly indicates a change in the rainfall intensity, temporal and spatial distribution, and an increasing trend in air temperature. Most of the decrease in the annual rainfall is from the NEM with no significant changes in the SWM and the second inter-monsoon. The number of rainy days has also decreased, prolonging the dry spells and increasing the intensity of rainfall. This change in rainfall distribution has caused a shift in the demarcation between the dry and wet-zones, with a reduction in the area of the wet-zone.

3.2 Future Climate Projections

3.2.1 South Asia Region

The IPCC Third Assessment Report (TAR) released in 2001 gives projections for regional climate changes based on Global Circulation Models (GCM) (IPCC, 2001) developed by several organizations including Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, Hadley Centre (HadCM) of University of Anglia, UK, National Institute for Environmental Studies (NIES), Japan and Canadian Global Coupled Model (CGCM). These projections were determined corresponding to different IPCC emission scenarios designated A1FI, A2, B1, B2 to represent different global demographic and economic situations in the future (IPCC, 2000). According to these models, the range of projected temperature rise by 2100 applicable for South Asia lies between 1.0°C and 3.6°C, with a mean of 2.0°C.

While the temperature projections shown for all emission scenarios and GC models give increasing trends though in different magnitudes, the rainfall projections show both increasing as well as decreasing trends which also depend on the season. The IPCC rainfall projections for South Asia show mostly increases up to about 5% with a few going up to 15%, but two models show decreases up to about 5% during winter and summer months.

3.2.2 Sri Lanka Projections

The IPCC projections are given on a very coarse resolution and may not be appropriate for determining climate variations in a small country such as Sri Lanka. Though there are several standard techniques available for downscaling the global projections to national levels, Sri Lanka lacked the capacity to do so, both in terms of human resources and computing facilities. In an initiative taken by the Sri Lanka Association for the Advancement of Science (SLAAS), funds were obtained from the GEF/UNEP sponsored global project on Assessment of Impacts of and Adaptation to Climate

Fig. 3.6 Mean temperature (°C) baseline (1961-1990) during SWM months

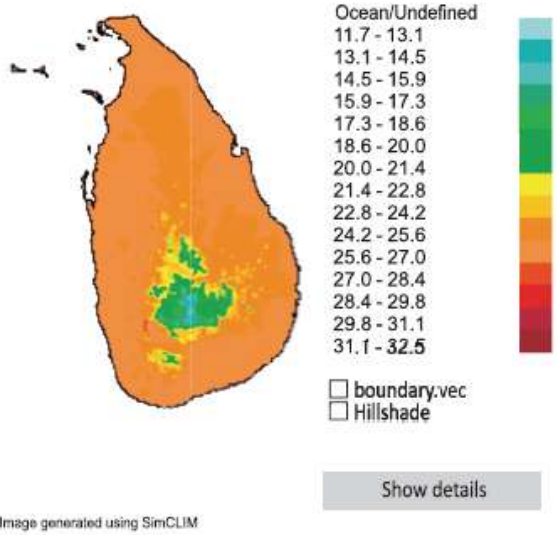
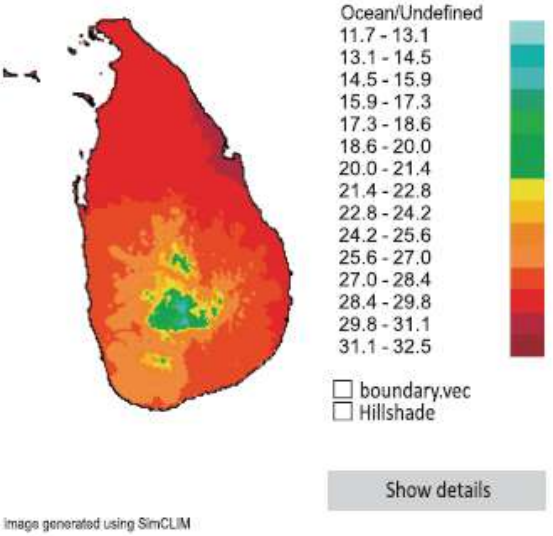


Fig. 3.7 Mean temperature (°C) baseline (1961-1990) during NEM months



Change (AIACC) to undertake a study in the coconut and tea sectors in the country (Ratnasiri, 2006). As a part of this study, a detailed interpolation of IPCC temperature and rainfall projections applicable to Sri Lanka was carried out using software developed by the International Global Change Institute (IGCI) of University of Waikato, NZ (Warrick, 1996).

Under this project, temperature rise and rainfall change projections were developed corresponding to different IPCC emission scenarios and GCM models for different time frames. The scenarios obtained with the medium emission scenario A2 and the model giving moderate values, HadCM3, for future temperature and rainfall are given in Figs. 3.6 - 3.7, corresponding to SWM and NEM months.

The summer high temperature regions above 30°C which is limited to a narrow region around Trincomalee Bay in the baseline scenario is seen to spread into the country covering the northeastern region by 2050 and over a greater part of the country by 2100. The temperature rise in the winter months is less prominent except in 2100.

The projections of rainfall change given for the two seasons - SWM and NEM - are more complex, though it is possible to identify some main features of the changes anticipated. For example, during the SWM, the SW quadrant receives a maximum rainfall of about 2500 mm under baseline case, whereas in 2100, the maximum rainfall received is about 3500 mm over the same area. In the rest of the country too, there is an increase in the rainfall received during SWM period. During NEM, however, the maps do not show a significant change in the rainfall received, except for a slight increase in the eastern slopes of the central hills.

Fig. 3.8 . Mean temperature scenario (°C) during SWM months in 2050

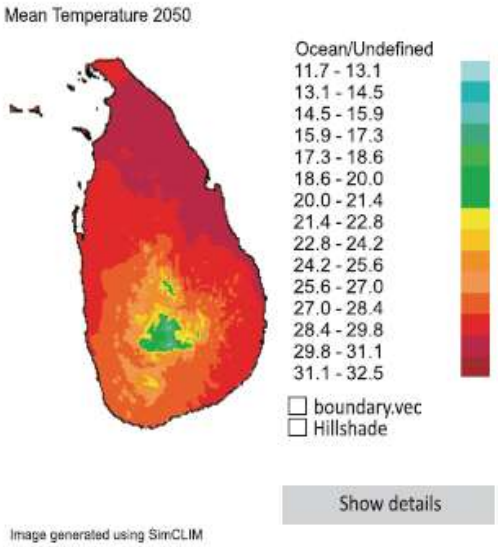


Fig. 3.9 . Mean temperature scenario (°C) during NEM months in 2050

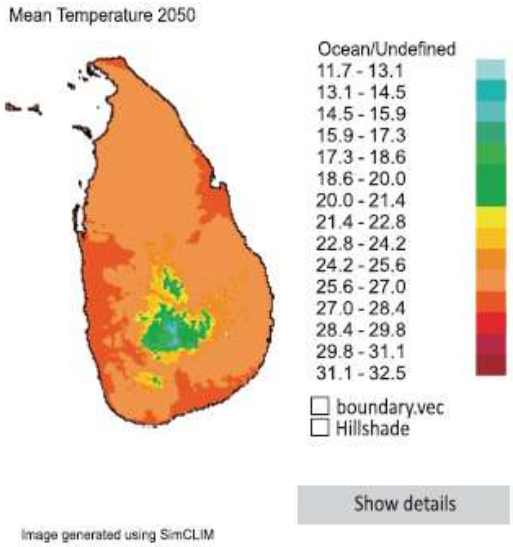


Fig. 3.10 . Mean temperature scenario (°C) during SWM months in 2100

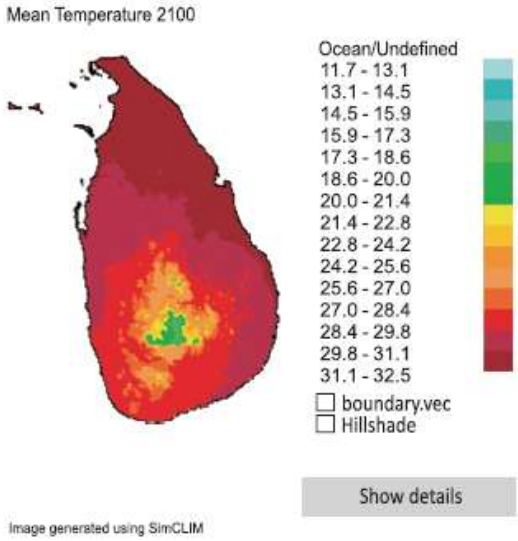


Fig. 3.11 . Mean temperature scenario (°C) during NEM months in 2100

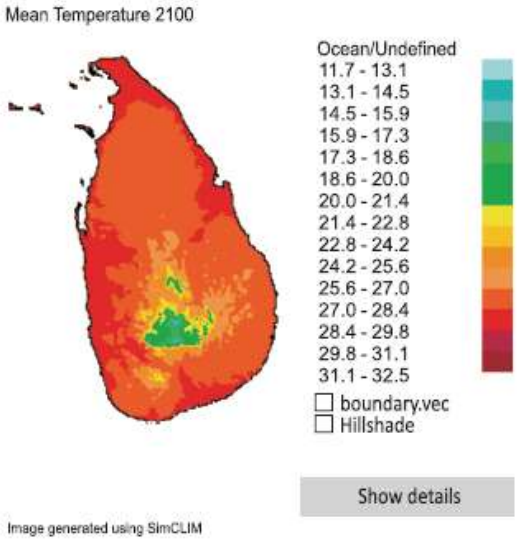


Fig. 3.12 Baseline (1961-1990) average Rainfall in SWM months

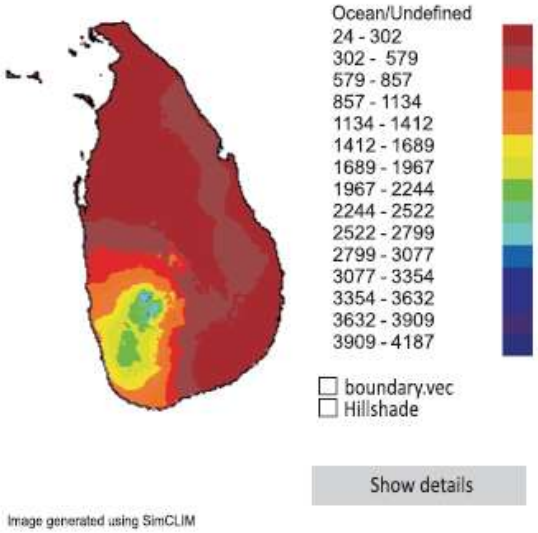


Fig. 3.13 Baseline (196-1960) average Rainfall in NEM months

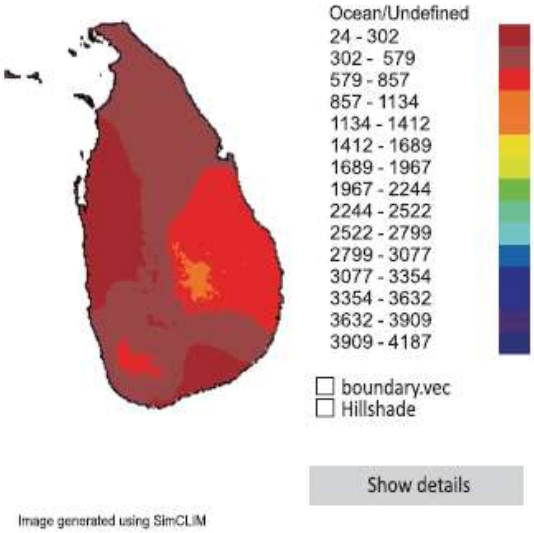


Fig. 3.14 Average Rainfall during SWM months in 2050

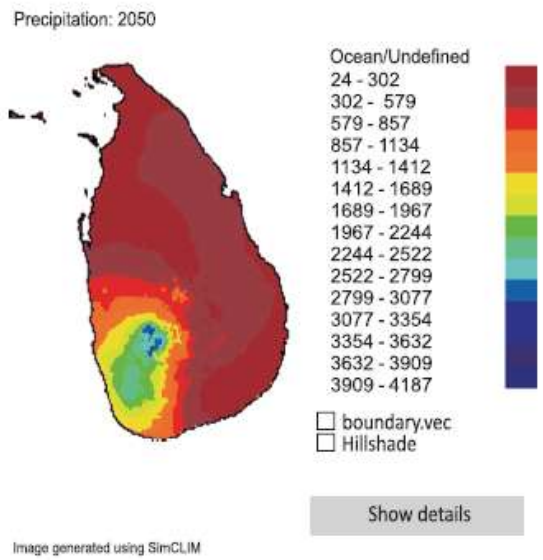


Fig. 3.15 Average Rainfall during NEM months in 2050

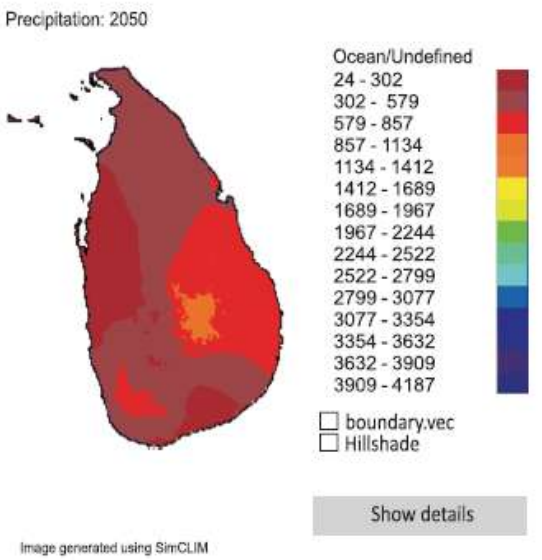
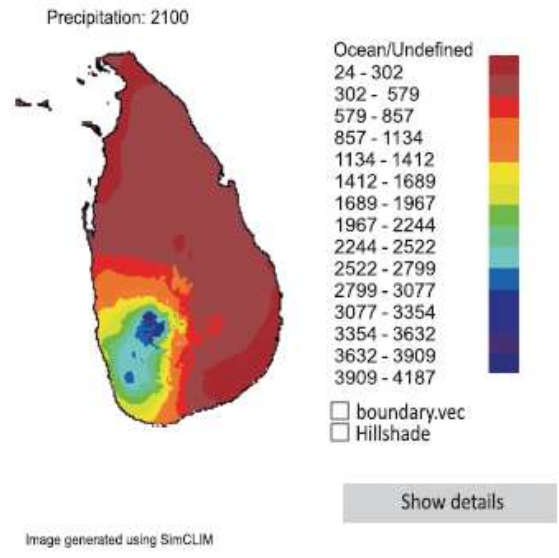
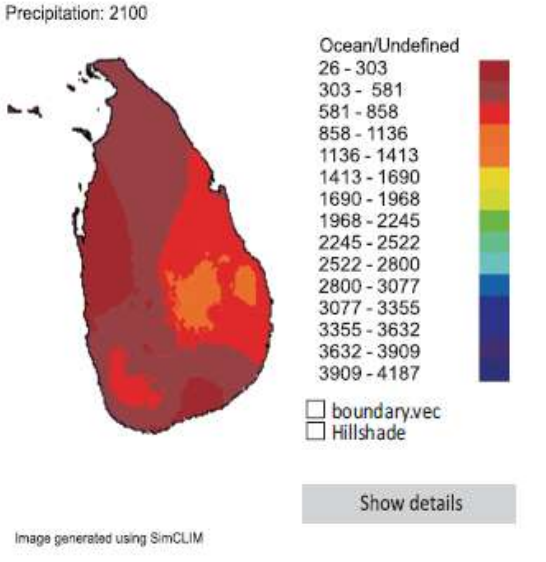


Fig. 3.16 Average Rainfall in SWM months in 2100Fig.



3.17 Average Rainfall in NEM months in 2100



A summary of these results are given in Tables 3.1 and 3.2 for temperature and rainfall projections, respectively. Each Table shows the temperature rise in degrees Centigrade and rainfall change in mm for each of the three emission scenarios and three GC Models, for the summer months (June, July and August). The range of values shown within each cell gives the temperature increases at different locations in the country. The positive sign indicates that the increase within the country is towards North and the negative sign the opposite.

Table 3.1. Projected temperature change under three GCM and three emission scenarios in SWM months, 2100

Scenario	Temperature Rise in °C in SWM months in 2100			
	HadCM3 +	CSIRO -	CGCM +	Mean
A1FI	2.5 - 3.0	2.2 - 2.4	2.0 - 2.2	2.4
A2	2.1 - 2.5	1.9 - 2.0	1.7 - 1.8	2.0
B1	1.1 - 1.4	1.0 - 1.1	0.9 - 1.0	1.1

Source: Ratnasiri (2006)

Table 3.2. Projected Rainfall change under three GCM and three emission scenarios in SWM Months, 2100

Scenario	Change in Rainfall in SWM months in 2100			
	HadCM3 +	CSIRO -	CGCM +	Mean
A1FI	0 - 476	2 - 157	-190 - 6	-94 - 213
A2	0 - 403	2 - 133	-161 - 5	-80 - 180
B1	0 - 215	1 - 71	-86 - 3	-43 - 96

Source: Ratnasiri (2006)

The increments of temperaturchange obtained by this means for different scenarios and GCM sets were added to the baseline climate maps showing the temperature and rainfall distribution durie change and rainfall ng 1961 - 1990, and a new set of maps were generated. These maps give the projected temperature and rainfall values for different time periods corresponding to different emission scenarios and GCM values. The IGCI software automatically extracts the temperature and rainfall values from these maps corresponding to any emission scenario, model and the time slice when these are specified, which can then be used in the crop models that were developed for use along with this software.

In another study carried out using a regional model developed by the Hadley Centre, the rainfall received by 2050 in the WZ during the SWM was found to increase by about 48% relative to the average rainfall received during 1961-1990, while during the NEM, the rainfall received in the DZ, particularly in the EP, was found to decrease by 27-29% (de Silva, 2009). In other words, the wet zone is expected to become wetter and the dry zone drier with climate change.

3.3 Agricultural Sector

Agriculture is considered to be a key sector subject to climate change. Described below is a qualitative analysis of the climate change impacts on crops of economic significance - rice, rubber, coconut and sugar cane. In the case of tea, a quantitative analysis has been carried out under the AIACC project.

3.3.1 The Rice Cultivation

Current and projected Yields

Rice is grown in almost all parts of Sri Lanka with the exception of high elevations of the central highlands. A substantial proportion of the national rice production comes from the low-country DZ and IZ, with districts of Anuradhapura, Polonnaruwa, Batticaloa, Trincomalee, Ampara (all in the dry zones) and Kurunegala (intermediate zone) being the major contributors. It is interesting to note that, despite DZ and IZ are considered to be water-deficit regions, the combined paddy (rice with husk) production in these two regions (3,025 kt) far exceeds that from the WZ (625 kt), being nearly 5 times, according to 2009 production figures (CBSL, 2010b). The Table 3.3 shows the average paddy yields in the two seasons, according to which the WZ average yield has been only 3.50 t/ha while DZ/IZ shows a higher average yield of 4.48 t/ha, a 28% increase. The most important contributory factor for this higher yield in the DZ is the high solar radiation it receives, being free of cloud cover for most parts of the year. However, Weerakoon and De Costa (2009) claim that with proper agronomic practices, yield could be increased to 6-7 t/ha in the irrigated DZ/IZ and to 4.5-5 t/ha in the rain-fed WZ, by 2020. The DPF projections for paddy production in 2020 shows a yield of 6.5 t/ha.

Table 3.3 Rice Yield in different climatic zones and seasons in 2009

Climatic Zone	Paddy Yield t/ha/season		
	Maha	*Yala*	Average
Wet Zone	3.63	3.37	3.50
Dry/Int Zone	4.53	4.43	4.48

Source: CBSL (2010b)

3.3.1.1 Climate Change Impacts

Increase in atmospheric CO_2 concentration, rise in ambient temperature, declining rainfall and increase in salinity, which are associated with climate change have direct impact on rice cultivation as described below.

Impacts of increasing atmospheric carbon dioxide concentrations

Experimental work carried out at the Rice Research and Development Institute (RRDI) of Sri Lanka has shown clearly that increasing CO_2 per se increases the rice yield and also its water use efficiency (i.e. yield per unit of water used) (De Costa et al. 2003 a,b). The yield increases have been shown to be greater in the *Yala* season, in which the crops would benefit more from the higher water use efficiency under higher CO_2.

Impacts of increasing air temperatures

Grain development of tropical rice varieties has an optimum temperature of around 30 - 32°C beyond which a significant increase in grain sterility, resulting in empty grains, occurs (Horie, 1993). Hence, the predicted increases in both annual mean and seasonal temperatures are most likely to have significant adverse impacts on rice production in the DZ and IZ where the current temperatures are already around the optimum. Further increases in temperature in the future due to long-term climate change, especially in the *Yala* season, would increase grain sterility and decrease rice yields in the major rice growing regions of Sri Lanka, thus bringing national food security in to considerable danger. Weerakoon et al. (2003) have shown that high temperature-induced grain sterility is exacerbated by higher levels of

atmospheric relative humidity, which decreases transpiration and thereby further increases grain temperatures. Even though the current air temperatures of the DZ and IZ during the *Maha* season are lower than the optimum for grain development, the higher relative humidity levels that prevail during this season could push the grain temperatures beyond the optimum.

Impacts of decreasing water availability

Decreasing rainfall and increasing evapo-transpiration rates (De Costa 2006) triggered by the increasing air temperatures have reduced the available soil water balance (SWB) (i.e. the difference between rainfall and potential evapo-transpiration) in the DZ and IZ (De Costa, 2008). So far, the decreases in SWB have been more prominent during the *Yala* season than in *Maha* (de Silva 2009). However, climate models predict significant decreases in SWB in *Maha* also during the next 50 years (de Silva, 2009). Because of the strong dependence of rice production on water availability, the above decreases in SWB are highly likely to have strong adverse impacts on the rice production in Sri Lanka.

Decreases in the *Maha* SWB are likely to have a direct impact on national rice production as a greater proportion of it comes from *Maha* season. Reduced SWB in *Yala* would substantially increase the drought-induced production losses in *Yala* in all major rice growing districts of Sri Lanka. Furthermore, decreases in *Yala* SWB would increase the demand for irrigation water to minimize the potential yield losses and maintain even the current levels of productivity. De Costa (2009) has showed that substantial decreases in rainfall and SWB have occurred in the central highlands (e.g. Nuwara Eliya). As run-off water in the central highlands feeds in to the Mahaweli River and its network of reservoirs and tanks, which support the *Yala* season rice cultivation in the dry zone, the observed reduction in the rainfall and SWB in the central highlands would have significant long-term adverse impacts on rice production in the dry zone. In addition to the decreases in rice yield per unit land area, a long-term reduction in the water availability of the reservoirs and tanks of the dry and intermediate zones would decrease the cultivated land extent of rice, especially in *Yala*, thus decreasing overall rice production further.

Impacts of increasing salinity

Coastal salinity has been most prominent along the western coast of Sri Lanka, especially in the south-west. In parallel to expanding coastal salinity, inland salinity has been expanding in the major irrigation schemes primarily due to a combination of increased addition of salts in to the soil in the form of inorganic fertilizers and increased soil evaporation rates, triggered by increased air temperatures, which bring the salts up to the crop root zones. The main impact of increased salinity is that it would decrease the land extent available for rice cultivation and thereby decrease the overall national rice production. The rice crop is most sensitive to salinity during its early vegetative stage. Hence, salinity would lead to incomplete and patchy crop establishment and retarded crop growth leading to substantially decreased yields per unit land area.

3.3.1.2 Adaptation to Climate Change

The main adaptation measure that is available with respect to all four aspects of climate change is the development, through plant breeding, of new rice varieties which are tolerant to different environmental stresses that are brought about by climate change. In addition, a few crop management options are available. These will be discussed below:

Adaptations to increasing air temperatures

Heat tolerant rice varieties, respecially with heat tolerance at the critically-important reproductive stage (i.e. between panicle initiation and heading), need to be developed. Work carried out the RRDI has identified heat tolerant varieties among the existing rice germplasm. Selective irrigation during periods of supra-optimal temperatures may help lower the spikelet (i.e. small flowers which develop in to grains) temperatures by promoting transpiration and thereby avoiding heat-induced sterility.

Adaptations to decreasing water availability

Here again, the best option would be to develop drought tolerant rice varieties through plant breeding. However, breeding rice varieties, which combine drought tolerance with high yield, has been extremely difficult. Research is in progress at the RRDI and the University of Peradeniya to identify drought tolerant genotypes from local rice germplasm and from germplasm received from drought-screening nurseries at the International Rice Research Institute, Manila. A few other adaptation options are available to minimize the impacts of decreasing water availability on rice. Development of ultra-short duration rice varieties, such as BG250, developed by RRDI, which mature in about 75-80 days, is one such option.

The ultra-short duration rice varieties have a lower overall water requirement and also have the ability to complete their life cycle before significant water deficits develop, especially during the Yala season. Hence, they are ideally suited to the water-limited scenarios that are predicted under future climate change. Development of alternative water management techniques is one of the few crop management options that is available as adaptations to water-limited environments. Alternative water management techniques are being tested by the RRDI and the University of Peradeniya with a view to reduce the water use in rice cultivation without a significant yield reduction.

Adaptations to increasing salinity

Breeding of salt-tolerant rice varieties is the primary adaptation measure to maintain national rice production levels in the face of expanding salinity. At354 is a salt-tolerant rice variety which was developed at the Rice Research Station, Ambalantota. Genotypes with greater salt-tolerance than At354 are being developed at RRDI. Research work is in progress at the University of Peradeniya to identify genes responsible for salt tolerance and quantify their expression. Field demonstrations by RRDI have shown that it is possible to reduce field salinity by a combination of agronomic measures which include improved field drainage, application of organic manure, rice straw and burnt paddy husk and transplanting instead of direct seeding (Gamage et al., 2009).

Other Adaptation Measures Recommended

Agronomic management

Dry zone

- Reduce irrigation water losses
- Adopt *'Kakulan'* or *'Manawari'* cultivation practices. (*Kakulan* and *Manawari* refer to an indigenous system of dry seedbed preparation when water supply is limited. Dry seeds are sown to dry soil in rows or in random. The "Manawari" system is similar to *Kakulan*, but the rice field may not have standing water throughout the season.)

- Introduce lowland rice cultivation with saturated soil instead of continuous submerged soil.
- Practice aerobic rice cultivation.

Wet zone

The negative impacts of climate change are less compared to the dry zone's. The potential offered by the availability of water should be exploited. Erratic rainfall and unpredictable onset of monsoons is a problem. In the coastal areas, rise in the sea-level leading to submergence and sea-water intrusion would increase coastal salinity in the paddy fields.

The capacity of paddy fields to act as a buffer to store excess flood waters duringfloods should be considered. Imbulana (2007) has estimated that the 26,000 ha of paddy land not cultivated, amounts to a loss of 80 million m^3 of flood retention.

Climate information: Availability of advance information on seasonal climate changes to the farmer, to adjust cropping calendar from the Meteorology Department, in a necessity.

Research needs: In addition to developing varieties tolerant to high temperature and limited water availability (ie. high water use efficiency), and varieties with submergence and salinity tolerance as described above, a new generation of crop varieties is needed with:

- Water and fertilizer efficient
- Weed smothering ability
- Resistance to pests and diseases

Different cultivation technologies to meet decreased water availability need to be adopted and Post-harvest impacts of climate change assessed.

Extension services

Extension services are vital to convey to the farmer the significance of climate change and adaptation measures that can be adopted at low cost.

3.3.2 The Tea Plantations

3.3.2.1 Climate Change Impacts

The optimum growing conditions for tea are temperature in the range 18 - 25 °C and a well distributed annual rainfall in the range 2500-3000 mm, while 1300-1400 mm is considered adequate, and such climate parameters are found in most tea growing regions of Sri Lanka.

Increase in Temperature

The optimum temperature giving highest productivity in tea was found to be 22 °C. The yield increases by 15 kg per ha per month for each °C increase up to this temperature and declines by 10 kg thereafter (Wijeratne, 1996). An increase in temperature increases plant respiration and loss of assimilates. Contrary to previous findings, recent observations at the Tea research Institute (TRI) have shown that at high temperatures (>25-26 °C), the yield components of tea, shoot

population density, shoot weight, and shoot extension rate, tend to decrease with increasing temperature (Wijeratne et al. 2007). Cooler temperatures are necessary for the development of seasonal high quality teas at higher elevations, which fetch a premium price.

Changes in Rainfall

Being a rain-fed crop, productivity of tea is dependent on the availability of soil moisture. The droughts in 1992 caused a 25% loss in yield, in 1983 a 4% loss, and in 2009 a 24% decline. The loss in production in 1992 and the subsequent increase in cost of production cost the country an estimated US$ 70 million in revenue, an indication of the magnitude of the cost from adverse weather conditions. Prolonged and increased rainfall causes soil erosion, poor growth due to cloud cover and increased disease incidence. The estimated loss of productivity for a 100 mm deficit of rainfall is given in Table 3.4 for five agro-ecological zones. Tea being a plantation crop, results in a large loss of productivity in quantity and earnings, when the total area is considered.

Soil erosion and drought

Table 3.4 Estimated loss of productivity in five agro-ecological zones from a 100 mm deficit in rainfall

Agro-ecological Regions	Optimum rainfall (mm)	Loss of productivity kg/ha/month
Wet-Low (WL)	350 ± 20	29 ± 3
Wet-Med (WM)	417 ± 29	36 ± 6
Int-Med (IM)	227 ± 10	81 ± 11
Wet-Up (WU)	223 ± 38	55 ± 7
Int-Up (IU)	303 ± 34	39 ± 3

Source: Wijeratne et al. (2007)

High intensity rainfall causes damage through soil erosion. Recently pruned tea and young tea fields during the first two years are more vulnerable to erosion due to inadequate ground cover. Drought conditions combined with increase in temperatures, soil moisture deficit and vapour pressure deficit creates plant water deficit retarding growth. Experimental results in the low country have shown that clonal tea yields could be adversely affected at temperatures >26 °C, soil moisture deficits >30-50 mm and saturation vapour pressure deficits >1.2 kPa.

Increase in Carbon-dioxide

Carbon-dioxide affects carbon assimilation of the tea plant and carbon-dioxide enrichment studies have shown a 34-37% increase in yield at 600 ppm carbon-dioxide. However, this beneficial effect of enhanced photosynthesis may not be achieved in years to come due to the negative impacts of high temperature, especially at low and mid elevations, and drought effects (Wijeratne et al. 2007).

Future Yield under Climate Change

Based on the IPCC scenarios of A1 and B1, and using three Global Circulation Models, the projections for tea yield in 2050 at three (low-, mid- and up-country) stations are given in Table 3.5 in a study carried out by the TRI under the AIACC Project.

Table 3.5 Tea yields at three locations projected for the year 2050 by three General Circulation Models

Model	Yield kg/ha/yr Ratnapura (Low)	Kandy (Mid)	Nuwara Eliya (Up)
Baseline	2489	2217	2454
CGCM-A1FI	2314	2217	3108
CGCM-B1	2380	2228	3072
HadCM3-A1FI	2348	2174	3130
HadCM3-B1	2419	2189	3115
CSIRO-A1FI	2401	2246	3167
CSIRO-B1	2472	2245	3137

Source: Wijeratne et al. (2007)

Impacts studies on tea carried out by Wijeratne et al. (2007) were extended by Ratnasiri et al. (2008) to assess the vulnerability of tea plantations to climate change. These studies indicated that the agro-ecological regions of WL, WM and IU are more vulnerable to the adverse impacts of climate change, while WU stands to benefit. The study further showed that the country will suffer a loss of 4% in revenue from tea exports due to climate change, by 2100.

3.3.2.2 Adaptation Measures in Tea Cultivation

The framework for an Adaptation strategy for the tea industry is to:

- exploit beneficial impacts of climate change
- minimize the adverse effects
- adopt a no-regrets approach, and
- practice economically viable options.

These strategies would be implemented through improvement of the crop, soil and aerial environment.

Crop Improvement

- Use of drought tolerant cultivars and grafted plants with drought tolerant characteristics, in drought prone regions.
- Intercropping with other tree cash crops, such as rubber and coconut
- High intensity intercropping would reduce the ambient temperature around tea bushes and increase land utilization efficiency.
- Planting a basket of cultivars.

Soil Improvement and Irrigation

- Soil and moisture conservation - physical and agronomic practices
- Improvement of soil organic carbon levels - implementing Sloping Agriculture Land Technology (SALT), burying tea pruning, using compost.
- Rainwater Harvesting
- Irrigation during dry spells.

Other Measures

- Diversification of marginal lands to "thatch banks" by planting rehabilitation grasses, and used as a source of green manure to improve soil fertility.
- Low yielding lands with poor soil condition to be diversified to fuel-wood or timber plantation (for eventual carbon trading)
- Selection of land with suitable soil for new and replanting

Aerial Environment

Planting and management of shade trees to reduce ambient temperature can be achieved by planting high and medium shade trees based on TRI recommendations and management of shade trees according to weather patterns.

3.3.3 The Rubber Plantations

3.3.3.1 Climate Change Impacts

Between rainfall and temperature, the former has the greater impact on productivity of rubber plantations. The ideal annual rainfall for rubber should fall within the range of 1650 - 3000 mm and be reasonably uniformly distributed throughout the year. It was reported that, in general the tree performance is severely affected if rainfall over a six-month period is less than 500 mm, especially when it is not uniformly distributed (Yogaratnam, 2001). The ideal mean annual temperature range for rubber was identified as 23°C to 28°C and temperatures below 20°C aggravate disease incidences and temperatures above 30°C over a prolonged period also affects physiological processes of the rubber tree. As reported by Fernando (2004), cool nights with mist, dew on leaves, intermittent light rains, low temperature and high humidity aggravate disease conditions in rubber plantations. The limitations imposed by climate on rubber cultivation are given in Table 3.6.

Table 3.6 Climatic requirements for rubber

Climate characteristics	Degree of limitation*				
	0	1	2	3	4
Mean temp. ºC	28-25	24-22	21-20	19-18	<18
Mean daily max ºC	34-29	28-27	31-32	33-34	>34
Mean daily min ºC	>20	20-19	18-17	16-15	<15
Mean annual rainfall: not <500 mm in any consecutive 6 months	>2000	2000-1750	1749-1500	1499-1250	<1250
Exp. Rain interference days/yr	0-30	31-60	61-90	>90	
Sunshine hrs/year	2100	2100-1750	1749-1500	1499-1250	<1250
Mean annual RH%	<80	80-100			
Dry season length mths/year	1-1	2-3	4	5-6	>6

* 0 : No limitations, 4 : Very serious limitation
Source: Handbook of rubber, Vol.1, Agronomy (2001)

From the above limitations for the cultivation of rubber, the mean daily temperature would not affect rubber in the immediate future scenarios of climate change. What is of concern is the rainfall and sunshine hours. The vulnerability at different stages of establishment (Table 3.7) is due to erratic rainfall patterns and prolonged dry spells, which are characteristics of climate change.

Table 3.7 Vulnerability at different stages of development in rubber plantations to climate change

Stage	Issue/ Cause(s)
Nursery	Erratic seed production/ Erratic rainfall pattern Scion dieback/ Prolonged dry spells & high temperatures Disease problems/ Low temperatures
Establishment	Poor establishment success/ Prolonged dry spells
Immature stage	Poor growth conditions/ Prolonged dry spells Disease problems/ Low temperature Disturbed routine agronomic practices/ Erratic rainfall pattern
Mature stage	Low yield/prolonged dry spells & high rain interference Disease problems/ Low temperature Disturbed routine agronomic practices/ Erratic rainfall pattern

The issues are inter-related and would finally affect the productivity of the system. Under wet conditions, a tree growth of 4.9 cm is achieved with 90% establishment success whereas under dry conditions, it is 3.2 cm with 60% establishment success. There is a variation among clones in their response to rainfall. The latex volume and rubber yield of the clone RRIC121 responds positively to rainfall while the clone RRIC100 is independent to change in the distribution and amount of rainfall. A higher number of rainy days would decrease the number of tapping days and if rainfall occurs in high yielding months, a considerable yield loss would result.

3.3.3.2 Adaptation Measures

Technological options

- Of the rubber clones selected for agro-climate variability, clones RRISL217 and RRISL215 were identified as highly stable for all environments and the clone RRIC100, for the small-holders in non-traditional areas.
- Planting material - different young buddings are used for propagation. Of these young buddings in polybags gave 100% establishment success and the highest girth of 48.6 cm.
- Seeds for nurseries - erratic seed fall affects nursery management. The field should be well maintained and cleaned before seed-fall with a good seed bearing clone eg. RRIC100.
- Soil and moisture conservation - establishment success is improved by 85 - 98% with an application of organic matter at the rate of 50g per polybag.
- Increase in potassium fertilization - higher girth and tappability is achieved with increase in potassium applied.
- Reduce moisture stress using cover crops and mulching to increase water holding capacity.
- Land selection - soil parameters should be considered before selecting land for rubber plantations or cultivation.
- Fix rain-guards on trees.

Institutional options

- Technology transfer to the estate and smallholder sectors by RRISL
- Conduct awareness programs on climate change adaptation
- Extension services to smallholders who are the most vulnerable
- Subsidy schemes for introducing adaptation measures

3.3.4 Coconut Plantations

3.3.4.1 Climate Change Impacts

Climate requirements

Coconut is a rain-fed plantation crop and can be adversely affected by long durations of dry spells associated with high temperatures that are predicted with climate change. It requires a uniformly spread annual rainfall of >1500 mm. Coconut is cultivated in seven Agro-ecological Regions (AER), and it is noteworthy that coconut is grown more in the intermediate zone than elsewhere. The annual rainfall exhibits a decreasing trend in all the coconut growing AER, except in two regions (DL3 and DL5). The maximum and minimum temperatures also show an increasing trend in all the coconut growing AERs.

Impact of increasing CO_2

Trials were conducted at CRI under the AIACC project to determine the effect of elevation of atmospheric CO_2 concentration on vegetative growth of coconut plants (see Fig. 3.18). The mean photosynthetic rate of seedlings increased by about 25% and the mean instantaneous water use efficiency ($\omega_i = A/E$) increased by about 40% in elevated CO_2 levels. However, these differences were not so conspicuous in vegetative growth parameters and this indicated that CO_2 elevation for a short time period may not be sufficient to achieve improvements in vegetative growth in coconut although improvements were observed in physiological parameters. This indicates that although there is a potential of increasing the growth rate of coconut seedlings by CO_2 elevation, exposure of substantial period is required to gain significant impact in seedling growth.

Fig. 3.18. Open Top Chambers (OTC) with coconut seedlings exposed to elevated CO_2 (left) or ambient CO_2 (right).

Source: Ranasinghe 2005

Impact of Drought

Coconut is very sensitive to previous year drought conditions and dry spells should not exceed two consecutive months. It requires a relative humidity of 80 - 90% and well-drained deep sandy loamy soil. The most significant effects of climate on the productivity of coconut are high temperature and prolonged drought. Changes in the monsoon rainfall pattern and increase in maximum air temperature are key factors in the variability of coconut production.

Impact of Temperature Rise

High temperature affects reproductive development, particularly the development of pollen and ovules in the flower. The development of pollen mother cells and microspores are very sensitive to high temperatures which reduce starch and sugar concentrations in the developing pollen. It also reduces pollen viability, pollen release from the anthers and fruit-set, which is ultimately reflected in reduced nut yield per tree. The sensitivity of reproductive development to temperature varies with the variety and therefore enables selection for temperature tolerant genotypes from the germplasm. Prolonged drought and high temperature affects the fruit set, and fruit growth which reduces the yield and quality of the coconuts.

It would be advantageous for plants to exhibit greater reproductive survivability under moderately high temperatures and water stress conditions normally encountered during plant reproduction and processes leading to fruit set. Screening for tolerance of cultivars to high temperature and water stress, using reproductive and physiological traits, is now given high priority in the CRI research programs.

In a CRI study in two regions in the low-country, with different climates (WZ and IZ), the influence of climate on coconut yield was found to be different. Therefore the assessments of impacts and adaptation to climate change for coconut should be carried out separately for each coconut growing region. Rainfall alone was not sufficient to explain climate change over extended time.

3.3.4.2 Adaptation Measures

Decreasing water availability

Some varieties such as Tall x Tall, Tall x San Ramon have been recommended for drought -prone areas. Furthermore, Dwarf Brown appears promising for plant breeders as an ideal parent material due to some characteristics such as non seasonality, high yielding capacity (higher number of nuts per bunch and higher number of inflorescence per palm per year) and relatively higher tolerance to water stress conditions compared to those of other dwarf varieties. Therefore, a number of hybrids were developed using Dwarf Brown as male as well as female parents and they are under evaluation for drought tolerance. Several hybrids developed using exotic pollen are also under evaluation for heat tolerance.

Increasing air temperature

A number of hybrids were developed using Dwarf Brown as male as well as female parents and they are under evaluation for heat tolerance. Preliminary experiments conducted to develop an index for screening coconut varieties for high temperature tolerance by in-vitro pollen germination revealed some useful information. TxT, San Ramon (SR), Dwarf Green (DG), Dwarf Yellow (DY), Dwarf Red (DR) and Dwarf Brown (DB) cultivars were evaluated and they differed for in- vitro pollen germination percentage (%PG). The variety with highest % PG (SR) had the highest Topt and it could maintain relatively higher pollen germination compared to other varieties even at 32^{0}C.

Breeding Programme

- Selection for tolerance to high temperature and drought.
- Screening for varieties using water relations, biochemical parameters (carbohydrate and sugar content).
- Evaluation of existing varieties and new crosses developed using indigenous germplasm.
- Creating new hybrids using exotic germplasm.

Screening for reproductive survivability under temperature stress

Duration of exposure to stress

- Pollen quality
- Screening varieties for in vitro pollen germination at temperatures of 20º - 42 ºC and look for varietal differences at maximum, minimum and optimum temperatures. Screening experiments showed varietal differences in pollen germination for Tall, and San Ramon varieties with a temperature optimum of 28 ºC.
- Effect of water and temperature stress on fruit quality.

Agronomic practices

- A quantification of different management practices is necessary.
- Soil moisture conservation: mulches, ground cover crops.
- Improve soil organic matter.
- Provision of Irrigation facilities.
- Rain water harvesting.

Economics of Adaptation

To determine the significance of investment in adaptation measures for climate change in the coconut sector, the economic value of climate variability was computed in terms of foregone or additional coconut production, as a consequence of climate change (Fernando, 2005). Analysis of coconut production data from 1971-2001 showed that foregone income to the economy due to crop shortages from unfavourable climate varied around US$ 32- 73 million, and the additional income to the economy from favourable climate years producing a crop glut was US$ 42-87 million. This implies the potential for significant economic benefits from investments in adaptation that would reduce variability in coconut production, caused by variation in climate.

3.3.5 Sugar-cane plantations

3.3.5.1 Climate Change Impacts

Sugarcane is cultivated mainly under rain-fed conditions in Sri Lanka, and hence the cropping calendar depends on the two rainy seasons - *Yala* and *Maha*. Therefore, the understanding of the links between climate variability and agronomy of sugarcane is stressed in term of cropping systems and management practices in order to achieve conditions optimum for sustained productivity.

The temperature for optimum growth of sugarcane is between 20° to 30°C. In rain-fed sugarcane cultivation areas, the water requirement of sugarcane depends on the climate. Sensitivity to water stress is not constant throughout the

growth stages. Some growth stages are more sensitive than the other. Adequate water availability is needed for germination and the tiller formation phase. However, water logging during the monsoons will reduce the tillering ability and finally will result in poor cane plants. Excess water during the maturation phase will affect the quality of cane harvest.

Another important climatic factor that determines the development of sugar content in the plant is to have a low night time temperature during the flowering stage. However, with the observed increase in the minimum night time temperature at most stations in the cane growing areas, there is a likelihood of Sri Lanka getting a low sugar yield in the future.

Sugarcane is highly resistant to water stress. It could however survive as low as 5% soil moisture by weight in the Reddish Brown Soils of the Dry Zone. However, the growth rate of sugarcane is low under water stress conditions. Germination, tillering, canopy development, grand growth period and the maturity of plants are directly dependent on the rainfall in plantation areas. As the scarcity of water and prolong drought periods severely affect the sugarcane crop, the rainfall and the shifts in monsoonal weather are considered as more critical climatic factors for sugarcane cultivation systems.

Sugarcane is a typical C4 plant and thus an efficient user of carbon dioxide and sun shine. As sunshine plays a major contributory role in photosynthesis, extreme cloudy conditions interfere with the sugar production in sugarcane. In addition, the positive role of cloudy weather and winds during the North-East monsoon period has been reported as the cause for establishment and spreading of pests.

3.3.5.2 Adaptation in the Sugar cane sector

Agronomic management

Small ponds: Even though, the possibilities for adaptation for such adverse climatic variations is limited in the present context, the change of planting and harvesting schedules of the sugarcane crop to minimize the impact of drought conditions and establishment of small ponds within plantation areas to maintain the ground water at a higher level are recognized as possible adaptations. However, these adaptations are an extra cost to the growers even though they do not involve new technologies.

Irrigation management: The possible options should be based on proper irrigation management practices. Hence, the promoting of on-farm soil and moisture conservation methods, improving water use and conveyance efficiency, promoting micro-irrigation (drip, sprinkler etc.) and encouraging re-use of drainage water where ever possible are among the priority areas for adaptations.

Recovery of waste water: Re-use of drainage water and construction of tail-water recovery pits for lift irrigation with combination of naturally drained water are also considered as potential infrastructure modifications.

Cropping schedule: Implementation of adjusted planting and harvesting time schedules to suit the monsoonal changes can be arranged at the institutional level.

Breeding program

As an additional option the sugarcane breeding program should be strengthened, based on agro-ecological suitability, to produce varieties resistant to drought, high temperature, pests and diseases and salinity.

Institutional measures

- Introduce irrigation management practices
- On-farm harvesting of rain water and run-off water
- Changes to planting and harvesting schedules

Infra-structure

Minor irrigation tanks should be rehabilitated to operate at their design capacity. There are a number of such minor tanks in the Pelwatta area which should be implemented as infrastructure modifications.

Rehabilitation of irrigation canal network

- Reuse of drainage water where possible
- Use of tail-water recovery pits for lift irrigation with combination of naturally drained water.

3.3.6 Other Field Crops

The main crops coming under Other Field Crops (OFC) sector are Chillies, Onion, Maize, Finger millet (Coarse grains), Cowpea, Mungbean, Blackgram, Soybean (Grain legumes) Sesame, Groundnut and Sunflower (Oil crops). The dry zone is the major production area of these crops contributing more than 80% to the national production. Nearly 580,000 farm families are dependent upon the agriculture related to Other Field Crops covering an extent of around 114,506 ha. Many OFCs can be successfully grown in the *Maha* season under rainfed condition in many parts of the DZ while only a few short age crops could be grown in *Yala* season.

3.3.6.1 Climate Change Impacts

During *Maha* season the common farming system in the uplands of the dry zone is rain-fed agriculture which is a fairly low productive system due to frequent moisture stress, low fertilizer use efficiency and poor adoption of good agricultural practices. Decrease in the rainfall would further aggravate the productivity of this system in the dry zone. High temperature accelerates the physiological development of plants leading to hastened maturation resulting in reduced yield. In onion seed production the bulbs are subjected to a treatment called vernalization to induce dormant flowering buds by exposing them to a low temperature (10-15°C). Vernalized onion bulbs are devernalized if they are exposed to high temperatures. Further, growth of pollen tube is affected above the temperatures of 40°C and seed abortion occurs above 52 $^{\circ}$C in onion.

Plants of C4 type would be at an advantage if they are exposed to low moisture situations at elevated CO_2 concentrations. Thus, weeds in C4 group would get comparative advantage over C3 crops under water shortage situations. In this respect impact of certain weeds which are at present the threatening weeds on uplands in the dry

zone would be unavoidable. At the same time problematic C4 weeds common in the lowland rice fields would flourish during comparatively drier *Yala* season where OFC are grown under rice based cropping systems.

3.3.6.2 Adaptation Measures

There are several options available for introducing adaptation measures. Among these are:

- Alter the adaptive capacity of the agriculture systems by deliberate crop variety selection, substitution of new crops with old crops etc.
- Introduce conservation farming practices after testing them as a means of maximizing incidental rainfall and to mitigate the effects of periodic droughts that may have on crop growth.
- Introduce soil moisture conservation with mulching, soil erosion control under intensive rainy conditions.
- Introduce organic farming approach which will improve and stabilize the soil structure so that the soils can absorb higher amounts of water without causing surface run off and improving the water retention capacity to mitigate drought conditions.
- Grow low water demanding crops such as finger millet and sesame and short age crops for mid seasons cultivation with appropriate agronomic management practices.
- Adjust the present cropping calendar especially with reference to the time of planting, and at the same time, adjust existing cropping sequences as well.
- Provide accurate seasonal weather forecasts to possibly reduce losses due to weather variability.

3.3.7 Degradation of Agricultural Lands

Land degradation manifests itself in several ways such as soil loss, high sediment yields, soil fertility decline, marginalization of agricultural lands, salt accumulation and landslides. The degradation of land would reflect itself on the productivity of the crops and the necessity of increased investments on the land. It is important to determine the vulnerability of particular AER to the changes in climate parameters. Climate change studies in Sri Lanka indicates that though the total rainfall remains constant, higher frequencies of high intensity rainfall or low rainfall occurs to give drought conditions.

The Natural Resources Management Center (NRMC) of the Department of Agriculture has identified potential land areas liable to undergo soil degeneration. It is estimated that 44% of the land mass is under some form of degradation (Wickramasinghe and Munasinghe 2009). The erosion hazard in the central province of Sri Lanka as identified by this study is given in Table 3.8.

Table 3.8 Hazard of soil erosion in 3 districts in the central province of Sri Lanka.

Soil erosion hazard	Nuwara Eliya		Kandy		Matale	
	Extent ha	%	Extent ha	%	Extent ha	%
Low	49,623	29.0	46,792	24.7	94,500	46.5
Moderate	53,655	31.4	54,618	28.9	75,919	37.4
High	28,194	16.6	36,171	19.1	13,437	6.7
Very high	32,896	19.3	47,790	25.3	18,877	9.3
Extremely high	6260	3.7	3,790	2.0	162	0.1
Total	**170,628**	**100**	**189,161**	**100**	**202,895**	**100**

Source: NRMC

3.3.7.1 Impact of increasing temperature

Increasing temperature accelerates the decomposition of soil organic matter and adversely affects the soil bio-physical properties increasing the erosivity of the soil. High temperature also increases evapo-transpiration and pan evaporation. Temperature rise and evaporation would increase salt accumulation in the soil particularly in dry and coastal areas.

3.3.7.2 Impact of Sea level rise

This is important in the coastal regions where sea water intrusions can rapidly degrade arable land and their abandonment. The potential paddy lands that can be affected are in the districts of Kalutara,Batticaloa and in the northern peninsula

Adaptation measures to arrest land degradation

The following measures have been recommended in order to arrest degradation of land quality for agriculture use.

- Soil and water conservation measures
- Run-off water harvesting
- Land-use planning

Adaptation measures recommended to avoid land slide risks

Identifying the importance of implementing landslide disaster risk reduction measures within the mountainous area of the country, the National Building Research Organization (NBRO) has introduced Landslide Disaster Management Programme which is structured into:

- Landslide hazard identification by landslide hazard zoning mapping to avoid, if possible, the highly landslide potential areas from future development
- Taking steps for disaster prevention by introducing guidelines for appropriate land use and construction practices
- Mitigating landslides in urban and already developed semi urban areas where avoidance is no longer applicable
- Increasing the preparedness of the people who are already living in landslide prone areas through a large number of awareness programmes targeted to all stakeholders.
- Issuing landslide early warnings based on the rainfall threshold values and distribution of landslide potential.

NBRO conducts research on improving the methodologies applied within each of the above mentioned steps and continuously updates her knowledge for the benefit of the lives affected by landslides.

3.4 Water Resources

In Sri-Lanka, rainfall is the primary source of useful precipitation and is received in the two monsoons and during the inter-monsoon periods from convection currents. Rain is also received during local thunderstorms and following

tropical cyclones originating in the Bay of Bengal. The mean annual rainfall received during 1961-1990 period has been 1860 mm, which is equivalent to a volume of 122 Gm^3 of rain water over the entire land area. Of this amount, only about 10% is used for irrigation, domestic and industrial purposes, and about 10% seeps to the ground. About 45% of water recieved is lost to the atmosphere through evapo -transpiration, and the balance 35% is lost to the sea. The anticipated change in rainfall distribution described in Section 3.1 has caused a shift in the demarcation between the dry and wet-zones, contracting the WZ area. This has a direct impact on the availability of water resources which in turn would affect the livelihoods of the people.

3.4.1 Surface Water

The 103 river basins have wide variations in their hydrological characteristics and provide the main source of surface water - water available in open sources such as rivers, tanks and reservoirs as well as in near subsurface wells. Sri Lanka depends on its surface water resources for agriculture, domestic and industrial uses. Agriculture is dependent on rain in the WZ and on irrigation water from the rivers and reservoirs in the IZ and DZ. There are nearly 18,400 village tanks in the country (Panabokke, 2009), some of which have been abandoned. These reservoirs provide several services such as irrigation water for agriculture, water for sanitation and drinking purposes. The total volume of the man-made reservoirs is estimated at 7000 Mm^3.

The ancient irrigation works are concentrated mainly in the DZ of the island. The reservoirs in the dry zone also compensate for the unequal distribution of surface water in the wet zone. The large reservoirs were meant to irrigate vast extents of land, while the smaller reservoirs or village tanks were generally intended for the supply of water to villages around these and provide irrigation to small extents of paddy lands. The diversion of Mahaweli River to the DZ, an initiative taken to provide the people in the DZ with adequate water for agriculture and domestic needs, has resulted in augmenting the ancient irrigation system of tanks, by feeding into them the diverted water amounting to 750 Mm^3 on an average annually at Polgolla.

The Mahaweli River, unlike the rest, does not flow radially. It begins from the Horton Plains in the central highlands, flows first northwards past Kandy, takes a bend and flows south-eastwards for some distance cascading from mid-elevation to low-elevation (in the process driving 380 MW of hydro turbines), and again takes a bend and flows northwards before falling to the sea at Trincomalee Bay (see Fig. 1.9). The government undertook a project in the seventies to take Mahaweli waters to NCP by partially diverting it at its first bend to take water northwards through a tunnel and a canal system to feed the existing ancient irrigation network as well as a network of new canal systems in the NCP. This project, which was estimated to cost about Rs. 20 billion (at 1980 prices), has brought immense benefits to the people in the DZ uplifting their livelihoods and enhancing the economy of the country, though in terms of conventional cost-benefit analysis, its economic viability has been questioned (Fernando, 2000). Though carried out to meet the recurring drought conditions in the DZ, the project would also serve as an adaptation mechanism for the future against climate change.

The surface water is vulnerable to reduced river flow from the variability of precipitation. Reduced river flow seriously affects the generation capacity of the hydropower plants, irrigation systems and availability of drinking water. Reduced rainfall from NEM and FIM would prolong the droughts in the DZ and reduce the recharge of ground water subsequently affecting the irrigated paddy cultivation and livelihood of people. Annual droughts cause high economic losses in all sectors - agriculture, plantations, health, power and utilities.

Increased rainfall intensity, on the other hand, would cause increased floods and landslides - major causes of natural hazards- affecting a large number of people annually causing loss of lives and property. Increased soil erosion in turn would cause increased river sedimentation and decrease in soil fertility as well as loss of reservoir capacity in hydropower systems. The annual soil erosion in the upper Mahaweli watershed is estimated at 100-150 tons/ha, from vegetable and potato and tobacco cultivation in the hills. About 80% of the area is already eroded from cultivation on steep slopes of intense rainfall. Organic and chemical pollution from pesticides pollute the waters in the rivers and reservoirs. Low rainfall would concentrate these pollutants and high intensity rainfall would spread them downstream, even taking them to tanks and canal system in the NCP.

3.4.2. Ground Water

There are two types of ground water: renewable - associated with near surface hydrologic processes and non-renewable - water deposited a long time ago in deep sediments. It is the former that is affected by climate change. Ground water is a reliable source of water, and less susceptible to the annual fluctuation seen in surface waters. It has been exploited in the past for domestic and irrigation purposes, particularly in the northern regions.

Ground water is also vulnerable to misuse and contamination. Misuse result from over extraction due to demands from increasing population and insufficient supply from the regular sources of water. Contamination is from leaching of pesticides and fertilizer into the ground water table. In many urban areas, solid waste is disposed in open dump-yards causing their contaminents leaching to pollute the ground water.

In the coastal regions, when ground water extraction exceeds recharging, salt water intrusion takes place from the sea. The climate change scenarios which predict higher temperatures and longer dry spells in the northern and north-eastern regions of the dry-zone would further deplete the ground water resources.

3.4.3 Vulnerability of ground water

The major threats to ground water resources are the over-extraction, using pumps, to irrigate cash crops and provide water for agriculture farms both in the coastal areas and interior land, particularly in the NCP and NP. Contamination by agro-chemicals, fertilizers and from sewage pits is also a problem in urban areas. The construction of many wells and salinity intrusion are also threats to ground water resources.

The reduced rainfall would have a negative impact in the north-eastern and eastern dry zones of the country. Low rainfall combined with high temperature and other unfavourable climate factors are expected to increase the potential maximum annual soil moisture deficit in the dry zone, which is already under pressure for water resources. Scenarios developed for 2050 based on the HadCM3 model show that Jaffna will experience a 12% increase in moisture deficit, and regions in the northern, eastern and south-eastern will also experience an increase in soil moisture deficit (de Silva, 2008) However, the exception is Hambantota where 2050 scenario is for an increase in mean annual rainfall and the decrease in soil moisture deficit.

Research on climate change impacts on the quantity and quality of ground water resources in Sri Lanka is few. It is estimated that 40% of the tube wells constructed in the last decade were abandoned due to contamination from iron, manganese and fluorides, while in the Jaffna peninsula nitrate concentration of over 200 mg/L and bacterial contamination from pit latrines were reported by a UNEP study (UNEP 2005). Salt water intrusion was reported in the

northwestern regions of Puttalam, Mannar, Paranthan, Killinochchi and Mullaitivu. High concentration of chloride, nitrate and potassium were found in the Kalpitiya peninsula in the same study.

Besides contamination of ground water from human factors, the natural geo-chemical composition of the soils and rocks contribute to the chemical composition of the ground water. A geo-chemical atlas of Sri Lanka produced in 1985 (Dissanayake and Weerasooriya, 1985), shows salt-water intrusion in the northern coastal region. Salinity is confined to the northern region and small areas near Hambantota and Puttalam. However, hardness of water is present in most parts of the country, except in the wet-zone. Fluoride concentrations were low in the wet-zone (<0.1ppm) and high in the eastern and north central dry-zone (>3.0ppm). The increase in evaporation is expected to further increase the concentration of soluble minerals in ground water.

3.4.4 Adaptation in the Water sector

3.4.4.1 Rainfall Variations

Under the scenario of more intense rainfall in the wet regions and less in the dry regions, the increased variability and unequal spatial distribution, increased rainfall would be lost as surface run-off. Measures should be implemented to capture this excess rainfall through use of the uncultivated paddy-fields suggested by Imbulana (2004) and rehabilitating the tank system.

The water resources in general are faced with the following problems which would intensify with the predicted climate change.

- High intensity short duration rains, and reducing trend of rainfall
- Aging water infrastructure
- Inadequate dam safety arrangements
- Outdated hydro-meteorological information systems
- Lack of a comprehensive policy for the water sector.

The first three of these issues are being addressed by the Dam Safety and Water Resources Management Project funded by the World Bank (Mahaweli Authority, 2010).

3.4.4.2 Water storage in agriculture

One of the major consequences of climate change would be the lack of water in the drier regions of Sri Lanka, where temperatures would increase and the dry season prolonged. The International Water Management Institute has examined flexible water storage options for agriculture and adaptation to climate change (IWMI, 2009). Their key findings are:

- Water storage should be one component of a multi-pronged approach.
- The full continuum of physical water storage from ground water, through soil moisture, small tanks and ponds to small and large reservoirs. All these physical resources of water are available in the dry zone of Sri Lanka, and now a strategic approach should be implemented.

- Appropriate water storage for agriculture can contribute to poverty alleviation and climate change adaptation.
- Agriculture uses the largest volume of water for land preparation, irrigation and maintenance of livestock. The variability of the primary source of water, rainfall, is going to increase further. With less rainfall and higher soil moisture deficits predicted from climate scenarios for the dry-zone, the farming community should be made aware of the possibilities to adapt.

Water management

With increasing stress on the water resources, management of the demand for water resources should be considered by the major agencies responsible for water resources. In the agriculture-irrigation sector, cultivation or cropping calendar should be adopted for the vulnerable agro-ecological regions and an irrigation schedule. Community participation with irrigation officials in the decision making process is well established in Sri Lanka. This needs to be strengthened in the context of climate change.

3.4.4.3 Adaptation in the irrigation sector

Irrigation systems are normally designed considering the crop-water requirement of the selected crops, for the scheme. However, due to changes in the climate the water management system has to be redesigned with new design variables and performance should be assessed. Factors such as increased carbon-dioxide on crop growth, effects of high temperature, availability of water and extreme climate events which influence agricultural performance have to be taken into account. Additional investments may be needed for new dams, reservoirs, canals, wells, pumps and pipes.

Water management needs to be improved through available systems at national level to mitigate wastage, prevent pollution and encouraging rain water harvesting. Also, it is necessary to rehabilitate ancient irrigation tank systems and maintain them through an integrated water management system.

The country has about 350 large/medium dams including those built in ancient times for irrigation and in recent times for hydro power development. In order to investigate the safety aspects of 32 of them, improve the hydro meteorological information system and undertake multi-sectoral water resource planning, a 4-year project was commenced in 2008 with financial assistance from the World Bank (Mahaweli Authority, 2010).

The Ministry of Irrigation and Water Management is currently conducting a "Preparatory Study for Flood Risk Management and Climate Change Adaptation in South Western Sri Lanka" with JICA assistance(Irrigation Dept. 2010).

The objective of the project is

1) To conduct a feasibility study on the priority areas for short term flood measures in the Kalu River basin with adapting to climate change impacts,
2). To formulate a rehabilitation and renewal plan for existing flood management infrastructures in the Kelani River basin and the pumping stations in the Gin and the Nilwala River basins, and
3). To build flood management capacity of organizations concerned.

3.4.4.4 Adaptation through Rain water harvesting

Domestic Use

The most significant impact of the domestic rainwater harvesting system in Sri Lanka is the ensured supply of water in the homestead. Rain water harvesting has brought much relief to people during times of drought, water scarcity and recently to those affected by the devastating tsunami of 2004.

For household purposes, ferro-cement tanks can be conveniently located in the homestead in the dry zone villages to supply 300 liters/day to a household, in the districts of Anuradhapura, Hambantota and Puttalam. Substantially higher degrees of success can be obtained within the wet and intermediate zones, where despite rainfall probability being high, particularly in hilly areas of Central, Sabaragamuwa and Uva Provinces where these people do not have easy access to water.

According to the Department of Census and Statistics (C&SD 2001) about 89% of houses in Sri Lanka have tiled, asbestos, galvanized iron sheets or concrete roofs which are most suitable to collect good quality water in a more efficient manner. Average annual rainfall in Sri Lanka is 1860 mm and most parts of the country receive over 1000 mm of rainfall per year. This amount of rainfall is more than sufficient to collect enough water for household needs.

Agricultural Use

The rural sector in Sri Lanka constitutes around 80% of the population and most of those in the rural sector depend on rainfall-based sources of income, such as agriculture, livestock production and inland fisheries. Freshwater availability is a key limiting factor in food production and improvement of livelihood.

If the run-off water is stored in the home garden itself, it would be available to plants when there is a water shortage. In some parts of the dry zone, small ponds called Pathahas have been used to collect and store rain water. Such a water collecting system on farm would enable farmers to cultivate crops during the dry seasons.

3.5 The Health Sector

Sri Lanka as a tropical country is vulnerable to direct effects of extreme, intense and frequent weather changes on human health. These extreme events include high temperatures, heat waves, winds, storms, floods and precipitations. Indirectly, these conditions will influence human health through microbial contaminant pathways and transmission dynamics of vectors which are common in Sri Lanka. The equilibrium of the ecosystem is liable to be changed along with the hydrological cycle and related impacts on agriculture as a consequence of climate change. This will have a significant impact on the nutritional status of the Sri Lankan population. As a country which depends on agriculture for food availability and having still not realized the optimal potential in terms of nutritional status of the population, this would have severe repercussions in terms of growth and development of children, the productivity of the older age groups and future generations.

The changes in socio- economic status will also have significant bearings on the human health. Thus it is obvious that the human health status of the Sri Lankan population is bound to be affected in great deal through changes in these proximal and distal determinants of health in the future due to climate variability. The broad categories of health

outcomes which are anticipated to increase are morbidity and mortality related to changing temperature, extreme weather related health effects, air pollution and its impacts, water borne and food borne diseases, vector borne diseases including rodent borne diseases, health effects of food and water shortage, mental and nutritional disorders and infectious diseases

3.5.1 High ambient temperatures

The extended exposure of people to high ambient temperature could result in several adverse consequences, among which are:

- Extreme effects of temperature (heat waves) may imbalance the thermo regulation process of the vulnerable population
- Changes in the population dynamics of disease vectors (malaria, dengue, filiariasis and Japanese encephalitis vectors in Sri Lanka) as a result of creating favourable conditions for vector breeding
- Increased temperatures may increase air and aero pollutants

Effect on human health and well being

- Increased morbidity and mortality depending on the severity of the heat and the vulnerability of the exposed population. As Sri Lanka is the fastest ageing population in the South Asian region, the relatively high numbers of the elderly population, outdoor workers and soldiers of armed forces are at enhanced risk.

- Air pollutants may exacerbate of existing respiratory and cardio vascular diseases. This has a significance for Sri Lanka as the country is experiencing epidemiological and demographic transition leading to an increased number of non-communicable diseases including diseases of cardio-vascular and respiratory system.

3.5.2 Extreme weather events

Sri Lanka is a tropical country occasionally experiencing intense precipitation triggered by disturbances in the Bay of Bengal which cause landslides in addition to regular monsoons, tropical storms and periods of drought.

Consequences of Precipitation

- Water loggings in various, multiple sites favourable for mosquito breeding may result in increase of vector (larval and adult) density
- Water logging and congested water being contaminated with important pathogens (eg. contamination with leptospirosis through urine of rat/mice and buffaloes)
- Breaking down of sewers, washing pit latrines, open defecated areas of humans and animals leading to contamination of drinking water sources for drinking water
- Human displacement due to land-slides, floods causing concentration of internally displaced people in closely confined areas.
- Disruption to provision of both curative health care and preventive health care services and health infrastructure damages leading to breakdown of routine service provision during floods, landslides and other disasters.
- Emergence of favourable conditions for the onset of disease outbreaks related to vector borne, rodent borne, food and water borne diseases.

Effects of precipitation on human health and well being

- Increased morbidity due to common vector borne diseases in Sri Lanka
  - Dengue (the major public health problem in Sri Lanka)
  - Malaria (controlled in Sri Lanka)
  - Japanese encephalitis (controlled in endemic districts in Sri Lanka)
  - Filariasis - (endemic in the Western coastal belt with signs of spreading into the interior)
- Increased morbidity due to common rodent borne diseases in Sri Lanka
  - Leptospirosis (second major problem of communicable disease in Sri Lanka)

  Increased morbidity due to water borne diseases
  - Watery diarrhea, dysentery, enteric fever,
  - Viral hepatitis (endemic in many districts with disease outbreaks from time to time)
  - Possibility of increased morbidity due to parasites such as amoebiasis, giardiasis
- Increased morbidity related to chronic poisonin with pesticides and toxic contents of fertilizers etc Increased morbidity due to acute respiratory tract
- infections (the leading cause of hospitalization in Sri Lanka)
- Increased morbidity and disability due to injuries linked to flood and landslides.
- Increased morbidity related to mental health (stress, anxiety, depression, aggression and at times suicides) as a result of displacement, loss of property, livelihood and loved ones.

Consequences of drought

- Scarcity of water leads to poor personal hygiene of the population in affected areas
- Scarcity of water pushes people to store water at home and this may give rise to increased dengue vector breeding even during drought
- Rock pools and small collection of water on river beds may increase density of malaria vectors in malaria endemic districts in Sri Lanka
- Scarcity of water compromises the quality of drinking water
- Emergence of ideal conditions for the spread of pathogens causing respiratory infections during droughts
- Drought affects the availability and affordability of food. Issues related to food security may exaggerate the nutritional disorders among vulnerable populations
- Onset of trigger factors for compromised mental health (stress, anxiety, depression, aggression and at times suicides) as a result of internal displacement, destruction of crops, harvest, livelihood and income

Effects of droughts on human health and well being

- Increased morbidity due to water washed skin diseases (example: scabies in drought prone areas)
- Increased morbidity due to dengue, malaria during droughts in drought prone areas
- Increased morbidity due to water borne infectious diseases in drought prone areas
- Increased morbidity due to acute respiratory tract infections in drought prone areas
- Increased morbidity due to minor or/major mental disorders

Effects of increased air pollution

- Climate change will potentially influence development, transport, dispersion and disposition of air pollutants, aero pollutants, particulate matter and increased concentration of ozone at ground level

Effects on human health and well being

- Increased Ozone accumulated at the ground level may exacerbate existing respiratory diseases. This is a significant impact on human health since acute and chronic respiratory tract diseases occupy the leading position among hospitalizations in Sri Lanka.
- - Increased hospitalizations for pneumonia
- - Increased morbidity due to asthma, chronic
- obstructive pulmonary diseases
- -Increased premature mortality due to
- respiratory diseases
- Increased particulate matters may potentially act as a cause for high morbidity and mortality in Sri Lanka
- Climate change can affect aero allergens such as pollen leading to increased allergic manifestations such as rhinitis and asthma in areas where these allergens are found

3.5.3 Adaptation measures and strategies

Adaptation to health impacts of climate change could be two fold. Suggested adaptation strategies may be at the individual level and the community level.

Individual strategy

In the individual adaptation strategy, informed individuals adjust themselves to moderate effects of climate change by modifying their current life style.

- Need for awareness building on climate change related impacts on health
- Communication for behavioral change
- Educating favorable practices and support for inculcating and adopting these strategies
- Facilitating attitudinal transformation to adopt individual adaptative measures

Further it is suggested to expand current strategies of individual risk minimization in relation to climate change sensitive variables in the event of the anticipated climate change.

Community Strategy

The community strategy of adaptation will be geared towards promoting primary and secondary adaptation measures. These measures could be grouped under following broad categories of action.

- Advocacy on adaptation to climate change sensitive health implications for the political leadership and health administrators
- Projection on anticipated health outcomes of climate change and gap analysis for an effective adaptation

- Review current policies and formulation of new policies related to health implications of climate change
- Preparationofastrategicplan of action for adaptation to climate change and implementation
- Paradigm shift from ad hoc short term to planned long term adaptation measures
- Mobilizing adequate financial resources for implementation of the action plan
- Adaptation of the Public Health system adaptation system to the demands of anticipated climate change may entail following:

  - Strengthening existing public health services to cater to the needs of climate change sensitive health Implications

  - revising its scope, re orientation to address these new needs,

  - expansion of services to focus on concerns of climate change
- Promotion of individual adaptation measures
- Implementation of population adaptation measures
- Adaptation of the curative health system adaptation to the demands of anticipated climate change may entail following:

  - Capacity development to adequately cater to the additional burden of diseases sensitive to climate change

  - Moderation of effects of climate change on human (tertiary adaptation)
- Assessment and monitoring of the capacity of health workers and institutions
- Management, preparedness and rapid response , mitigation of and adaptation to health impacts of CC
- Designing capacity building programs for health workers
- Conducting capacity building programs
- Mapping vulnerable populations for targeting adaptation measures
- Applied research on climate change and health utcomes
- Providing evidence based adaptation measures relevant to the local context
- Strengthening disease surveillance systems /Management Information System (MIS) to capture climate sensitive health effects
- Ability to collect information on vulnerability
- Strengthening preparedness and rapid response to health impacts of climate change
- Activation of Rapid Response teams at districts
- In-built response mechanisms to respond to any health related event requiring rapid response
- Training relevant health staff on climate change related health implications
- Utilizing the health sector disaster preparedness and response establishment
- Coordination of activities with district disaster management units
- Implementation of the comprehensive national policy on nutrition to address the nutritional issues emanating from the climate change related health impacts also for planning and implementing the national plan of action.

Suggested other adaptation measures

- Using Maternal and Child Health (MCH) network to assess vulnerability
- Short term adaptation measures for nutritional issues during the acute phase
- Supplementary food to children with or vulnerable to moderate acute malnutrition

- Therapeutic food supply to needy, vulnerable children
- Treatment of severe acute malnutrition in the curative health sector

3.6 Impacts on the Coastal Zone

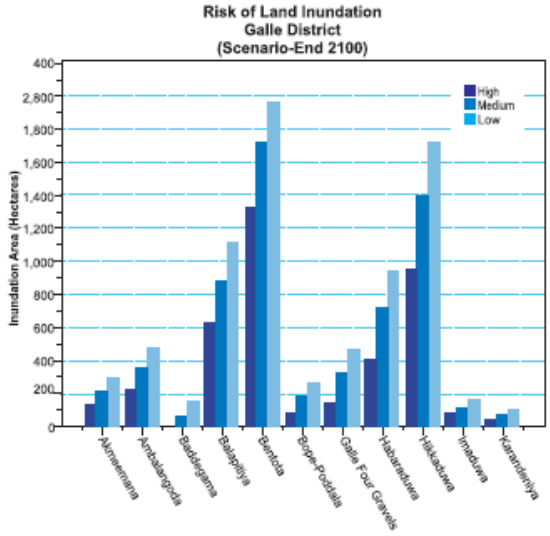
3.6.1 Inundation due to Sea Level Rise

The most direct impact of the rise in sea level is the inundation of land that is located just above the original water level. Low lying coastal settlements and coastal wetlands belong to this category. As a part of a study on Multi Hazard Profile Development carried out by several stake holder organizations in Sri Lanka with technical and financial assistance from UNDP, the Coast Conservation Department (CCD) has been collecting in its first phase LIDAR data from mid-western coast (Puttalam) to a south-eastern location at Arugambay to produce digital elevation model to identify tsunami, sea surge and sea level rise. Once the project is completed, it is expected that the coastal area likely to get inundated due to sea level rise will be known along this part of the coast.

3.6.2 Risk assessment in Southwest coast

As a post-tsunami activity, the CCD undertook a risk assessment study on the coastal zone of the southwestern part of the country (CCD 2010) The extents that will be inundated under three levels of risks in the different Divisional Secretary's divisions in Galle district, anticipated in 2100 are shown in Fig. 3.19

Fig. 3.19 Inundation of costal area in DS divisions in Galle District by 2100.



The two administrative divisions showing the highest risk - Bentota and Hikkaduwa - are the most popular tourist destinations among the beach resorts in the country. Hence, the accelerated sea level rise will affect the tourist industry in years to come.

3.6.3 Coastal Erosion

A rise of the mean sea level will lead to increased wave height thereby disturbing equilibrium in beaches and making them more prone to erosion and interfere with existing longshore sediment transport rates and distribution. Changes of wave pattern will also influence the developments with a coastal frontage. The UNDP study referred to earlier is also expected to cover the coastal erosion profile in the WP, SP and EP.

3.6.4 Flooding and Storm damage

High intensity rainfall arising from climate change contributes to short term inundation with serious impacts on life and infrastructure. The inundation will increase due to poor storm water drainage and a decrease in areas available for flood water retention. Ad-hoc reclamation has increased the vulnerability against flooding. Flash floods would be a significant problem in low lying areas, particularly in the coastal regions, where the topography is essentially flat, thus making natural drainage paths ineffective.

The city of Colombo is vulnerable to such a situation where the low-lying parts of the city go under water whenever there is a high intense rain falling even for a few hours. The topography of the city and its environ is such that rain water falling beyond a few hundred metres from the shore does not go direct to the sea, but instead take a long circuitous route along a system of canals before ending in the sea. The result is the flooding of the city when ever there is heavy rain even affecting the most sensitive areas. In 1992 and again in 2010, the Parliament House built in the middle of a lake for aesthetic reasons, went under nearly a metre of rain water. It is necessary to take precautionary measures to prevent such a calamity happening again for which a detailed study needs to be undertaken by local scientists and engineers. Under climate change, the occurrence of such events will become more frequent, and suitable adaptation measures need to be planned for immediate implementation which may cost a considerable sum of money.

3.6.5 Quality of Surface and Groundwater

Drought conditions arising from climate change can affect groundwater and its users essentially in two ways. Firstly, it could cause a net depletion of the groundwater recharge volumes including those of the coastal regions. Secondly, groundwater resources located in the northern dry zone coastal districts could be subjected to contamination with salinity intrusion.

Since shallow groundwater is slow in flowing into surface water bodies, it plays an important role in maintaining the river flows during dry periods and protecting important environmental areas such as wetlands and estuaries. Groundwater release helps to limit saline intrusion in the coastal river mouths, maintain an acceptable surface water quality in the dry zone and contribute to continued existence of coastal aquatic ecosystems. Therefore, droughts arising from climate change will have major impacts on the extent of groundwater release and the resulting increase of salinity.

3.6.6 Marine Eco-systems and Habitats

The sea level rise will affect coastal wetlands in many ways. Overall, climate change would also exert impacts on marine eco-systems and habitats. Important issues relating to coastal wetlands, reef systems and fisheries are presented below.

Coastal Wetlands

Rising sea levels, saline intrusion and coastal retreat will result in changes in habitat and species distribution. It will also result in landward migration of coastal wetlands resulting in the loss of freshwater and brackish habitats. This migration if allowed to happen will at least restrict the loss of coastal wetlands at the expense of freshwater habitats. If the coastal wetlands are unable to keep pace with sea level rise, it would lead to net loss of wetland area. Such losses would be greater if protection of developed areas prevents the inland migration and formation of new wetlands.

There are many occasions where wetlands are surrounded by high land, developed areas or protections works. This prevents the landward migration of wetlands creating a zone of high coastal stress in which intertidal habitats confront the surrounding features. Under such conditions there is a loss due to the absence of formation of new wetlands. The rates of sea level rise are very important in establishing whether wetlands can adjust by its migratory behaviour. Therefore, reservation of land for wetland and salt marsh migration requires long term planning based on scientific investigations.

3.6.7 Sea defense structures, Near-shore infrastructure and Land reclamation

Climate change and sea level rise will impose considerable pressure on existing coast and estuary protection and port structures such as revetments, sea walls and breakwaters. The pressures include, overtopping due to rising sea levels, increase in the frequency and intensity of extreme events such as storm attacks and flooding increase in the hydraulic force regime, beach loss in front of protection works, change in erosion and accretion trends arising from variations in drift and weakening of the support leading to the undermining of structures.

In the recent past, several proposals have been made by both the private and the public sectors in development projects, to acquire land via reclamation. While appreciating the need for such projects, the impacts of sea level rise have to be given very high consideration when preparing such development proposals.

3.6.8 Recommended Adaptation Measures for the coastal zone

In order to develop a strategic approach towards planning and management of impacts of sea level rise, it is necessary to conduct an impact and adaptation assessment. A primary requirement for this purpose is the availability of tools and methods and in particular the availability of reliable data and the most recent information on assets and activities which are exposed to hazards in the coastal zone. It is in this context that the proposed actions for the coastal zone are recommended.

a) *Assessment of Vulnerability*

- Prepare contour maps at suitable resolution (at least 0.5 m contour interval)
- Identify human population, natural resources, infrastructure and assets in the coastal zone
- Prepare a Vulnerability Database for the coastal zone
- Assess vulnerability to sea level rise along the coastal area of the country and estimate the economic cost of climate vulnerability

b) *Inundation*

- Incorporate climate change concerns in town and country planning and wetland conservation programmes

c) *Salt water intrusion*

- Assess the increase in salt water intrusion in important water bodies.
- Evaluate engineering interventions needed to counter threat based on the potential impact on agriculture

d) *Fresh water intakes*

- Review the performance of existing intakes taking sea level rise into account
- Design and cost new water intakes giving due consideration to sea level rise

e) *Groundwater*

- Prepare groundwater extraction regulation policy
  Introduce monitoring systems for groundwater extraction and water quality assessment in vulnerable areas

f) *Irrigation and low-level Agriculture*

- Study impact on existing irrigation structures
- Introduce salinity tolerant varieties of crops, alternative land use or engineering interventions to maintain the existing regime

g) *Fisheries Industry*

- Conduct sectoral assessment on climate change impacts on fishery development including fishery harbours, fishery settlements and sustainable use of fishery resource as a basis for long term planning

h) *Sea defence structure, nearshore infrastructure and land reclamation*

- Assess vulnerability and prepare plans for improvement as well as plans emergency response/contingency.
- Accommodate sea level rise in the design of new coastal structures
- Screen nearshore reclamation against sea level rise impact

I) *Coastal Zone Management*

- Prepare set back limits to take account of sea level rise
- Delineate critical areas and prepare special area management plans
- Formulate coastal database incorporating information on hazards and vulnerability for implementing integrated coastal area management
- Incorporate greater consideration of climate change impacts in the next revision of the Coastal Zone Management Plan (CZMP)

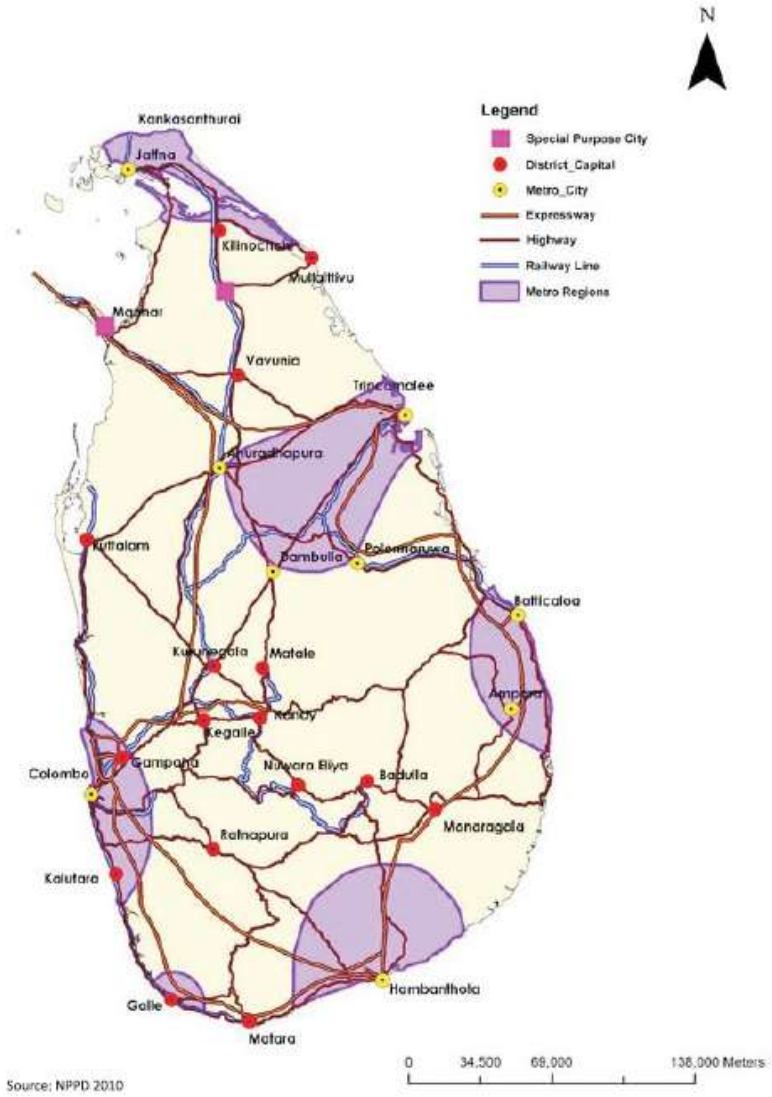
3.7 Adaptation Policies, Plans and Strategies

3.7.1 National Physical Planning Policy

The Government of Sri Lanka, as early as 1997, decided that there should be a national spatial plan for the country, and

established a separate department - National Physical Planning Department (NPPD) - for the purpose of preparing a National Physical Planning Policy (NPPP) and a National Physical Plan (NPP). The policy and the plan were expected to provide a broad framework to promote economic growth while maintaining integrated planning of economic, social, physical and environmental aspect of land. Among the environmental concerns that the policy took note were sea level rise, warming temperatures, uncertain effects on forest and agricultural systems and increased variability and volatility in weather patterns. Based on the principles of sustainable development, a policy was developed to provide a framework for addressing the issues and challenges that will face Sri Lanka towards 2030 (NPPD, 2010). The specific objectives of the plan were:

Fig. 3.20 Map showing the proposed metro areas



- **Protect the environment** through limiting development activities in fragile areas, the Protected Area Network and areas of local and regional environment significance;
- **Ensure that people live in areas that are safe from natural disasters** and the effect of global warming including sea level rise;
- **Create a strong network of cities, towns and villages** that provide a high quality of life, an appropriate range of services, diverse employment opportunities and community integration;
- **Protect water catchments and water resources** to improve water quality and ensure and sufficient supply of water for domestic, agricultural, industrial activities and power generation;
- **Balance production and protection** of natural resources and encourage economic development by providing an integrated spatial pattern of development.

The Central Highland of extent about 14,000 km^2 of the hill country above the 300 m contour was identified as one of the sensitive fragile areas. Another is the Coastal Fragile Area subject to sea level rise, and consequent inundation.

It is recommended that all development work within the fragile areas should be regulated and people, agricultural activities and structures living/lying on slopes above 60° gradient in the central fragile area should be relocated.

As an adaptation measure, it is further recommended to develop the major metro area bounded by the quadrangle Anuradhapura, Dambulla, Polonnaruwa and Trincomalee, and other metro areas around Hambantota, Batticaloa and Ampara, encouraging a shift of population from the WP to these areas, as shown in Fig. 3.20.

3.7.2 *Haritha* (Green) Lanka Programme

Meeting the Challenge of Climate Change is one mission among the 10 missions that have been identified for action in the *Haritha* Lanka programme described in section 1.14.2. The Plan has recommended a number of measures to be undertaken by 2016 on mitigation and adaptation. Among these are introducing bio-fuels in the transport sector, improving efficiency in industrial and energy sectors and increasing forestation coming under mitigation. For adaptation, the Plan has recommended carrying out health surveillance and identifying health risk areas when exposed to climate change and taking control measures, promoting growth of crop varieties not sensitive to temperature rise and responding positively for carbon dioxide increase, encouraging rain water harvesting, discouraging development activities near the coast and encouraging carbon trading.

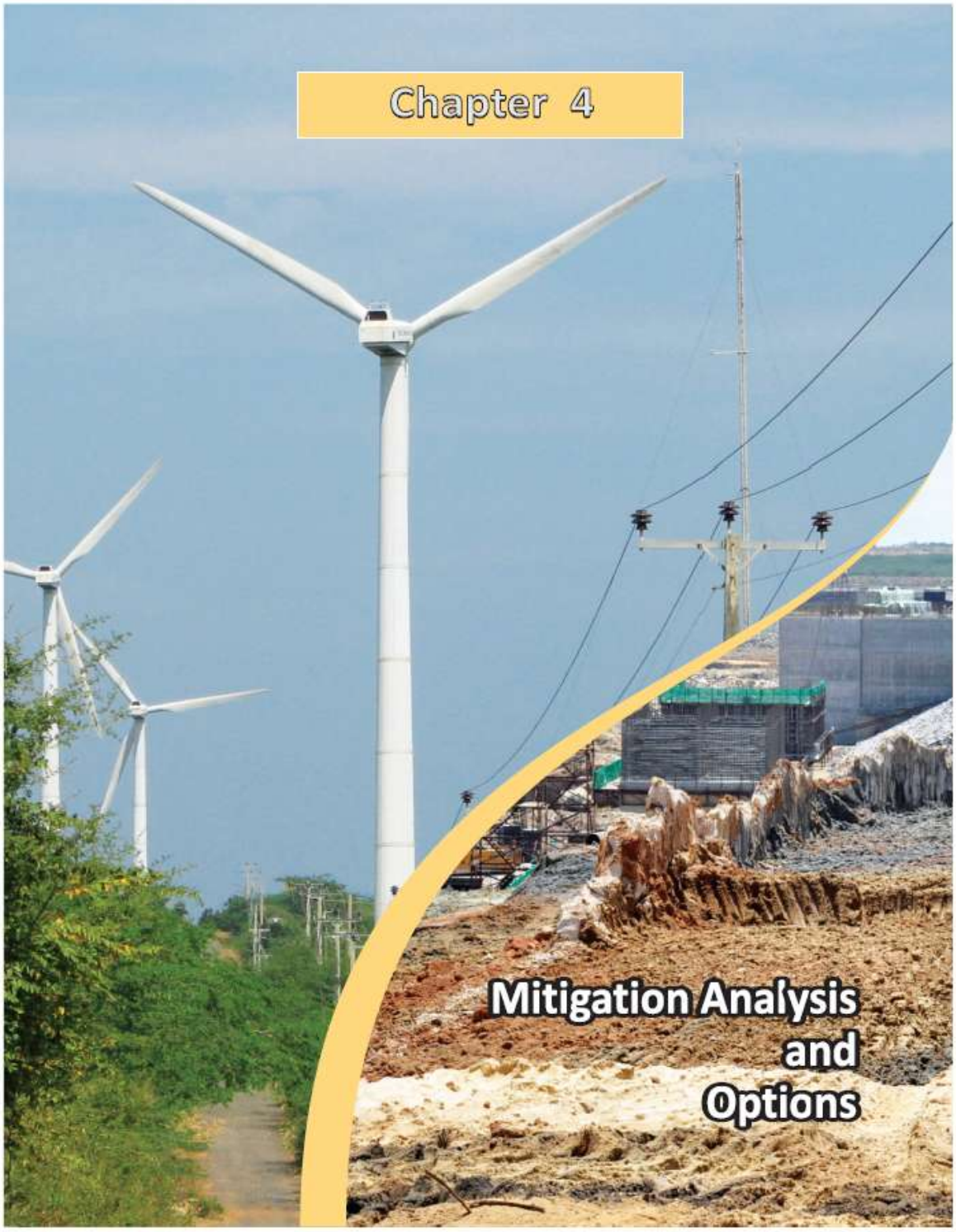
3.7.3 Adaptation Strategy for Sri Lanka

A study has been undertaken by a team funded by ADB in association with the Ministry of Environment in formulating a National Climate Change Adaptation Strategy (NCCAS) to increase Sri Lanka's resilience to climate change impacts whilst pursuing sustainable economic development (MoE, 2010). In the development of the NCCAS, first, Sector Vulnerability Profiles (SVP) were prepared for the five key sectors - agriculture and fisheries; water; health; urban development, human settlements and economic infrastructure; and biodiversity and ecosystem services. These were then subject to a detailed consultative process and the findings were next synthesized into a national adaptation strategy.

The strategy was presented in 5 thrust areas:

- Mainstream climate change adaptation into national planning and development,
- Enable climate resilient and healthy human settlements,
- Minimize climate change impacts on food security,
- Improve climate resilience of key economic drivers, and
- Safeguard natural resources and biodiversity from climate change impacts.

Under each thrust area, key thematic areas for action, along with priority adaptation measures, have been identified, and individual project concepts have been developed. Altogether 51 project concepts have been identified including the lead agencies responsible for their implementation. In order to implement these projects over the 6-year (2011-2016) duration of NCCAS, additional expenses necessary, beyond current and on-going expenditure, have been estimated at Rs. 47.7 billion (US$ 427 million). It is envisaged that most projects will commence only in 2012, in view of the lead time necessary for fund allocation.


Chapter 4
Mitigation Analysis and Options

Mitigation Analysis and Options

According to national inventories of GHG prepared for 1994 and 2000, CO_2 emissions from fossil fuel combustion have increased from 5,447 Gg to 10,430 Gg. The corresponding per capita CO_2 emissions were 304 and 546 kg, respectively, the increase being close to doubled. These are still much less than the global values. Nevertheless, Sri Lanka has adopted many policy measures that would result in mitigating emissions. These policy decisions were in fact taken to bring in environmentally friendly concerns among the people and industrialists and to avoid pollution of the country in general. In deciding mitigation options in the future, it is necessary to first make projections of future emissions making certain assumptions with regard to future growth of various sectors of the economy.

4.1 Policy Measures for Energy Conservation

4.1.1 Sustainable Energy Authority

With a view to promote the use of sustainable and renewable energy resources, the government in 2007 established the Sri Lanka Sustainable Energy Authority (SLSEA). Among its mandates were to declare renewable energy development areas, promote energy security, reliability and cost effectiveness in energy delivery and information management. Under renewable energy development, SLSEA is mainly functioning in the following areas:

- Resource mapping (identify the potential for wind, hydro and biomass resources and maintains a database)
- Resource allocation (approval for exploiting and developing identified resources)
- Facilitation (help the developers by assisting in getting permission from other organizations CEA, Divisional Secretariat etc.)

In addition, SLSEA is engaged in several activities that would increase energy efficiency and thereby reduce the GHG emissions, implement energy efficiency measures, manage the energy intensity of economy at a favorable level by steering the country away from the path taken by many other developed economies and undertake conservation programmes. Some of these are described under mitigation options.

4.1.2 Clean Development Mechanism

The Kyoto Protocol (KP) on Climate Change has established the Clean Development Mechanism (CDM) for the purpose of assisting Annex I country Parties in meeting their obligations under the KP for emission reduction while assisting developing country Parties in achieving sustainable development (SD) through undertaking GHG saving projects with incremental costs borne by the Annex I countries. Though the CDM is meant to assist the Annex I countries, the onus of submitting proposals, getting them validated, verified and certified, all of which cost much money, lies with the Non-Annex I countries.

Sri Lanka has identified several projects that would mitigate emissions and having the potential of bringing some revenue to the country if the projects are accepted for CDM benefits. However, from the past experience, it is unlikely that every project that saves GHG emissions such as small hydro, biomass power projects and similar would be accepted for CDM benefits.

During the past several years, out of many projects from Sri Lanka that had sought CDM benefits, only 7 projects have been registered with the CDM Executive Board, and these are shown in Table 4.1, according to which a total of 254 $GgCO_2$ could be saved a year. Further, eleven projects were either rejected (3) or terminated at validation (8). Of these, 8 were small hydro projects and 3 were biomass power projects. Further 11 projects, comprising 4 small hydro projects, 4 biomass thermal projects, 2 methane capture projects and one wind power project, are under consideration for validation (Climate Change Div, 2010). The total CO_2 saving expected from these 11 projects is 243 $GgCO_2$ annually. It is not known how many of them would get through the validation process. Hence, implementation of these projects and meeting country's obligation for achieving mitigation targets should not depend on CDM projects that are under consideration.

Table 4.1 Projects registered under CDM to date

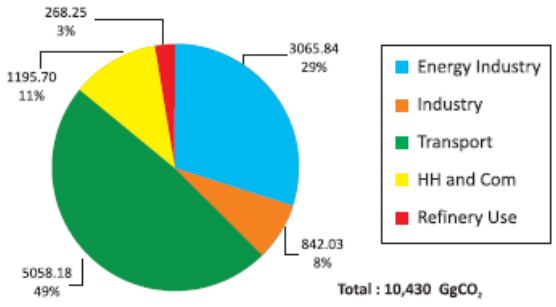
Year	Project Title	Saved CO_2 Gg/yr
2009	10 MW Biomass Power Generation Project	43.800
2009	Coconut shell charcoaling and power generation at Badalgama	43.265
2006	Sanquhar and Delta Small Hydro Power Projects	5.489
2005	Hapugastenne and Hulu Ganga Small Hydropower Projects	44.842
2005	Small Hydropower Projects at Alupola and Badulu Oya.	25.109
2005	Magal Ganga Small Hydropower Project	34,179
2010	Adavikanda, Kuruwita Division Mini Hydro Power Project	13.484
	Total CO_2 saved per year	**253.968**

Source: Climate Change Division(2010)

4.1.3 Forecasting Future Emission in Energy Sector

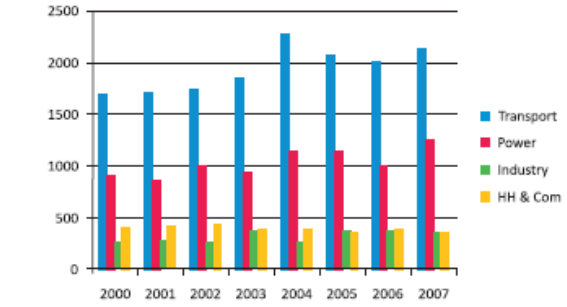
According to the GHG Inventory for 2000 presented in Chapter 2, 61% of aggregate emissions come from the energy sector, 25% from the agriculture sector, 11% from the waste sector and 3% from the industrial sector. A breakdown of the emissions from the energy sector is shown in Fig. 2.1, which shows the CO_2 emissions from fossil fuel combustion. The breakdown of the energy sector contribution in shown in Fig. 4.1, according to which the major component is from the transport sub-sector, with road sub sector contributing the highest. It is therefore important that the road transport sub-sector be given the highest priority in planning out a mitigation strategy.

Fig. 4.1 CO_2 Emissions from Fossil Fuel Combustion



The fuel consumption data in each of the four sub-sectors – Power, Transport, Industries and household and Commercial - during the period 2000 – 2007, based on data given in the Energy Balance 2007 (SLSEA 2008) report, are shown in Fig. 4.2, but these do not display a regular trend, though the Transport and Industry sub-sectors have shown an overall increase between the two extreme years. On the other hand, the house-hold and commercial sub-sector does not show any growth and hence excluded from the analysis.

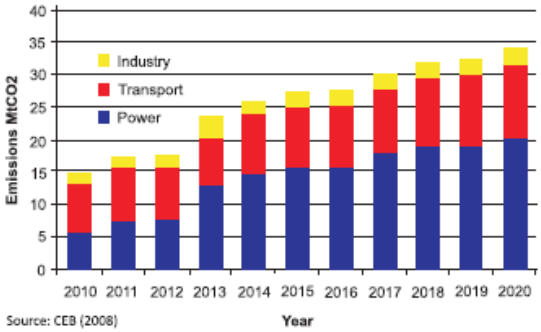
Fig. 4.2 Oil consumption data in kTOE during 2000-2007



Source: SLSEA (2008)

Between the two extreme years 2000 and 2007 the transport sub-sector and the industry sub-sector have shown average annual growth rates of 3.8% and 5.6%, respectively. Future projections of emissions in each sub-sector up to 2020 were estimated on the basis of these growth rates; an annual 4% growth rate in the case of transport and 6% in the case of industry (rounding off the past growth rates). For the power sector, future generation scenarios given in the LTGE Plan of CEB (2008) have been made use of. This Plan gives an updated Base Case in its Addendum Annex 1 and this has been included as the future projections in the power sector. These business-as-usual (BAU) projected emissions are shown in Fig. 4.3.

Fig. 4.3 Projected Energy Sector annual CO_2 emissions under BAU case



Source: CEB (2008)

In forecasting future energy scenarios, cognizance has been made of the mitigation targets that have already been incorporated into the *Haritha* Lanka Programme (HLP). The Cabinet of Ministers has adopted this programme and the organizations responsible for it implementation have also been identified. The Ministry of Plan Implementation is expected to monitor the implementation of the HLP.

4.2 Power Sector

4.2.1 Status and Trends

In 2007, the main share of primary energy had come from biomass (48%) followed by petroleum (43%) and hydro (9%) (Fig. 1.18). In the generation of electricity alone, petroleum oil has contributed 60% while hydro has contributed only 40% which also includes small hydro plants. According to the GHG inventory of 2000, the CO_2 emission from the power sector has contributed 29% to the total emissions from fossil fuel combustion (Fig. 2.1). With the government's decision to phase out dependence on oil for electricity generation as included in the National Energy Policy and Strategy (NEPS) (MP&E, 2006) and the non-availability of any more major hydro plants that are economically viable as

well as socially and environmentally acceptable, the future generation of electricity will have to depend on the development of NCRE sources and coal power. The latter has been identified as the least-cost option by the electric utility, but this is taking into consideration only the cost of production without including any environment damage cost or human health damage cost.

The first coal power plant is currently under construction on the west coast, and its first generating unit of capacity 300 MW is expected to come into operation in early 2011. Two more units, each of 300 MW capacities will come into operation a few years later. Subsequently, the government plans to build one more coal power plant with capacity 1000 MW, on the east coast, close to Trincomalee.

Among the electricity consumers, the highest are the domestic and commercial sectors. These have shown an increase from 58% in 2000 to 62% in 2007, while that of the industrial sector has shown a decline from 40% to 36% during the same period. According to the Long Term Generation Expansion Plan (LTGE) Plan of the CEB, in 2007 the thermal plants generated 60% of the total energy demand. From 2011, the major contribution to electricity generation will be from coal. By year 2022, thermal plants are expected to supply 81% of the energy demand.

Sri Lanka has included many renewable energy resources such as hydropower, wind, biomass and solar power in its electricity systems. As at end of October 2010, 219 MW of embedded renewable energy plants are already connected to the national electricity grid. Out of this, 178 MW are from mini hydro power plants while 11MW are from biomass power plants and 30 MW are from wind power plants. Construction is underway on 70 mini hydro plant (138 MW), 8 dendro power plants (36.75 MW), 11 wind plants (100 MW) and 12 waste to energy projects (44.75 MW) while provisional approval granted for 117 mini hydro plants (148 MW), 10 dendro plants (59.4 MW), 14 wind plants (116 MW) and 9 solid waste power plants (117 MW) (SLSEA, 2010). In addition, applications are pending on 1,060 small hydro plants, 208 wind energy plants and 25 biomass plants.

The energy intensity was estimated to be 167 TJ/GDP in 2000 and in 2010 it has already escalated to 209 TJ/GDP with GDP expressed in US $ / Capita.

4.2.2 Future GHG Emissions

The future emissions in the power sector were worked out based on the Long Term Generation Expansion (LTGE) plans formulated up to 2020 by the main utility of the country, the Ceylon Electricity Board (CEB), based on several of its options including a high base case and a low base case. From 2011, coal will be a major part of the energy mix which contributes significantly to the GHG emissions. It is projected to have a two fold increase in CO_2 emissions in 2015 compared with that in 2008 based on LTGE base case. The introduction of coal power plants will result in escalating the emissions to exceed 20 $TgCO_2$ by 2021, according to CEB.

CEB is required by statute to provide reliable, quality electricity to the entire nation at affordable prices, and the base case of LTGE plan of CEB has been worked out based on the least cost, selecting the economically optimal plant additions for future generations. A number of GHG mitigation options for the energy sector have been suggested. But it is important to note that most of these mitigation options would inevitably require an additional cost, the funding for which has to be realized through an international mechanism such as CDM or similar. Without such financial support, it would be extremely difficult for the Government of Sri Lanka to implement the proposed mitigatory measures.

4.2.3 Mitigation Options

4.2.3.1 Renewable Energy Options

The NEPS of Sri Lanka states that the government will endeavour to reach by 2015, a minimum level of 10% of electrical energy supplied to the grid to be from NCRE sources with a view to encourage the development of the NCRE sources, the CEB has revised its tariff structure so that the power units are purchased at a price fixed after taking into consideration the technology used and cost incurred in its development. In addition to this, the World Bank (WB) is also providing support to the developers through local banks eg. Energy Services Delivery Project followed by Renewable Energy for Rural Development (RERED) project. With the success of the initial phase of the project, WB has given a second grant of US$ 42 million to establish a target of 50 MW of grid connected small hydro systems and provide small solar PV systems to 60,000 households located away from the grid.

The CEB is also embarking on measures to reduce loss incurred in generation, transmission and distribution amounting to 12% as well as demand side management which involves education and awareness of the consumers on purchasing energy efficient appliances, designing households and commercial establishments to be more energy efficient etc. The national potential for Clean Development Mechanism (CDM), is estimated to be 613 $GgCO_2$/year in hydro power. The figures for wind is 673 $GgCO_2$/year, biomass is 1,680 $GgCO_2$/year (Batagoda, 2006). The estimated revenue from already commissioned projects by private sector is estimated to be US $ 39.5 million at the rate of US $ 12 per tonne of carbon.

If all the NCRE projects already commissioned under construction and which are in the pipeline at various stages of approval become operational by 2015 (Mini hydro power – 519 MW; Dendro power – 96 MW; Wind power – 246 MW and Waste to energy – 132 MW), the total energy generated by them and by those already commissioned would be about 4,400 GWh, assuming 25% plant factor for wind plants, 50% for small hydro and 80% for biomass plants. The CEB projection for energy generation in 2015 under its 2008 Base Load Forecast is 15,400 GWh (CEB, 2008), which yields the NCRE contribution to be about 28%. This means that the 10% target given in the National Energy Policy could be easily achieved by 2015. The DPF report on the other hand, has a target of 20% for the share of NCRE by 2020.

Further, if the total potential of wind energy can be harnessed, the share of clean energy to the energy supply system will be very much higher. The wind energy potential in the country has been found to be 24,000 MW covering both coastal and mountainous regions (SWERA 2008). Out of these sites, those covering the coastal regions, particularly the southeastern, northwestern and northern coasts were found to be economically and technically feasible for accommodating to the grid and these have a potential of about 1,800 MW capacity (ESMAP, 2003). However, achieving this target would involve an additional cost over the base case. Presently there are 60,000 PV systems installed in rural homes, however, only 6.4% of the non-electrified houses are using solar PV. It is expected that about 260,000 households who are not connected to the National Grid will opt for solar power in the near future. Heavy consumers of electricity should be encouraged through incentives of get PV panels of medium capacity (1-5 KW) installed with net metering facility enabling them to sell excess electricity generated to the grid.

4.2.3.2 Demand Side Option

The SLSEA has been promoting the following energy saving activities.

Energy labeling scheme
Energy labeling scheme is aimed at providing the consumer with the ability to check for the energy usage of electrical appliances before they buy, and it makes it illegal to sell without the label so that the consumer is protected from low cost inefficient products. Presently the scheme is implemented for CFLs and SLSEA aims has taken up steps to introduce the scheme for ceiling fans, refrigerators, air conditioners etc.

Energy efficient building code
SLSEA developed an Energy efficient building code for Sri Lanka and put it in to the voluntary implementation in 2009. Presently discussion is going on between SLSEA and UDA to incorporate it in to UDA check list for approval for new constructions.

Energy reporting and benchmarking
Energy reporting will be mandated by the above regulation which paves the way for establishment of benchmarks for most of the industries. In addition to that currently a web based energy reporting system is being developed to gather energy data for benchmarking. Based on available information for seven industries benchmarking has been done.

4.2.3.3 World Bank Study

Recently, the World Bank (WB) has a completed a study named "Sri Lanka – Environmental issues in the Power Sector" with the objective of assisting the Government of Sri Lanka to identify a path towards sustainable power development

Table 4.2 Emission reduction targets in the electricity sector and associated costs

Case	Year	Proposed Activity	Total saving of undiscounted GHG Emissions (Mt CO_2)	Additional cost as System NPV (US$Mn)
1	2009 -2028	Achieving 10% of total power generation from NCRE in 2015 and maintaining it up to 2028	27	698
2	2014- 2028	Introducing four medium scale candidate hydro power plants into the generation system	10	120
3	2017- 2028	Introduction of NG based CCGT plants to the generation system after the presently committed coal fired power plants were built	77	1,494
4	2009 -2028	Introducing case 1, 2 & 4 together (simultaneously) to the generation system	98	1,909
5	2009 -2028	Introducing Demand Side Management measures (increasing the penetration of CFLs and phasing out of incandescent lamps)	07	- (49)
8	2009- 2028	Total emission reduction (from cases 1,2 and 3 only)	114	2,312

(CEB, 2010). The study has provided a quantitative economic analysis for a number of generation options that will help decision-makers to assess various power sector policy options in terms of the trade-offs between environment, cost and other impacts. The anticipated emission reductions and associated additional costs for a number of mitigation options in the electricity sector has been obtained from the said report, which are given in Table 4.2.

4.2.4 Mitigation Targets in the Power Sector

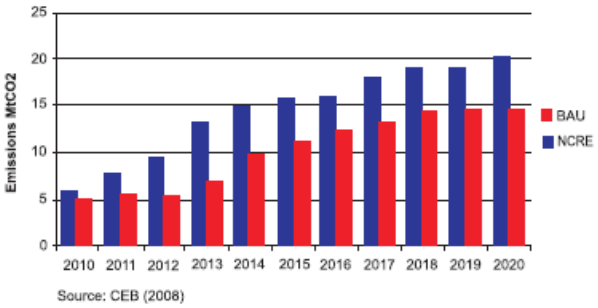
The Power sector mitigation scenario has been taken from the LTGE Plan (Addendum Annex 9) of CEB (2008) described as NCRE scenario. The latter includes addition of the 150 MW Upper Kotmale hydro power plant and 612.5 MW of renewable energy plants by 2020, along with 2,260 MW of thermal power plants. These mitigated emissions along with the BAU emissions in the power sector are shown in Fig. 4.4. Between the two, there is a 28% reduction in CO_2 emissions in 2020. However, the NCRE scenario that has been included in this report provides only a partial list of options to be undertaken in the future, and there is a greater potential to reduce emission further than what is given here, considering the number of NCRE projects under construction and approvals granted and the number of applications still pending.

The government has been considering the use of liquefied natural gas (LNG) as a source of clean fuel in the power sector with possible application in the transport and industrial sectors as well. In a 2007 Progress Report of the Ministry of Power and Energy posted in the Ministry website, the Ministry was planning to import LNG to operate a new thermal power plant to be built in the west coast and also to operate the existing gas turbine plants near the city, and a feasibility study was to be carried out. Subsequently, a team of Japanese Consultants had carried out a study but the report is yet to be published. Hence, the provision of including natural gas in the country's fuel mix has not been considered here. According to the governments DPF report, however, natural gas is expected to contribute 23% to the energy mix by 2020.

Additional mitigation options

The CEB's LTGE Plan mentions about the availability of 4 hydro power plants of capacities in the range 27 – 100 MW, with the total amounting to 211 MW, on which feasibility studies have been carried out. In view of their high cost of implementation, these have not been included in the NCRE case. However, if adequate funding is made available, these could be brought into the system avoiding annually about 1.0 $MtCO_2$ from oil or 1.3 $MtCO_2$ from coal. The capital costs of these hydro power projects have been estimated at more than US$ 3,200 per kW at 2007 prices (CEB, 2008), which makes them uneconomical. If, out of the 1,800 MW of wind energy plants that are found feasible, at least 1,000 MW could be installed within the next 10 years, an additional 2.0 $MtCO_2$ could be avoided annually from oil or 2.6 $MtCO_2$ from coal.

Fig. 4.4 Projected CO_2 emissions under BAU and Mitigated cases up to 2020



Source: CEB (2008)

4.2.5 Summary of Mitigation Options in the Power Sector

In summary, the following could be given as possible options available in Sri Lanka for the mitigation of emissions from the power sector.

- Develop all the major hydro power plants that have been identified as technically feasible with additional costs required to make them competitive, met from special funds
- Undertake system modification to the national grid enabling accommodation of a greater proportion of wind energy
- Encourage investors to exploit the country's wind energy potential by offering competitive rates
- Encourage the development of more dendro power plants by removing the present barriers in land acquisition for energy plantations and offering competitive rates
- Remove all duty and other taxes for the import of alternative energy systems including solar PV panels, small wind turbines and associated components enabling consumers to benefit from net metering systems already introduced.
- Introduce natural gas as an alternative fuel for base load generation

It is essential that adequate incentives and concessions be granted to developers, possibly through multilateral funding, to undertake these options which would help in mitigating emissions from the power sector.

4.3 Transport Sector

4.3.1 Status and Trends

The road transport sector is the highest contributor to GHG emissions, with a share of about 48% of all CO_2 emitted from fossil fuel combustion. Buses, trucks and vans are the main diesel consumers. Considering the vehicle fleet and the fuel efficiency, it is estimated that the trucks are responsible for at least 50% of the total diesel consumed. Gasoline is mainly consumed by cars, motor cycles and three wheelers. The new vehicle registration has increased significantly with time and motorcycles, three wheelers have shown a four to six fold increase compared with other vehicles in recent years. The railway operation is being gradually improved with the addition of new rolling stock.

Port services have shown a significant growth since 2006. The total cargo handling grew by 14% and container handling by 25% to 36% increase in trans-shipments in 2008. The fuel consumed consists of marine diesel and fuel oil. The civil aviation sector has shown a healthy growth in 2008, with increased consumption of aviation turbine fuel and aviation gasoline.

4.3.2 GHG Emissions

According to 2000 GHG Inventory, road, rail, aviation and sea transport systems have emitted 4444, 80, 497, and 37 $GgCO_2$, respectively. Their sum of CO_2 emissions, 5,058 Gg is 49% of the total CO_2 emissions from fossil fuel combustion of 10,430 $GgCO_2$, and 27% of the aggregate emissions of 18,843 $GgCO_{2Eq}$.

4.3.3 GHG Mitigations

The National Transport Policy drafted in 2008 includes several elements that would contribute to a reduction of emissions in a direct and indirect manner. An important policy recommendation is the improvement of mass public transport systems. The Transport Policy encourages environmental conservation as follows; annual emission test and make it mandatory for all vehicles, revise vehicle import tax to encourage low emission vehicles, phase out two stroke engines, enforce all noise and other standards under Motor Traffic Act, Higher taxes for high engine capacity vehicles, tax incentives for hybrid and alternative energy vehicles, electrification of urban rail and encourage hybrid or alternative energy vehicles Initiatives have already been taken to introduce public car parks and shuttle buses to the Colombo city to encourage bimodal transport. The National Transport Commission has introduced a car pooling system for car users who are willing to share a car in particular when commuting to work. In the corporate sector, executives who would be normally using personal transport systems for commuting from residence, also depend heavily on IT for their day-to-day office routine. With the availability of brand-band communication facilities, it is possible for them to perform equally well at home through a net-worked IT facility. They need not be physically available routinely within the office premises. Hence, the 5-day week could be reduced to a 4-day or even a 3-day week for the - IT dependent executives.

The introduction of a mass rapid transit system in the city and suburbs has been considered, but no decision has been taken in view of both technical and financial issues. This has however, been included in the DPF report as one of the strategies for improving the transport sector. In the meantime, government is embarking on a programme to improve the railway system with a view to draw more passengers away from road transport to railways. Today, the roads as well as bus terminals are almost saturated with vehicles, particularly at peak hours, and there is no room to accommodate any further increase in buses to ease the demand and over-crowding at peak hours. Even the existing buses cannot find time slots and one finds a large number of buses awaiting their turn at bus terminals. Though there have been proposals for building light or metro style railways to move city passenger traffic, the cost of their implementation would be enormous and also would bring about many logistic, spatial and social problems having to displace people.

A far more cost-effective and low-emission solution would be to improve the existing railway system by increasing their frequency and capacity to carry the passenger traffic at peak hours. This could be best achieved by electrifying the railway system, which is a far more efficient system as far as emissions are concerned. At present, the peak demand on the national electricity system is at night time from 6 pm to about 10 pm, and during the day time the demand is only about 60% of the peak value. Hence, the present generation system has adequate capacity to meet the added demand. The railway lines that are being double-tracked could be easily provided with electricity supply enabling introduction of a fast moving railway system which will attract the people away from the road transport thus reducing emissions from this sector. The Park & Ride system already commenced would work better with the railway system. Electrification of the railways has already been included in the DPF strategies.

Presently, the bulk of internal freight transport is through road transport, mainly because of its flexibility and convenience. However, long distance freight transport from city to city done on a regular basis, if converted to railway transport would be both an economical and low emission option. This applies to transport of building material, agriculture produce and petroleum oil for transport and power plants. Assuming a single train could haul 60 containers the emission released by switching to train from truck transport would be of the order of $1/30^{th}$ of emissions released

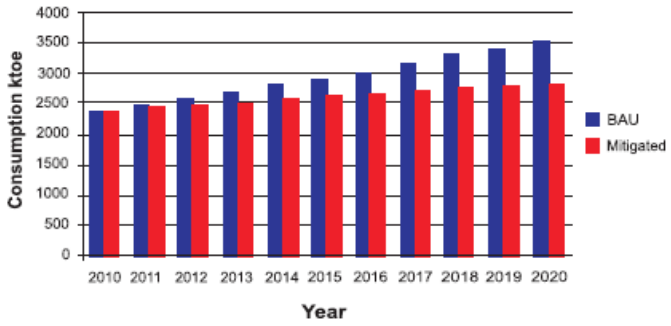
by transporting in 60 separate trucks to haul the same load. This demonstrates the high potential for mitigation in the transport sector by switching to railway for freight transport. The provision of better loading facilities at terminals, availability of flatbed trailers to carry containers, improvement of logistics and introducing competitive rates would automatically draw freight forwarders to railways. It would also eliminate congestion on highways.

Use of bio-fuels either solely or mixed with petrol or diesel had been explored stemming from its identification as a plausible alternative energy in the National Transport Policy and also in the *Haritha* (Green) Lanka Programme. According to this plan, 10% contribution of bio-fuel to the conventional fuel market share is envisaged by 2016. The report had recommended that the Ceylon Petroleum Corporation to purchase all locally manufactured bio-fuels once available at the respective equivalent price of the petroleum fuel. Using mitigation models it has been predicted that if bio-fuels are used at the rate 1% by 2012 and 5% by 2020 and the improvement of efficiencies in motor engines by application of VET (Vehicle Emission Testing) is 20% compared with the pre VET levels GHG emission reduction around 2,000 (out of 10,000) $GgCO_{2eq.}$ could be achieved. By granting low import duties and taxes on vehicles with high fuel efficiency a considerable amount of emissions could be saved.

4.3.4 Mitigation Targets in the Transport Sector

According to the projection of emissions described in Section 4.1.3, there will be 11.4 Mt of CO_2 emitted by 2020. According to the HLP, it is envisaged to introduce bio-fuels in transport up to 10% by 2016. In working out the emission reduction targets, it is assumed that the transport sector could achieve a reduction target of 20% between 2010 and 2020 or a 2% reduction annually, partly through introducing bio-fuels as envisaged in the HLP and partly through other means described previously such as shifting of freight and passenger transport to railways, reducing commuting days

Fig. 4.5 The Transport Sector projections under BAU case and mitigated case



of executives both in the private and public sector and other means. The projections made under BAU case and with reductions as described above are shown in Fig. 4.5. The emission reductions between these two cases are 10% by 2015 and 20% by 2020.

The SWERA (2008) study referred to earlier has a much greater potential of wind energy than what the CEB could accommodate, particularly in the central mountainous areas. Stand-alone wind energy plants could be set up in these areas and these could be used to generate hydrogen through electrolysis of water, which in turn could be used in the

transport sector once fuel-cell operated vehicles become affordable. One of the projects selected by GEF in its pilot study on technology transfer is on "Realizing Hydrogen Energy Installations on Small Island through Technology Cooperation", and Sri Lanka too could benefit from such technology (GEF, 2009).

4.3.5 Summary of Mitigation Options in the Transport Sector

The following are the possible mitigation options that could be introduced in the transport sub-sector in the short term.

- Encourage vehicle owners to improve fuel efficiency of their vehicles and phase out poor performing vehicles
- Introduce a preferential duty system to encourage the import of vehicles with high fuel efficiency
- Phase in bio-fuels as a blend in petroleum oil gradually, offering an attractive price to make the projects viable.
- Develop facilities for the railways to carry more long distance freight, by adding more rolling stock and improving loading facilities at stations.
- Electrify the railways in double track segments and increase its rolling-stock and introduce park and ride facilities near stations
- Encourage corporate executives to reduce their commuting days by working at home through networked systems
- Introduce compressed natural gas operated vehicles once natural gas is available.

However, it is imperative that adequate incentives and concessions are granted for the people to shift from the present systems to the proposed low carbon technologies and practices, if these were to make a success.

4.4. Industrial Sector

4.4.1 Status and Trends

The services sector continued to provide the highest contribution of 57% to overall growth while manufacturing industry sector contributed to 28%. The main growth in this sector is due to export oriented industries led by apparel and textile industry. Industrial development is also reflected in the consumption of fuel which has shown exponential increase in recent decades. Industrial sector still gets most of its energy from biomass (71%) followed by petroleum (17%) and then electricity (12%) (SLSEA, 2008). In 2007, demand for petroleum products in industry has been of about 351 Ktoe, which was 8.2% of national imports.

4.4.2 GHG Emissions

Urban air pollutions and global environmental changes associated with power generation and industrial processes are becoming serious issues. According to the GHG Inventory 2000, the CO_2 emission from the industrial sector (manufacturing & construction) was 842 $GgCO_2$ from fuel combustion and 492 $GgCO_2$ from industrial processes.

The refrigeration industry has introduced a new substance – Hydrofluorocarbons (HFC) as a substitute for Chlorofluorocarbons (CFC) which has been phased out under the Montreal Protocol on Ozone Depleting Substances (ODS). However, HFC, which has a global warming potential of 1,300 (for HFC 134a) relative to that of CO_2, is one of the

GHGs subject to control under the Kyoto Protocol, and is required to be included in the GHG Inventory. In 2000, there has been no report of any HFC being imported to the country, but in recent years, around 50 t of HFC134a, the refrigerant used in refrigerators, was reported to have been imported, contributing nearly 65 $GgCO_{2Eq}$. of emissions.

4.4.3 GHG Mitigations

GHG emissions can be reduced by reducing demand, improving efficiency, using lower carbon technologies, etc. Policy recommendations have been given by the government to encourage industries' wherever possible having a relatively low energy consumption and also to locate new industries in industrial estates wherever possible. Effort has been taken to locate industries in industrial estates as much as possible and a common environmental impact assessment carried out for the entire estate taking into consideration the types of industries that would be located there. Further, the Parliament has endorsed the Strategic Environmental Assessment (SEA) for regional development planning so that proper zoning can be done according to the existing resources, potential and challenges. It is hoped that this will soon be a law. Capacity building of the personnel in both the government sector and other sectors are being done now by the Central Environmental Authority and Institute of Environmental Professionals.

The Green Tax enforced by the Central Environmental Authority (CEA) in 2008 on items which have a more energy efficient alternative for example incandescent lamps against CFLs or white lights increase the demand for such items from the consumers and encourage industrialists towards manufacture/importation of such energy efficient items. Many industries have performed fuel switching, thus resorting to biomass from fuel-oil thus reducing the GHG emissions and also increased the CDM potential in the country in this sector. The potential from the use of biomass in industrial energy generation is 500 $GgCO_2$/year, assuming 50% of fuel switching. The CDM potential from energy conservation in the industries is 66 (out of 750) $GgCO_2$/year for electricity use and 114 (out of 1,000) $GgCO_2$/year for petroleum use.

A very significant initiative towards reducing the GHG from industries is the establishment of the National Cleaner Production Centre (NCPC). This is a UNIDO sponsored project of the Ministry of Industrial Development in Sri Lanka. Among the activities carried out by the NCPC in mitigation, the priority was given to the Cleaner Production and Energy Efficiency mechanisms. In introducing the mechanism, many awareness and training programs were conducted island wide to make stakeholders aware of cleaner production. The Cleaner Production Awards given to industries who have resorted to cleaner production and maintaining the same and the training of consultants in cleaner production are very positive moves towards sustaining cleaner production in industries and other sectors.

The infusion of these concepts to the school and university curricula ensures sustainability of the move. Stemming from the National Cleaner Production Policy and Strategies, sector wise policies have been for cleaner production ie fisheries, tourism and health. With the advice and guidance of the NCPC many industries have resorted to cleaner production ie ceramic, rubber, tea, building, food and textile. According to the NCPC, the total energy saving potential for some selected industries is 28.46 TJ/yr and the corresponding carbon dioxide reduction is 2.2 kt.

With regard to industries, there are six strategies outlined in achieving green industries. They are; consolidate cleaner production in industries, establish eco industrial parks, certification of industries, greening the supply chain, closing the loop and industrial ecology and incentive for environmental friendly investments. A comprehensive Action Plan

with performance indicators and short, medium and long term targets and lead responsible agencies is given in the *Haritha* (Green) Lanka Action Plan.

Greening the industries has penetrated to the hospitality sector also. Greening Sri Lanka Hotels programme which is a joint collaboration between Ministry of Tourism, Sri Lanka Sustainable Energy Authority and Tourist Hotels Association of Sri Lanka. The main objective/s of this initiative is to save costs, to attract consumer acceptance, to enhance the green image especially for marketing purposes and explore the opportunity of carbon trading. The target for reduction is 10% for energy and water and 20% for waste. Already 34 hotels are registered for this programme. Other initiatives in this sector are the Certification for Sustainable Tourism Programme, Jetwing Eternal Earth Programme etc.

In the apparel sector, there are many initiatives to reduce the carbon footprint. For example one company has managed to reduce energy use by 46%, water use by 70% by resorting to cleaner production and reduced its carbon footprint by 80%. The annual reduction/substitution potential of energy per year for industrial heat (tea, rubber and coconut) is 0.162 ktoe for biomass, energy conservation in the electricity is 20 ktoe and energy conservation for industries using petroleum is 36 ktoe.

Mitigation Scenarios had been developed using the assumptions that fuel switching to biomass will be 75% by 2020 and use of efficient motors and other Cleaner Production options will be adopted by 50% by 2020 and based on this the total emission reduction will be 2400 Gg in 2020.

4.4.4 Mitigation Targets in the Industrial Sector

According to the *Haritha* (Green) Lanka Programme, it is envisaged to introduce several measures to reduce oil consumption and improve efficiencies in industries with specific targets to be achieved by 2016 as shown in Table 4.3. In working out the emission reduction targets, it is assumed that the industrial sector could achieve a reduction target of 50% between 2010 and 2020 or a 5% reduction annually, partly through introducing bio-fuels and other renewable sources as envisaged in the HLP and partly through other means such as improving efficiencies. The projections made under BAU case estimated at a 6% annual growth and with reductions as described above, are shown in Fig. 4.6. The emission reductions between these two cases are 25% by 2015 and 50% by 2020.

4.4.5 Overall Mitigation in the Energy Sector

The combined BAU cases and the mitigated cases for the three sub-sectors – power, transport and industries – are shown in Fig. 4.7 and Fig. 4.8, respectively. The combined reduction in CO_2 emissions through fossil fuel combustion between the BAU and mitigated cases is 27% in 2020.

4.5 Agriculture Sector

4.5.1 Status and Trends

Agriculture sector showed almost a stable growth as the rates of growth was not very significantly different over the years. The highest growth was seen in 2006. The growth rate was 7.5 percent in 2008 as compared with 3.4 percent in 2007. The contribution of agriculture and livestock to the GDP is 13.2% while that of fishing is 1.8% as at 2008 making the total contribution to 15.1%.

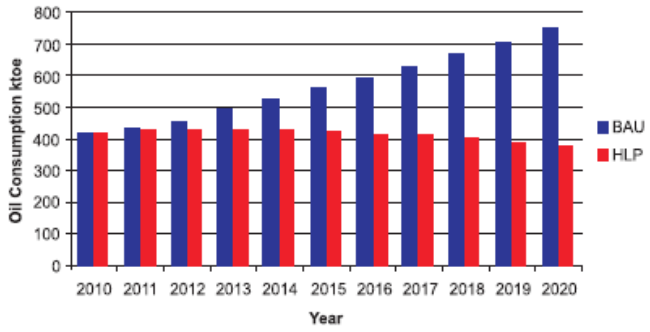
Table 4.3 Emission reduction targets given in *Haritha* Lanka Programme

No.	Proposed Action	Indicator	Target by 2016	Lead Agency
1.	Replacing oil with biomass in industry for thermal energy	Oil consumption	50%	MT&R
2.	Promoting energy efficiency in industries to reduce emissions from fossil fuels	Emission Level	50%	MID
3.	Switching of industries to renewable fuels	No. of industries	75%	MID

4.5.2 GHG emissions

In cropping and livestock activities, oxides of nitrogen, methane and oxides of carbon are emitted. As a practice many crop residues specially rice straw is burnt on site. This results in generation of GHGs. Methane is the major gas emitted

Fig. 4.6 The Industrial Sector projections under BAU case and mitigated case



from livestock especially ruminants ie: cattle, buffalo, goat and sheep. The total GHG emissions from agriculture related activities have been estimated to be 4,709 $GgCO_{2eq}$. The emissions from rice fields have been estimated as 2,466 $GgCO_{2eq.}$, while that of the enteric fermentation and manure management of livestock have been estimated as 1,253 and 182 $GgCO_{2eq.}$, respectively. Further, nitrous oxide emitted both directly and indirectly from soils and residue burning adds 759 and 48 $GgCO_{2eq}$, respectively, to the GHG emission. The total share of emissions from the agriculture sector to the total emissions is 23% in 2000.

4.5.3 GHG Mitigation

The National Agricultural Policy 2007 which identifies Agricultural Sector is an important part in the Sri Lankan economy emphasizes the importance of conserving the environment and spells out the adoption of technologies that are environmentally friendly and harmless to health. Among the actions that has been recommended by the Policy with regard to GHG mitigations, were promoting home gardening and urban agriculture to increases tree cover and

Fig. 4.7 Combined CO_2 Emissions from Energy Sector under BAU scenario

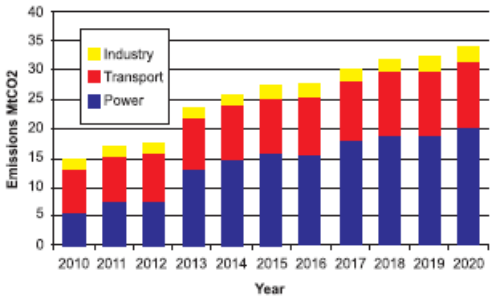
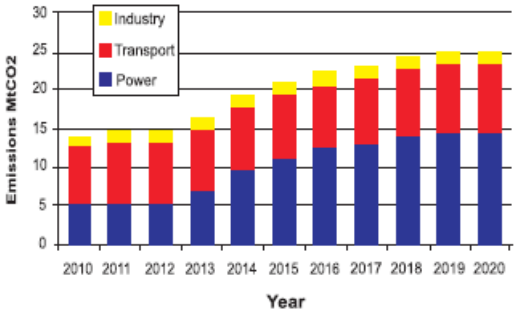


Fig. 4.8 Combined CO_2 Emissions from Energy Sector under Mitigated scenario



carbon sequestration, promotion of the investments in agriculture especially with regard to post harvest management which tends to reduce the waste accumulation and methane emissions, fostering, preserving and disseminating traditional knowledge in agriculture relating to organic farming, pest control and preservation and processing of food , use of bio fertilizers and integrated plant nutrition systems. These will in turn reduce the requirement of inorganic fertilizers having nitrogen which is a strong GHG, use of bio pesticides and integrated pest management, use of varieties of agricultural crops that use water economically so that GHG emissions are reduced.

The Policy emphasizes the use of novel and new technologies such as Nano Technology, Bio Technology for efficient agricultural production and environmental conservation. This is a significant provision where collaborative efforts could be made to use such technologies to enhance the mitigation potential of the agricultural sector. In order to further address the measures towards sustainability, Sustainable Agriculture Policy has been formulated by interest groups and had presented to the Minister in Charge. This draft Policy stresses the importance of conserving natural resources (land, water, forest, atmosphere etc.) while utilizing them effectively for agricultural production. This Policy recognized the need for Government's direct involvement in setting up a mechanism to promote organic agriculture which has become a compulsory issue in order to safeguard the interest of exporters who are involved in an internationally competitive organic trade as well as the producers in the organic sector. A long-term professional approach will help to generate more foreign exchange while our environment is being protected. This will also lead to maintain a sustainable development of the rural sector in Sri Lanka.

It is important that an institute to promote organic agriculture be established with the contribution of all stakeholders in the organic field. Government involvement is more important in making policy and finding a most suitable mechanism to implement them. Sustainable agriculture, which is ecologically friendly agriculture which conserves resources and preserves bio diversity has been promoted in the country to a certain level especially from both Department of Agriculture and non-governmental organizations. The Department of Agriculture has introduced the Conservation Farming Concept way back in 1980s with a view to conserve and sustainably use the natural resources to maximize the agricultural yield with minimum external inputs.

The Field Crops Research and Development Institute at Mahailuppallama gave the leadership to this programme with the participation of farmers. The components of conservation farming were Zero Tillage, Crop residue mulching, Mixed and Relay Cropping, Live Mulch System, Avenue Cropping and Multi Storey Cropping. Through this system, the application of external inputs by way of inorganic fertilizer and pesticides were minimized without compromising the yield. GHG emissions are mitigated by using less inorganic fertilizer through effective management of soil resources. Few companies in the Tea Plantation Sector have adopted the organic farming while organic cashew, sesame and spices and desiccated coconuts are also being exported. This has greater potential with time as the attention on healthy foods is catching up global markets very fast.

An island-wide programme to popularise food production utilising organic fertilizer is being implemented under a project launched by the Agriculture Development and Agrarian Services Ministry. The Government expects to manufacture 25 percent of the country's fertilizer requirement under this project.

A National Action Plan for Agro-biodiversity conservation and sustainable utilization of the same was adopted by the Biodiversity Secretariat of the Ministry of Environment and Natural Resources with the Faculty of Agriculture, University of Peradeniya in 2008. The main objective of the National Action Plan is to provide a comprehensive long term development framework including necessary guidelines, tasks, strategies and systematic approaches for conservation and utilization of agro-biodiversity in Sri Lanka using an ecosystem approach.

A method of upland paddy cultivation which uses minimum amount of water and no agrochemicals called 'SRI' was promoted by the Ministry of Agriculture in 2001. By 2002, this method was practiced by farmers in 18 districts. The data from six districts when averaged gave yield of 8.6 t/ha with a range of 5.36 to 12.79 t/ha. More specifically the average yield from Badulla District was 5.7 t/ha with the top yields in Badulla's eight sub districts ranging between 7.7 and 15.2 t/ha. In Kurunegala District, the average yield was 8.9 t/ha. However, this method is not widely used in the country now.

Five thousand (5,000) units of solar powered drip systems were provided to the farmers on the basis of need. This project is in operation in many districts namely Hambantota, Anuradhapura, Polonnaruwa, Matale, Ratnapura, Puttalam, Kurunegala, Ampara, Kandy, Kegalle, Moneragala, Badulla and Trincomalee. While boosting the agricultural yields it also helps to reduce the use of oil thus reducing GHG emissions to the atmosphere.

4.5.4 Mitigation Targets in the Agriculture Sector

Though there are many possibilities of reducing GHG emissions in the agriculture sector, in view of the large uncertainties in their estimation and also the logistic problems that would be encountered in implementing any mitigation programme through farmers, it would not be realistic to specify any mitigation targets in the agriculture sector.

4.6. Land use and Land Use Change and Forestry Sectors

4.6.1 Status and Trends

Around 80% of the land is owned by the government or under some form of the state control. The private land rightcomprises of different types of rights. The urban lands had experienced change from 0.3% in 1956 to 0.6% in 2007. The projected population in 2030 is expected to be about 22 million under high scenario (Fig. 1.7) and the land requirement for residential facilities would be in the order 222,275 ha and therefore this land parcel will be transformed from agriculture to urban/residential activities. This occurrence is predominant in Colombo, Kalutara, Gampaha, Galle and Matara districts. In Mahaweli areas the paddy lands had shown an increase.

The current forest cover in Sri Lanka has been gradually depleting and the present stand is estimated at 1.78 million hectares or 27.1% of the total land area. The forest losses are mainly due to encroachments and subsequent clearings, conversion of forest land to agriculture and reservoir development schemes and other land uses. The total extent of forest plantations is around 95,000 ha by the Forest Department while total recorded plantation extent by the private sector is 9500 ha by 2008 with a greater potential.

4.6.2 GHG Emissions

Carbon dioxide emissions relevant to biomass and soil carbon stock changes are due to land preparation and manure management with regard to the establishment of forest plantations, forest clearing for logging and other purposes, fertiliser applications especially urea and liming, Non carbon dioxide emissions (methane, nitrous oxide and precursor gases CO and NO_x) are due to forest fires and crop residue burning. In 2000, GHG from land use and forestry was found to be an uptake of 5,883 $GgCO_2$, 371 $GgCO_2$ from biomass and soil stock changes, respectively.

4.6.3 GHG Mitigations

The National Council for Sustainable Development in its *Haritha* (Green) Lanka Action Plan, 2009 has incorporated saving the fauna, flora and ecosystems as well as responsible use of land resources in its mission. Forests are the biggest storehouses of biodiversity. The total annual carbon dioxide abatement by forestry sector was estimated to be 2.4 Mt as for the year 2000.

The Forest Department as the umbrella organization for forestry in the country continues several projects to develop the forestry sector and to increase the forest cover in the country with the assistance of government, foreign development partner agencies and the private sector. The Forest Resources Management Project (FRMP) among other projects was implemented to promote the activities of forest maintenance and management and reforestation.

Despite the expansion of private sector forest plantation companies in the past, few companies have remained stable in the field and are hoping to increase the forest plantation extent considerably to cater to both local and international markets. This will increase the GHG abatement potential of the country. Sri Lanka's biodiversity is stored largely in forests as well as home gardens. Home gardens are found in almost all parts of the country. There are many moves to promote home gardening in the country including the Tree Domestication Project funded by CARP as a mitigation measure. However, in view of the many uncertainties involved in quantifying emission/sink in the LUCF sector, no effort was made to include it in the estimation of mitigation targets.

4.7. Waste Sector

4.7.1 Status and Trends

With changing consumption patterns, the quantity of solid waste has increased over the years. Solid waste management comes within the purview of the Local Government Authorities (LA). The total waste generated in Sri Lanka is 6400 t per day of which about 2500 t are collected by LAs. The waste from residential, public markets and other commercial services is mainly organic in origin, with smaller amounts of hazardous waste. The current urban MSW generation in Sri Lanka is approximately 0.80 kg per capita per day (MENR, 2005). It is estimated that the urban MSW generation will increase to 1 kg per capita per day by the year 2025. The total quantity of waste to be collected was 2,560 tonnes /day in 2000 and is projected to increase to 2,885 by 2010. The Colombo MC generates on an average 0.85 kg of waste per capita per day while other Municipal Councils generates 0.75 kg. The study further estimated that the per capita per day waste quantity was 0.60 kg in Urban Councils and 0.40 kg in *Pradeshiya Sabhas*. Of the waste disposed from industrial establishments and hospitals comprise largely of hazardous materials. The composition of the wastes is predominantly biodegradable (56%).

Of the MSW generated only 10-40% is collected and the rest remains either piled or dumped in low lands. Waste collection practices in LA areas differ greatly. Current trend is to privatize the collection and disposal of waste in most of MCs and UCs. Open dumping accounts for more than 85%. There are already 19 waste dumps in the Western Province and 236 islandwide. There are 4 main deep dumps in the Western Province i.e. Bleumendhol, Sedawatta, Karadiyana and Pohorawatta. There are two engineered landfills in both Nuwara Eliya and Mawanella. Under the Pilisaru Project more are to be constructed. Sri Lanka is lagging behind in thermal process of MSW management such as incineration and gasification.

Some local authorities are operating compost plants. There are 10 composting plants in Western Province in operation. Under the Pilisaru Project 44 Local Authorities island-wide have been supported in the establishment of composting plants. Biogas production is not well practiced in the country despite the fact that NERD Centre has conducted much research and demonstration on it. Waste recycling has gained momentum and in many municipalities kiosks had been set up to receive segregated waste. There are 20 polythene/plastic enterprises and few paper, glass, coconut shells and pet bottle recycling enterprises in operation. Polythene Recyclers Association has been formed under the aegis of the Central Environmental Authority.

4.7.2 GHG Emissions

Studies have shown that one ton of biodegradable waste gives 300 liters of CH_4 (0.4 tons of methane or 8 tCO_2e). The gross methane generation from solid waste is 470 Gg. Methane emissions from domestic waste water is 0.59 Gg while the figure for commercial waste water is 13.14 Gg. Basnayake et al. (2007) have calculated gas and methane emissions from waste under different conditions. The potential CH_4 emissions were 235 g/m^2/day from landfills and varied between 60-208 g/m^2/day for dumpsites in the Colombo District. The study has stated that the leachate generations is approximately 2.4 to 2.8 L/m^3/day and 3.0 to 3.5 L/m^3/day for open dumps and landfills, respectively. The leachate had high levels of quality parameters with 30,000 mg/L of BOD and 70,000 mg/L of COD.

The National Cleaner Production Centre (NCPC) also conducts awareness programs for various groups of people on the importance of cleaner production and energy efficiency in reducing GHG emission in respective sectors. They also conduct programs to increase climate awareness of officers of Municipal Councils, Urban Councils and Divisional Councils (*Pradeshiya Sabhas*) on cleaner production and energy efficiency. The programmes that have been carried out during 2003-08 period included 17 in schools, 4 in universities, 7 in Chambers of Commerce, 24 in the corporate sector, 11 in local government institutions and 37 in various industries.

4.7.3 GHG Mitigations

The Ministry of Environment and Natural Resources has identified solid waste management as a priority area in development agenda and formulated a national strategy for solid waste management in 2000. A National Policy on Solid Waste Management was also formulated in 2007 with the following objectives; ensuring environmental accountability and social responsibility of all waste generators waste managers and service providers, to actively involve individuals and all institutions in integrated and environmentally sound solid waste management practice, to maximize resource recovery with a view to minimize the amount of waste for disposal, to minimize adverse environmental impacts due to waste disposal to ensure health and well being of the people and on ecosystems.

Based on this Policy, National Strategy on Solid Waste Management was updated in January, 2008 and a set of technical guidelines prepared for solid waste management by the CEA.

A Waste Management Authority was also formed in 2007 under the Statute No. 1 of 2007 of the Western Provincial Council. This Authority is vested with the functions pertaining to the management of waste including collection, segregation, transportation, transfer, treatment and disposal of the waste in the Western Province. The National Council for Sustainable Development developed a National Action Plan for *Haritha* Lanka Programme and one of the important missions is doing away with waste dumps in the country. The main strategies of the mission are as follows; promote Life Cycle management of waste, strengthen the institutional mechanism for solid waste management in every Local Authority, establish necessary infrastructure for solid waste management in each Local Authority or adopt appropriate alternative methods, prevent accumulation of hazardous wastes into the non hazardous waste streams, apply Polluter Pay Principle and environmentally sound treatment and disposal of industrial solid waste and apply zero waste concepts in agricultural farms. It has identified key performance indicators, short, medium and long term targets and lead responsible agencies for carrying out the actions.

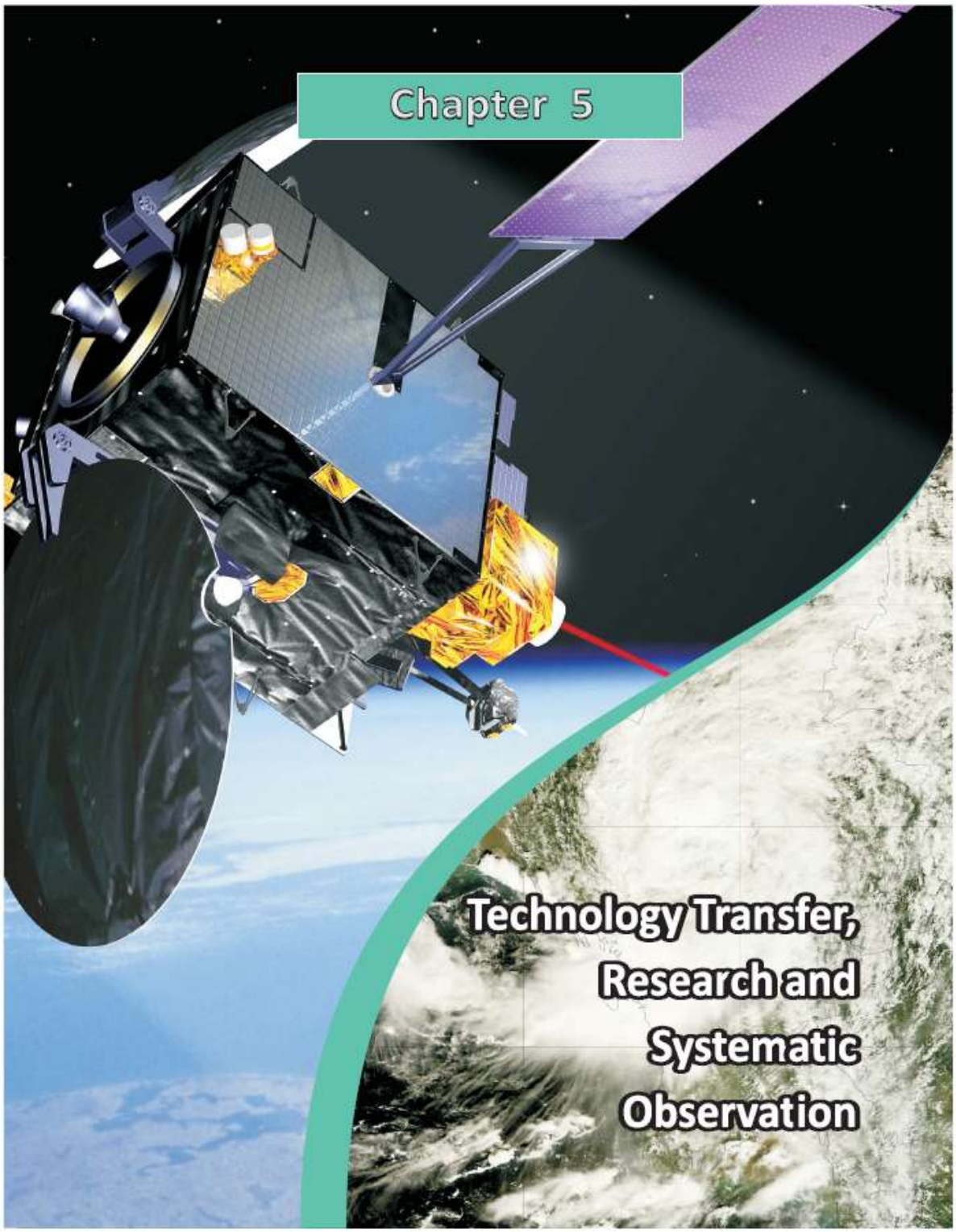
Waste recycling is taking effect to a certain extent in the country. Some of the municipalities have established kiosks to obtain segregated wastes for recycling. Glass, paper, metal, polythene and plastic are a few of reusable and recyclable items in Sri Lanka. There are 16 private institutions dealing with waste management registered with the CEA as polythene/plastic recyclers, one pet bottle recyclers, four paper recyclers and one coconut shell collectors and one glass recyclers. At present the Ceylon Glass Company (CGC) uses 40% of waste glass (cullet) in their production process. Ferrous and non-ferrous metal are recycled locally and exported, after sorting and cleaning. The price of scrap metals is high due to the export demand. Scrap metal (ferrous, copper, brass, aluminum) is present in relatively low quantities in Municipal Solid Waste and is quickly recovered for recycling. Recycling of plastic is an emerging industry in Sri Lanka although in many instances the daily amount collected is insufficient for the industry to be financially viable.

A National Post Consumer Plastics Waste Management Project for the Management of Post Consumer Plastic Waste in the Environment was established in the CEA. In order to give effect to a decision taken by the Cabinet of Ministers, 1% Cess was imposed on all plastic raw materials and finished goods imported under the HS Code 39 with effect from March 2005 with the purpose of utilizing this money to implement a post consumer plastic waste management programme through the Special Projects Implementation Unit in the CEA. With a view to reduce the excessive use of dumping of plastics which causes environmental hazards the Government has banned the use of polythene and polythene products of 20 microns or below in thickness with effect from January, 2007.

With regard to waste water, both aerobic and anaerobic digestion are being used. Under aerobic digestion, activated sludge process treatment, extended aeration and rotating biological contactors. Anaerobic digestion includes biogas production units, anaerobic filters and UASBs. Some hotels are using this. There are four waste to energy projects. EIA approval has already been granted to many solid waste management projects.

Fourteen (14) major composting plants are planned to be constructed and implemented directly by the Pilisaru project during the initial stage. Fifty LAs will be covered by this and is expected to handle an estimated 1,085 tons of waste per day. Total compost production of these direct implementing projects will be 60,272 t per annum and the annual revenue is estimated to be at Rs. 421 million. Expected net profit of this project is Rs. 130 million per year. The Project also envisages to bring down the waste dumps in the country, for example to bring the 19 dumps in the Western Province to 10 by the end of the Project. Three sanitary land fills have been proposed in the Western Province having capacities of 100 to 300 t/day to be established soon. However, due to lack of data and uncertainties in emission factor, no effort was made to quantify reduction targets in waste sector.

The Government bodies dealing with waste management are working with the private sector, schools, other government organizations like hospitals to achieve the target of making the country clean.



Chapter 5

Technology Transfer, Research and Systematic Observation

Technology Transfer, Research and Systematic Observations

The developed country Parties to UNFCCC are required, as per Articles 4.3 and 4.5 of UNFCCC, to promote, facilitate and finance the transfer of, or access to, environmentally sound technologies and know-how to developing country Parties, to enable them to implement the provisions of the Convention. This Chapter describes activities carried out in the last decade in compliance with these requirements.

5.1 Technology Transfer

Several Technology transfer projects have been implemented in Sri Lanka, both under the UNFCCC system and directly.

5.1.1 Technology Transfer within the UNFCCC System

In order to assist developing countries address their needs for Environmentally Sound Technologies (EST), at the request of UNFCCC, GEF had prepared a Strategic Programme on Technology Transfer which was adopted by COP 14 held in Poznan in 2008. This programme, referred to as the Poznan Strategic Programme (PSP) on Technology Transfer, consists of three funding windows:

- Technology needs assessments (TNAs)
- Piloting priority technology projects
- Dissemination of successfully demonstrated technologies.

In pursuing the second item, GEF has issued a Call for Proposals for Technology Transfer Pilot Projects in March 2009, Sri Lanka has submitted a proposal seeking funds up to US$ 2.7 million from GEF (with co-financing up to US$ 10 million from other sources) for cultivating bamboo, processing the wood product and scaling up to commercial production. The project document funded jointly with UNIDO is expected to be submitted by the end of 2010 and the 4-year project is expected to commence by the end of 2011 by the Ministry of Industrial Development.

5.1.2 Renewable Energy for Rural Economic Development (RERED) Project

The RERED Project was funded by a US$75 million line of credit from the International Development Agency (IDA) of The World Bank and a US$8 million grant from the GEF (RERED 2008). IDA provided an additional US$40 million line of credit for RERED Additional Financing. It is a market based project of the Government of Sri Lanka (GOSL) implemented by DFCC Bank of Sri Lanka. The RERED Project aims to expand the commercial provision and utilization of renewable energy resources, with a focus on improving the quality of life in rural areas by using electricity as a means to further income generation and social service delivery. Under this project renewable energy technologies including (Solar PV, Mini/ Micro Hydro, Wind and Biomass) generating and energy conservation machinery manufactured in many different countries have been introduced to Sri Lanka. A test facility has been established at NERDC to ensure that all equipment installed conforms to stipulated standards.

5.1.3 Introduction of fuelwood operated gasifier technology

Sri Lanka's major share of primary energy comes from biomass, being 48% in 2007. However, the technology that is being used for extracting thermal energy from biomass is at a very low level – around 10- 15%, resulting in the waste of this valuable resource. Though the use of biomass as a fuel does not add to the GHG inventory, its extraction from the forests and plantations contribute to emissions as a land-use change activity. Hence, it is important to improve the efficiency of biomass utilization for energy purposes that will result in the saving of biomass extraction from forests and plantations. A readily available technology for improving the efficiency of biomass utilization is the gasification which can improve the system efficiency to about 35-42%.

The Alternative Energy Division of the Ministry of Science and Technology (MST) has obtained fuelwood operated gasifier technology from India and introduced it here. An electricity generating unit with a capacity of 35 kW has been installed as a demonstration project for the use of fuelwood such as Gliricidia to generate electricity. A thermal gasifier of 600 KW was also introduced to Sri Lanka to demonstrate that Gliricidia wood could be gasified and used as fuel to replace petroleum operated boilers. Since introduction of these two gasifiers there are over a 20 such gasifiers introduced in Sri Lanka by the Private sector on a commercial basis and a few NGOs have provided funds for rural electrification. A local company has started manufacturing biomass gasifiers locally for small –scale electricity generating projects (12 kW) for off-grid rural electrification.

5.1.4 Electricity Generation from Agriculture Residue

A cement factory operating in the Eastern Province where rice cultivation is abundant, has acquired the technology to use rice husk which is a waste product, to generate thermal energy required to operate a 10 MW power plant. During off-season of rice production, biomass from grilicidea plantation is used to run the plant. This plant provides additional revenue to farmers by selling rice husk. It is grid-connected and has also received CDM registration.

5.1.5 Introduction of Biogas Digesters

With the availability of a large cattle population in the country, biogas generation utilizing cow-dung has been practiced for many decades in Sri Lanka, particularly where dung is available on site. The technology has been further developed to utilize market waste in urban areas which has a dual purpose – generating energy from the gas and producing fertilizer from the residue. The process was first developed by a local R&D institute and is now popularized by Practical Action (PA), a Non-Governmental Organizations formerly known as the Intermediate Technology Development Group (ITDG). This institution has been actively involved in the application of renewable energy for rural communities. PA has recently introduced a new type of biogas digester (plug flow) from India which is becoming popular in rural areas.

5.1.6 Electricity Generation from Biogas

Energy Forum (EF), a Non-Governmental Organization (NGO) engaged in the field of Rural Energy, has developed rural biogas units and introduced the technology of biogas operated electricity generating sets for off-grid applications. These generators are manufactured in the Republic of China and are designed for operating with LPG. The EF has successfully developed these machines for biogas operation. Many such units are now operational in Sri Lanka.

5.2 Development of Technologies Locally

5.2.1 Energy Sector

In the Energy sector, Sri Lankan institutes have made significant progress with respect to alternative energy technologies. National Engineering Research and Development (NERD) Center possesses technologies on solar thermal application for low temperature applications such as produce drying, water heating etc.; Solar PV for off-grid electricity generation (for areas remote from grid connection), wind for motive application (egs. water pumping) and wind for off-grid electricity generation. A large number of private firms too have been constructing and installing micro-hydro power plants below 1 MW capacity using waterways in rural areas not served by the national grid.

The University of Moratuwa is working on technologies such as compressed biomethane as fuel for transport vehicles, hydrogen (and chemical) production from intermittent or remote sources such as wind, bioethanol / biobutanol production from cellulose for transport application, biodiesel production from seed crops for transport application, bioethanol production from starch/ sugars for transport application and engine efficiency measurements and improvements to transport vehicles. Bio Energy Association of Sri Lanka has technologies for solid biomass from integrated energy plantations for electricity generation (grid-connection and off-grid) and solid biomass from integrated energy plantations for thermal application (household and industrial). Among the many options available for producing bio-fuels, the technology that gives the highest energy per hectare is extraction of energy from the biomass itself using gasification, rather than from oil or sugar or starch the crops produce (Ratnasiri 2008). The CO and H_2 present in syngas produced from gasification can be synthesized to produce liquid fuel for use in transport and other applications. This technology, however, is still not available freely, though fuel produced from this technology is used commercially elsewhere including South Africa.

5.2.2 Industrial Sector

In the Industry sector there are some schemes available in Sri Lanka which could be useful in technology transfer. ***Environmentally Friendly Solutions Fund (E friends) was*** aimed at providing technical assistance and low cost loans for waste minimization, resource recovery, energy savings and pollution control and abatement in industrial enterprises.

Under the E-Friends assistance Investments entailing a financial return in addition to the desired environmental protection/energy saving effect will get financing up to 70 percent to total project cost; and investments not entailing a financial return will get financing up to 100 percent of total project (max.Rs.50.0 Million)

When going through the criteria, it is evident that the projects for reducing GHG also could obtain assistance from E Friends, even though the eligibility criteria do not explicitly mention about projects on adaptation or mitigation in relation to GHG emissions.

A scheme is operational at present under the Ministry of Industrial Development where duty free concessions for importation of equipment and machinery utilized for environmental protection and pollution management could be obtained. This facility has been introduced to provide incentives to facilitate utilization of advanced technology with the objective of promoting Small and Medium Enterprises (SME) based investment for increasing productivity and enhancing their competitiveness, which in turn will facilitate reducing GHG emissions.

5.3 Technology Needs Assessment

The COP 13 has decided that non-Annex I countries should include their Technology Needs Assessment (TNA) findings in the SNC. In identifying technology needs, only those technologies currently not available in the country and not freely available commercially were considered.

The technology needs identified are listed below.

5.3.1 Weather and Climate

- Technology for the forecasting of short and medium range weather to build a weather information system for the farmers
- Technology for the projection of future climate, both temperature and rainfall based on the latest IPCC projections and local agro-ecological conditions

5.3.2 Agriculture

- Technology for the development of crop simulation models applicable to crops of economic importance such as rice, tea, coconut and rubber
- Technology for the strengthening of the plant breeding programmes with the following characteristics applicable to crops of economic importance (indicated above)
- drought resistant
- high temperature resistant
- pest and disease resistant
- salinity resistant

5.3.3 Transport

- Technology for introducing compact wood gasifier systems which can be mounted on heavy such as buses enabling them to operate with fire-wood, feeding the syn-gas directly to the engine.
- Technology for synthesizing CO and H_2 present in syn-gas obtained from wood gasification into liquid fuels which could be used in vehicles and other applications.
- Technology for the production of bio-butanol from cellulosic material

5.3.4 Energy

- Compact gasifier systems for use in commercial establishments and households for cooking purposes using wood chips helping to reduce the high biomass consumption.
- Technology for accommodating a high percentage of wind power into the national grid thus exploiting the high wind power potential in the country.
- Clean biomass technology combustion which can be adopted in industries to reduce their fuel oil combustion
- Hydrogen generation from stand-alone wind power plants, its storage and distribution for use in fuel-cells for use in vehicles and embedded power generating plants.

- Detailed study on the ocean energy system available off-shore including wave energy potential and under-water current systems having the potential for power generation off-shore for feeding to the grid.
- Technology for building a concentrated solar thermal system in a suitable site enabling harnessing of solar energy on a large scale for connection to the grid.
- Technology for the production of biogas from degradable material and store it in cylinders for distribution among consumers.

5.3.5 Coastal Zone

- Low cost aerial photography technology for the assessment of the elevation profile along the shore-line enabling assessment of the land area vulnerable to sea level rise
- Technology for the development of simulation models to estimate the impact of sea level rise on the coastal erosion and accretion rates at different location.

5.4 Research Activities

5.4.1 Research conducted under Enabling Activity Project

Sri Lanka, in 2001, received a grant of US$ 118,000 from GEF under its Enabling Activities Programme to undertake research needed to fill gaps in the preparation of the second national communication on climate change, including assessing technology needs. A variety of projects were funded on the areas of adaptation, mitigation and vulnerability assessment and 58 working papers have been prepared. The full list of studies is given in the Project Terminal Report (MENR 2004b). Some of the more important studies in different areas carried out under the Project are listed below.

Agriculture Studies

Studies undertaken in the Agriculture sector are

- Identification and evaluation of the adaptive measures to offset the anticipated drought occurrences with special emphasis on rice production in the dry zone of Sri Lanka.
- Agro-climatic potential and risk assessment for crop intensification in home gardens of Southern Sri Lanka: A case study in Embilipitiya area.
- Impacts of climate change on land productivity of rubber, possible adaptation measures and the role of rubber plantations as a mitigatory option.
- Estimation of Methane and Nitrous Oxide Emission from Rice Fields in Low Country Intermediate Zone of Sri Lanka
- Impact of Climate Change on Agriculture in Sri Lanka and Possible Response Strategies.
- Assessment on potential capability of fixing carbon in different genotypes of the rubber crop
- Screening of selected forest tree species of Sri Lanka for their response to increasing atmospheric carbon dioxide
- An assessment on the vulnerability of *Hevea* seed production to climate change
- Adaptability/Stability of different rubber genotypes for agro-climatic variability of Sri Lanka
- Coconut cultivation as a measure of adapting to and mitigation of climate change.
- An assessment on the vulnerability of the rubber crop (with respect to growth) for climate change.

Climate Analysis

Studies undertaken in the area of climate analysis are :

- Development of rainfall and temperature scenarios for Sri Lanka based on IPCC 3rd Assessment Projections
- Study on changes of rainfall in the Mahaweli Upper watershed, due to climatic changes and develop a correction model for global warming.
- Trends in seasonal rainfall and behaviors of growing season characteristics due to climate change in wet- and intermediate-zones of Sri Lanka
- Urban climate change mitigation through manipulation of urban morphology: Strategies for Colombo.
- An investigation of ambient air temperature trends at Hambantota-Angunukolapelassa, Nuwara-Eliya –Talawakelle and Colombo-Bombuwala
- Influence of changing weather patterns on earth movements: A case study of the Puwakgahawela Area.
- Release of methane and carbon-dioxide gases from municipal solid waste landfills in the Colombo Metropolitan Region

Other Studies

- Implication of climate change on land degradation: A study on changing rainfall regime and its effect on soil erosion in Central Highlands of Sri Lanka
- Effects of climate change on harnessing of off-grid village micro hydropower generation in Sri Lanka
- Survey of steam boilers in order to quantify and mitigate greenhouse gases in the desiccated coconut industry
- A Study of Climate Change Impacts on Peasant Behavior and Natural Resources in North Central Province
- Vulnerability to Urban Warming and Adaptation response options for the City of Colombo and suburbs

5.4.2 Other Research Studies

Several other research studies have been conducted with funding from other sources.

APN Study on CO_2 Elevation Studies on Rice

With funding received initially from the Asia-Pacific Network (APN), studies were conducted at the Batalagoda Rice Research and Development Institute (RRDI) jointly with the Crop Science Department of University of Peradeniya on the dependence of rice yield on CO_2 elevation and other factors, as a part of a South Asia regional programme. These studies were subsequently continued with local funds from the government. It was found that CO_2 elevation increases the yield, while temperature rise, water deficit and increased salinity would reduce the yield . In order to determine the extent and direction to which the yield responds to all four factors under different climate scenarios simultaneously, it is necessary to undertake a crop modeling exercise. In the case of rice, proven crop models are available and it is expected that as the next stage, quantitative yield analysis would be undertaken using these simulation models.

Studies on water management in rice cultivation

Research is being done at RRDI on alternative water management techniques that would reduce the water demand without compromising the yield. The techniques that are being tested include alternative wetting- and drying (AWD), saturated rice culture (SRC) and aerobic rice culture (ARC). SRC involves maintaining the rice crop on a water-saturated soil, but without standing water. In ARC, soil water is lowered below saturation at selected stages of the crop. All the above techniques of alternative water management achieve significant reductions in water use and significant increases in water productivity (i.e. yield per unit of water used). However, the presently-cultivated rice varieties show yield reductions as well in comparison to a crop grown with standing water. Part of these yield reductions occur because of the increased weed growth which results when standing water is not maintained. Hence, research is being conducted to identify genotypes, from both local and exotic germplasm, which are able to produce higher yields under alternative water management techniques.

AIACC Study on the Coconut and Tea Sectors

Studies were undertaken to assess the impacts of and adaptation to climate change (AIACC) in the coconut and tea sectors in the country with funding received from GEF in 2002 (Ratnasiri, 2006). The project included CO_2 elevation studies on the two crops, analysis of past yield performance to identify their dependence on temperature and rainfall independently and training of a group of scientists from the Coconut research Institute (CRI), Tea Research Institute (TRI) and the Meteorology Department (MD) in conducting crop modeling. The training in crop modeling, which necessitated knowledge of these relationships, was conducted by a scientist from the Indian Agricultural Research Institute, New Delhi. The necessary temperature and rainfall projections were made using software developed by the International Global Change Institute (IGCI) of University of Waikato, New Zealand. The study was able to forecast the tea yield in different elevations under different emission scenarios (Wijeratne et al., 2007). In the coconut sector, the project was able to develop a statistical model to forecast the national coconut production in the short term (Peiris et al. 2008).

Ricardian Analysis of the future Agriculture Production

A study on the economic impact of the climate change on agriculture in Sri Lanka based on a Ricardian model and agro-economic model along with climate change scenarios developed by HadCM and CSIRO models was undertaken (Sao et al., 2005). The net return changes due to different climate change scenarios for major crops in different districts were found to vary between -74% and 121% of 1995 net revenue with the HadCM model, while the CSIRO model gave a variation between -2% and -202%.

Impacts of climate change on water resources and agriculture in Sri Lanka: a review and preliminary vulnerability mapping

Under this study (Eriyagama et al., 2010), the International Water Management Institute (IWMI) has developed a pilot level climate change Vulnerability Index consisting of three sub-indices (Exposure, Sensitivity and Adaptive Capacity), which was subsequently mapped at district level. The maps indicate that typical farming districts such as Nuwara Eliya, Badulla, Moneragala, Ratnapura and Anuradhapura are more sensitive to climate change than the rest of the country due to their heavy reliance on primary agriculture. Coupled with their low infrastructural and socioeconomic assets (or

low adaptive capacity), and high level of exposure to historical hazards, these areas are the most vulnerable to adverse impacts of Climate Change. There is, however, a need for a more detailed assessment of vulnerability of the country's water resources and agriculture to climate change to validate the findings with past experience. This study was funded from the core funds of IWMI during 2009.

Carbon Sequestration Studies on Coconut Plants of Different Varieties and at Different Locations

Under the first phase of the study on carbon sequestration potential of 25 year old Tall x Tall coconut (Cocos nucifera L. variety typica) plantations under S2 and S4 Land Suitability Classes in the wet (WL3), intermediate (IL1a) and dry (DL3) agro-climatic conditions variation in carbon input (plant photosynthesis), carbon output (plant and soil respiration) and the carbon balance of the ecosystem and carbon stock of plantations (plants and soil) were assessed. Coconut plantations were found to be net Carbon sinks and the Carbon sequestration rate under six different growth conditions varied between 0.4 (S4 of DL3) and 1.64 (S2 of WL3) Mg C ha-1 month-1. The Carbon stock of the total ecosystem was highest in WL3 (63 Mg C ha-1) followed by IL1a (54 Mg C ha-1) and lowest in DL3 (37 Mg C ha-1). (Ranasinghe and Thimothias 2010).

5.4.3 Further Research Needs in the Agriculture Sector

Advanced technological approaches are very much necessary to develop more tolerant crop species/varieties and to introduce improved management practices. Crop development, Weather and climate information systems and Resource management innovations are recognized as technological developments in agriculture sector in adaptation to climate change. Research and development efforts should include crops better suited to grow under climate change conditions. Crop varieties that are more resistant to extreme weather events will be needed with climate change. Applied research in the field of impacts and adaptation of agriculture to climate change is needed.

Following is a list of research needs in the agriculture sector.

- Prepare a Best Practice Inventory of available technologies for different agro-ecological regions through re-examining the technologies already developed for biotic and abiotic stresses that are likely to occur under a changing climate, conducting adaptability trials for identifying appropriate practices out of them for different agro-ecological environments of the country.
- Conduct fertilizer and water management research to identify practices that reduce methane and nitrous oxide emission.
- Develop or adapt crop models suitable for Sri Lankan crops and validate them using past performance data to project their yield under future climate conditions, and undertake studies to determine changes in yield under projected climate conditions.
- Identify the existing potential of the agriculture sector to deal with the changes in different climate parameters.
- Identify climate change related pest and disease risks for agriculture including frequency and intensity and propose environmentally and economically viable adaptation strategies
- Identify suitable tree species that suit different environmental conditions that do not cause negative environmental impacts such as excessive water use and biodiversity depletion.
- Identify improved management systems where resources are effectively used with sufficient

sequestering potential for different agro-ecological regions, along with monitoring of measures for current sequestration capacities.

- Research on current land use and land use change that provide new information to enable the production of regular updates on the distribution of land use to parameterize climate and other environmental factors in models, using remote sensing techniques.
- Undertake ground-based measurements to provide information on- site conditions including species composition, soil type, habitat quality, tillage and crop rotation history, wildlife population statistics, and land use classification. Integrating ground-based and remote sensing data collection systems is vital in evaluating land use change.
- Assess the impact of climate change on forestry sector and its potential for carbon sequestration.
- Mapping of vulnerable areas in respect of each of the crops – rice, tea, coconut, rubber and sugar cane, in different AERs.
- Undertake a study to find ways to promote urban forestry to establish vegetation in urban and metropolitan areas.

5.5 Systematic Observations on Climate Change

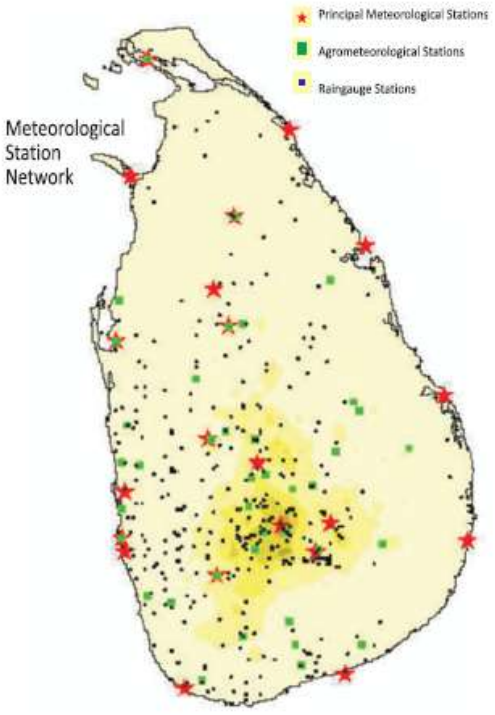
5.5.1 Meteorological Observations

The Department of Meteorology (MD) currently operates 20 meteorological stations in all districts of Sri Lanka (Fig. 5.1). Each station of the department observes meteorological parameters such as temperature, humidity, atmospheric pressure etc. Meteorological measurements of all these parameters are taken eight times per day for three hour period starting from 0000 GMT according to the standards of World Meteorological Organization (WMO). The department has a good spatial distribution of rainfall measurement with about 350 rainfall stations installed throughout the country which comply with the WMO standards. These rainfall stations are maintained by government departments, private organizations and some estates, and 24 hour rainfall data are recorded daily at 0830 h.

In addition to measurement of three-hourly data, continuous measurement of such parameters as rainfall intensity, pressure, relative humidity and temperature are being carried out using self-recording instruments namely, barograph, pluviograph, thermograph and hygrograph at limited number of stations.

The department has digitized daily values of rainfall, maximum and minimum temperature data from 1861 to date. However, the more important three-hourly data still

Fig. 5.1 Meteorological, Agro-meteorological and rainfall network in Sri Lanka



Source: Meteorologicl Department

remain in the form of hardcopies. Three-hourly data hold such an importance because some impacts of climate change cannot be detected using only the daily data and maximum and minimum temperature. For example, some impacts on the agricultural crops and health sector which can occur during the morning or afternoon from high temperatures might not be identifiable using daily data.

Under a Japan International Cooperation Agency (JICA) technical assistance programme, 33 Automatic Weather System (AWS) linked to the central monitoring station via satellite transmission have been installed, to mitigate impacts of natural disasters by having access to real-time data. Systems are yet to be installed only in the North and the East. In addition, a locally developed set of 20 automatic rainfall gauging stations linked to the central monitoring station via a cellular telecommunication network has been in operation in land-slide prone areas.

The department exchanges meteorological data at some stations (three hour basis) with the other countries through GTS (Global Telecommunication System) via New Delhi. These data and data from selected meteorological stations are sent directly to the Global Climate Observing System (GCOS).

5.5.2 Agro-Meteorological Observations

The Agricultural Department maintains an agro-meteorological network since 1976 for agricultural development purposes. The department collects weather data in agro-climatic zones continuously and shares with MD. Success of agriculture is closely linked with climate and suitable varieties for cultivation in different areas are also identified considering the climate of that area. In addition to the meteorological parameters normally measured at meteorological stations, other data such as evaporation, soil temperature data at various depths and solar radiation are taken at the agro-meteorological (Agromet) stations. Agromet data observations are recorded twice a day at 0830h in the morning and 1630h in the evening. The network of meteorological and agro-meteorological stations is depicted in Figure 5.1.

5.5.3 Hydro-Meteorological Network

The Irrigation Department maintains a hydro-meteorological network comprising 69 hydrometric stations in 17 river basins, 16 river gauging stations and 11 evaporation pans. Of these, 16 river gauging stations and 8 rain gauging stations are automated with real time data transmission to a central monitoring station. The system monitors rainfall and river water levels in all major rivers prone to floods. With the information received from gauging stations upstream, the Department issues flood warnings to people living in downstream low-lying areas. Improvements to the present hydro-meteorological equipment and improvements to the data collection and transmission system are being planned. The Department is also in the process of developing a hydro-dynamical model for forecasting floods in the 4 major rivers prone to regular flooding.

5.5.4 Ocean and Off-shore Observations

The parameters in the ocean surface and ocean subsurface are measured by the National Aquatic Resources Research and Development Agency (NARA). NARA has an Ocean Observation Centre (OOC) which operates on 24-hour basis for monitoring ocean conditions around Sri Lanka. The center is dedicated to provide ocean based disaster information and technical assistance to all relevant authorities. The center collaborates with the Ministry of Fisheries and Aquatic

Resources, Ministry of Disaster Management and Human Rights, the Disaster Management Center (DMC), and the MD in respect of ocean based disasters, early warning and mitigation of impacts from ocean based natural disasters. The parameters monitored by NARA are shown in Table 5.1.

In addition to the ocean-based disaster prevention and mitigation activities, the centre gathers and analyses

Table 5.1 Monitoring Status of ECVs in Sri Lanka

Location	Essential Climate Variable	Responsible Monitoring Agency (SL)	Whether monitored?
Atmosphere surface	Air temperature	MD	Yes
	Precipitation	MD	Yes
	Air pressure, Mean sea level pressure	MD	Yes
	Surface radiation budget (Solar radiation)	MD	Yes
	Wind speed and direction	MD	Yes
	Water vapour	MD	Yes
Ocean surface:	Sea surface temperature (SST)	NARA	No
	Sea surface salinity (SSS)	NARA	- . —
	Sea level	NARA	Yes
	Sea state	NARA	Yes
	Sea ice	N.A.	
	Current	NARA	No
	Ocean colour (for biological activity)	NARA	Yes – satellite
	Carbon dioxide partial pressure (pCO_2)	-	No
Ocean subsurface:	Temperature	NARA	Yes
	Salinity	NARA	Yes –monthly
	Current	NARA	No
	Nutrients	NARA	Yes – monthly
	Carbon	NARA	No
	Ocean tracers	NARA	No
	Phytoplankton	NARA	Yes – monthly

MD –Meteorology Department
NARA – National Aquatic Resources Research and Development Agency

oceanographic data within Sri Lanka's maritime boundaries for other research and development applications such as fisheries, safe navigation, climate and environmental studies and coastal development planning.

NARA continuously monitors sea level at three locations in the western, southern and eastern coasts at Colombo, Kirinda and Trincommalee, respectively, as part of the Indian Ocean Sea Level Monitoring Network established after the 2004 Indian Ocean Tsunami. The Colombo station consists of 2 pressure sensors, 1 radar sensor and 2 floating gauges and is assisted by University of Hawaii Sea Level Centre (UHSLC), USA. The Trincomalee and Kirinda Stations are equipped with pressure and radar sensors and are assisted by Federal Maritime and Hydrographic Agency (BSH), Germany. All three stations monitor sea level every minute and transfer data every 15 minutes via satellites to the central monitoring station. The online data is accessible to all interested parties, free of charge.

5.5.5 The Global Climate Observing System

The Global Climate Observing System (GCOS) was established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. It is co-sponsored by the World Meteorological Organization (WMO), Intergovernmental Oceanographic Commission (IOC) of UNESCO, United Nations Environment Programme (UNEP), and International Council for Science (ICS).

GCOS has identified Essential Climate Variables (ECVs) to predict climate change. Long-term data analysis on these variables could be used to understand or discover any climate changes. The said variables are measured at the atmospheric surface, ocean surface and ocean subsurface. The accurate measurement of these variables throughout the world will help assess global climate change accurately and produce more accurate models.

The GCOS provide principles for satellite monitoring. However, Sri Lanka at present does not have its own satellite monitoring operators but use the data from satellites NOAA of USA and GMS of Japan.

5.5.6 Needs in Systematic Observations and Research

It is important to have the meteorological data in the digital form in order to identify trends of extreme cases. Therefore, it is required to convert the data available in hard copies at the MD to digital data. One challenge faced by the MD is extracting the digital data from the data recorded in paper by the self-recording instruments. Technologies for scanning the charts and converting to digital format are needed for the department.

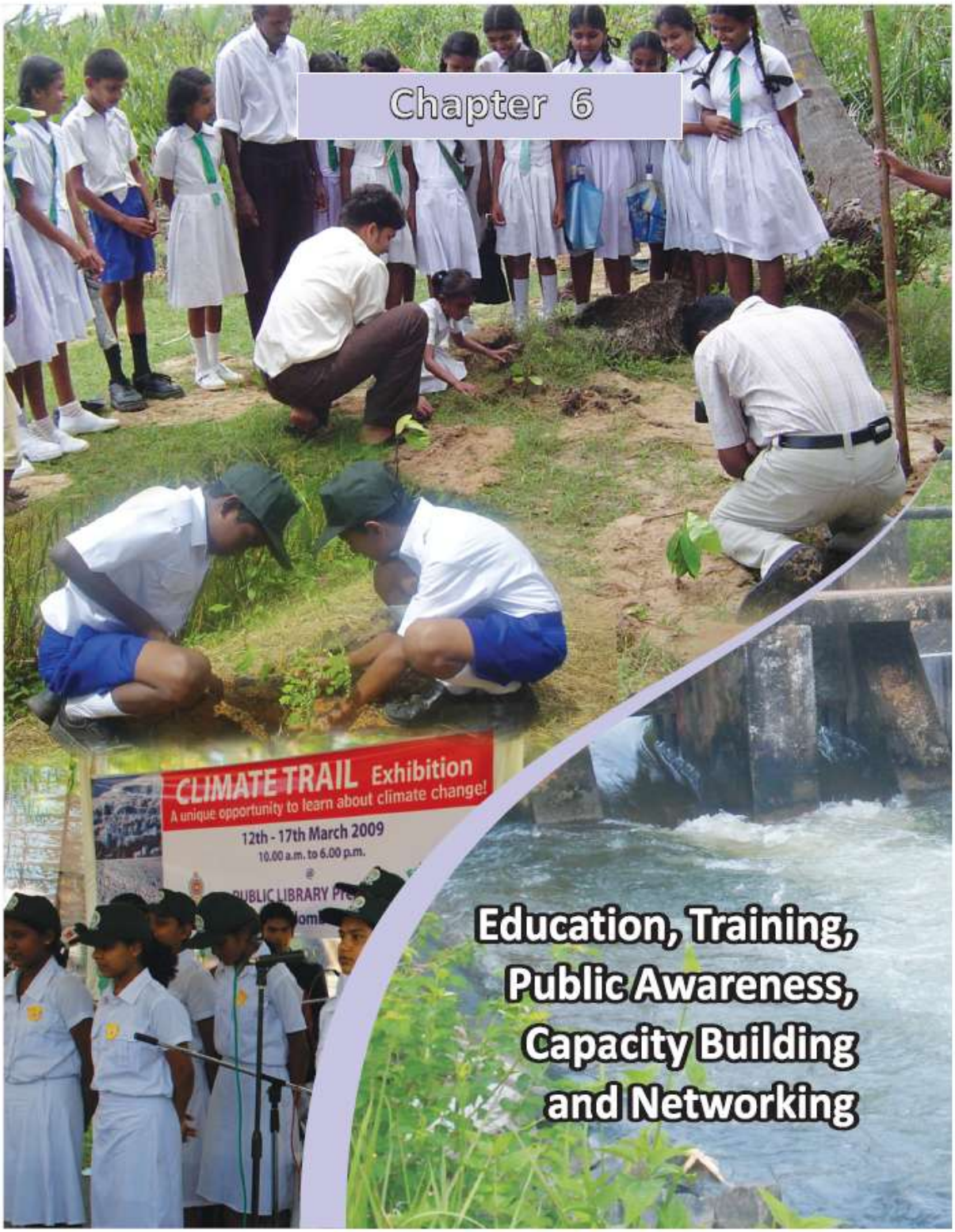
The IPCC Assessment Reports publish periodically anticipated temperature rise and rainfall variations corresponding to different global circulation models and emission scenarios for given time frames on a regional scale. It is necessary to downscale these projections applicable to Sri Lanka taking into consideration the country's orography and wind patterns, for which there is a need to train scientists at the MD to carry out these tasks.

It is essential to identify the sectors and sub-sectors that are most vulnerable to adverse impacts of climate change. Knowledge of the degree of vulnerability in important sectors such as agriculture, forestry, ecosystems and health sector is needed in order to facilitate the policy makers to make decisions regarding the adaptation and mitigation measures at national level in an efficient and effective manner.

It is also important to project future scenarios of climate parameters such as temperature and rainfall on a 10 year basis for next 100 years for different climatic and agro-climatic regions. Projections on crop productivity, ecosystem change, impacts on forestry based on crop models are necessary to respond to the future climate change scenarios.

GIS based zoning maps have to be developed to better communicate and take proactive measures to remedy the impacts. The maps should indicate the impact assessments on each vulnerable sector. Awareness creation among the policy makers/implementers, scientists, and investors about the impacts is also necessary.

A major problem faced by researchers in Sri Lanka is the lack of literature regarding climate change research. It is very necessary to have updated reference material regarding weather, climate, climate change and vulnerability for the different sectors. It is suggested that the CCCS Library be provided with the necessary journals.


Chapter 6
CLIMATE TRAIL Exhibition
A unique opportunity to learn about climate change!
12th - 17th March 2009
10.00 a.m. to 6.00 p.m.
Education, Training,
Public Awareness,
Capacity Building
and Networking

Education, Training, Public Awareness, Capacity Building and Networking

This Chapter describes above activities conducted in Sri Lanka by various organizations during the last decade, as required in Article 6 of UNFCCC. These programmes were carried out with a view to enhance the knowledge of people including school children, undergraduates, government officers and other interested parties, on climate change, its impacts on their lives and what they need to do to adapt to new situations. With a high literacy rate (> 92%) in the country, people generally have some idea of climate change and its possible impacts, mainly because of the wide coverage given to news items on such activities disseminated in international news services as well as in local electronic and print media. The accessibility to international news coverage through satellite transmissions available island-wide at a nominal fee has helped in creating this situation in the country.

6.1 Educational Programmes

The subject of climate has been taught in schools and universities as a part of the curriculum in geography classes for many decades. With the emphasis given to environment and climate change in recent times, Sri Lanka has introduced these topics in the normal education system to enhance this knowledge among students in schools and vocational training institutions, undergraduates in universities and postgraduate students in postgraduate institutions. This is carried out through the existing formal educational system by revision of curricula, and also as non-formal programmes conducted by other organizations in schools.

6.1.1 Formal Environmental Education

The subject of environment has been recently included in the syllabi from the primary level up to secondary levels in schools by the National Institute of Education (NIE). The topics covered up to Grade 10 include basic concepts such as meteorology, climatology, biodiversity, climate and climate change, among others. More detailed topics such as climate, climatology, weather and global warming have been included in the curricula of science and geography subjects taught to students in Grades 10 and above. Field work on environment is encouraged among students, with the assistance from the Central Environmental Authority under its Environment Pioneer Programme.

In the Colleges of Education, which provide training in pedagogy to newly recruited school teachers, topics such as atmospheric sciences, geography and water resources, climate and climatic regions in Sri Lanka, exploration of biodiversity, natural disasters such as floods, landslides, lightning, forest fire, drought etc., climate change, global warming and its impact and vulnerability, adaptation and mitigation have been included in their syllabi. The teachers after completing their training, in turn, are expected to impart this knowledge to students. Curricula information guides for teachers and supplementary reading material related to climate change have been prepared by National Institute of Education (NIE) for the use of education and training purposes.

At the tertiary level, most Sri Lankan universities have included environmental science as a separate discipline, either as a stand-alone department or combined with another discipline. Among these are University of Colombo, University

of Peradeniya, University of Sri Jayewardenepura, University of Moratuwa, University of Kelaniya, University of Sabaragamuwa, Wayamba University, University of Ruhuna, Rajarata University, University of Jaffna and Open University of Sri Lanka.

Subjects such as hydrology, meteorology, climatology, earth resources, atmospheric science, aquatic and soil science, solid waste and hazardous waste management, environmental policies and legislations, forest resource management, water resource management, air and water quality management, wetlands and their resources, and marine and coastal resources management, which are of interest in climate change studies, are among the topics covered.

In recent years, climate change and ozone depletion too have been added to their syllabi. Some universities even offer separate modules on climate change in their environment science courses. At the postgraduate level, environment, oceanography, forestry and climate change have been included as special subjects in Masters degree courses. Several universities also offer post-graduate diploma courses in environmental science, environmental conservation and atmospheric science, incorporating climate and climate change. Climate change related topics have been selected for dissertations for PhD degrees in some universities.

The post-graduate diploma course in environment science offered by the Open University of Sri Lanka, in its climate change module, has included two lessons explaining the IPCC methodology for the calculation of the GHG inventory, enabling anyone following the course to undertake this activity.

6.1.2 Non-formal Education in Environmental Science

A number of government organizations dealing with environment, climate and allied fields have been conducting programmes in schools and universities to educate the students of the latest situation with regard to climate change and its impacts on the people and the country in general. Among the more significant of these are the following.

Central Environmental Authority (CEA) conducts environmental educational programs for school children from Grade 1 to Grade 13 for which badge awarding programs have been introduced from 1980s. The highest level badge is awarded by H.E. the President of Sri Lanka for environmental pioneers. A pre-school program called Eco-Clubs is also organized by CEA. This program begins from Grade 1 to Grade 5 and a series of activities have been introduced for awarding medals to the members of Eco-Clubs which have been formed at school level.

The National Aquatic Resources Research and Development Agency (NARA) continues to conduct regular education programs since 2004 for educating coastal communities, officials of the Coast Conservation Department, and students in higher education institutes on sea level rise and related coastal hazards. Curricula have also been developed for training requirements of University students on sea level science, modeling of coastal inundation and GIS mapping. Since 2004 University students are attached annually to NARA to follow courses as a part of their B.Sc. degree programs and M.Sc. postgraduate degree programs.

The Epidemiology Unit of the Ministry of Health conducts education programs on health consequences to educate Medical Officers of Health (MOH), field Epidemiologists, Undergraduates of the Faculty of Medicine and Postgraduate students at the Postgraduate Institute of Health. In support of these programs curricula have been developed incorporating climate change and health for M.Sc. (Community Medicine) students. A folder for climate change related health consequences has also been prepared by the Directorate of Environment and Occupational Health.

Sri Lanka Sustainable Energy Authority (SLSEA) has facilitated the inclusion of theoretical aspects of energy conservation in the national curricula of Grade 7-9 Science subjects, in order to motivate children to save energy from their childhood.

The Waste Management Authority of Western Province (WMAWP) has prepared curricula to increase awareness of children at nursery level on waste management under a program called "*Pivithuru Kekulo*" (Clean Children). Concepts on the necessity for proper waste management have been introduced to the pre-school, primary and secondary levels of education in the Western Province.

6.2 Training Programmes

6.2.1 Programmes of the Ministry of Environment

Air Resource Management Centre (Air Mac) Division has conducted several training programs for government officers, technical officers of technical colleges and automobile training institutes and technicians of garages on reduction of vehicular emissions leading to control of GHGs.

The National Ozone Unit of the Ministry, under the technical training program for good practices in refrigeration, has trained a total of 3008 participants during 2004 - 2008, to ensure minimizing of CFC emission into atmosphere. Also, during the same period 966 participants in the Custom Department have been trained on the prevention of illegal trade of ozone depletion substances (ODSs).

6.2.2 Programmes of Government Departments

The Meteorology Department conducts regular in-service training programs for officers and meteorological observers on observing meteorological parameters which are required to predict climate and climate change. Further, the Department conducts short term training courses for University students for upgrading their knowledge on weather, climate, climate change and its impacts. In addition to the above activities, the Department also organizes short term training courses on weather, climate and climate change and aviation meteorology for the Navy, Army and Air Force personnel when requested. For these training purposes specific curricula have been prepared.

The Agriculture Department trains farmer communities on adopting strategies to mitigate negative impacts of climate change on crop production. The Department has the expertise to train in-service officers on climate change and its impacts related to agriculture and water resources. These programs are conducted at schools of agriculture and in-service training institutions of the Department.

The Irrigation Department conducts regular training programs for in-service officers who are involved in irrigation, water and flood management. These include Diploma in Irrigation Engineering, Farmer awareness training programs, and training on water management.

The Coast Conservation Department conducts training programs for in-service officers to raise their knowledge on the importance of the protection of coast in view of possible sea level rise. It also trains coastal communities on the protection of coast through planting mangroves forest along the coast, protecting coastal coral reef and preventing unnecessary constructions along the coast.

6.2.3 Programmes of other government Institutions

Central Environmental Authority (CEA), under its Environmental "Pioneer" Programme, has been training school children to provide leadership to the community on environmental matters. Selected school teachers have been appointed at district and zonal level as pioneer commissioners. The program is expected to build environmental consciousness of citizens and is being implemented in more than 6,000 schools throughout the country. Training for the teachers and student leaders is being conducted at district and divisional levels. Training has been given annually for directors of education down to the environmental pioneers on sustainable environment protection. In addition school leavers, housewives, Industrialists etc. are also trained regularly on environmental friendly activities.

The Urban Development Authority (UDA) conducts training programs for in-service officers in preparation of urban development plans in the context of climate change. In year 2003, a training program for UDA planners was held on preparation of hazard maps at local authority level and natural disaster mitigation in connection with environment and climate change. Technical officers working in Tsunami affected local areas in Northeast were trained on UDA regulations and formulation of development plans with special reference to environmental planning in year 2006.

The National Aquatic Resources Research and Development Agency (NARA) provides training for university undergraduates and local and foreign postgraduates students, who are following short term training programs and the coastal managers are given a thorough training on long term sea level trends and modeling since 2004.

National Engineering and Research Development (NERD) Centre has developed many devices for extracting energy from biomass both at domestic and industrial level. These include efficient and clean wood stoves for domestic cooking, gasifiers for bakeries and crematoria and commercial scale bio-gas generators. NERD Centre conducts training programs to persons willing to produce these energy efficient equipment on a commercial scale.

Industrial Technical Institute (ITI) under a three year project "Enhancing Environmental Performance in Key Sri Lankan Export Sector (EEPEx)" which commenced in 2009, has trainedthe staff of five export sector industries namely Clay (ceramics, tile, porcelain), Rubber & plastic, Leather & footwear, Coconut (charcoal, desiccated coconut, coir), Tourism (hotels & tour operators) has been trained on environmentally friendly products. Eco-friendly plant designs, waste water disposal, solid waste disposal, reject products recycling/disposal, dust emission control, air pollution control, odour control, noise and vibration abatement, energy efficiency and water conservations are the main themes of their training. ITI also conducts regular training programs for skills development of operators and supervisors of waste water treatment plants too.

6.3 Public Awareness Programmes

Several stake-holder organizations have been involved in conducting public awareness programmes on climate change during the past few years. The more significant programmes are described below.

6.3.1 Programmes of Ministry of Environment

The Ministry of Environment under a technical assistance project supported by the Asian Development Bank, facilitated by TVE Asia Pacific (Survey Research Lanka, 2010), conducted a sample survey in mid 2010, covering 1,000 men and women aged above 18 years, in urban and rural areas across all 25 districts of Sri Lanka, to determine the public perceptions on climate change in Sri Lanka. The survey found that most Sri Lankans – nearly 9 out of 10 across the country - have heard of climate change and/or global warming. Among those who have heard of climate change, 36 per cent are 'strongly concerned', while another 57 per cent are 'somewhat concerned' about how climate change can personally affect themselves and their families. The impacts they most fear are water and food shortages, and the spread of diseases due to weather anomalies.

The Ministry of Environment (MoE) has taken the initiative to conduct climate change related awareness programs through its several divisions - Climate Change Division (CCD), Air Resource Management Centre (AirMAC), National Ozone Unit (NOU) and Promotion and Environmental Education Division (PEED). Climate Change Division (CCD) organizes awareness programs mainly for officers both in the state and private sectors as well as NGOs on climate change issues and CDM processes.

Air Resource Management Centre (AirMac) conducts activities related to air pollution caused by vehicles. Air Mac, has been taking measures to create awareness among students, teachers, drivers, general public and key institutions directly involve in implementing of the Vehicle Emission Testing (VET) standards gazetted in June 2003 under Environmental Act No. 47 of 1980. It is expected that with the reduction of the precursors CO, NOx and NMVOC levels, CO_2 level too could get reduced. It has conducted 14 workshops during 2004 and 2009 for the benefit of government parties responsible for implementing the vehicle emission testing programme.

National Ozone Unit (NOU) in the Ministry has been conducting many awareness programmes to school children, refrigeration technicians and members of the public annually on the potential harm of the refrigerant CFCs as a greenhouse gas having a Global Warming Potential (GWP) of 8,100 and the advantage of substituting it with HFCs having a much lower GWP of 1,300, while at the same time having zero ozone depleting potential.

Promotion and Environmental Education Division (PEED) conducts public awareness programs to celebrate environmentally significant days such as World Environment day, World Water day, World Wetland day etc. Every year, 5-6 awareness programs are being conducted for the benefit of Media Personnel on environmental issues of national and regional importance. Each year about 10 awareness programs are being conducted in schools targeting a wider group of school children, general public, Non Governmental Organizations (NGOs) and Community Based Organizations (CBOs) on such topics as global warming and climate change, its vulnerability and adaptation, emphasizing autonomous and planned adaptation to climate change impacts. Further, the environmental journal "Soba" is provided to school libraries free of charge. For raising awareness among users, the Ministerial website (www.environmentmin.gov.lk) includes environment related information, policies, divisional programmes and projects implemented in Sri Lanka. Exhibitions, awareness campaigns and demonstrations are the most common tools used to create public awareness. Street dramas, poster competitions, art exhibitions, photo exhibitions and drama competitions are also conducted based on the requirement to improve the effectiveness of awareness creation. Handouts, leaflets and in some occasions booklets are also distributed. In addition, in some years, teacher awareness programmes are also conducted by this division.

6.3.2 Programmes of Government Departments

The Central Environmental Authority (CEA) conducts many awareness programs annually to commemorate International days related to environment such as World Water Day, World Tree Plantation Day, World Environmental Day, World Earth Day and Wetland Day educating the general public on various environmental related issues too. Through the regular programs of the CEA, awareness is created amongst school children, industrialists, non-governmental organizations, house wives, teachers, and the business community etc. on the impact of climate change on the environment, human health, biodiversity and wetlands.

The Meteorology Department is a popular stop for school children making educational tours to the city, with about 30,000 students visiting the Department annually. They are given talks on the basic concepts of weather and climate including climate change. Further the Department conducts regular media awareness programs/ media conferences on weather hazards, cyclones, lightning, climate change issues and monsoons etc. Awareness materials such as leaflets, brochures, posters etc. related to weather, climate and climate change are prepared for distribution by the Department. Brochures are also prepared by the Department on the science of climate change, climate change and extreme weather, climate change and agriculture and CDM. The documentary film "*Kalaguna Aguna*" (Bad Weather) prepared by CCCS on climate change is an additional tool used to increase awareness among the general public. The quarterly Newsletter on current issues of climate change has been regularly issued for the use of the general public.

The Centre for Climate Change Studies (CCCS) of MD has been mandated to carry out awareness programs by a Cabinet decision taken in 1999 Accordingly, the CCCS has engaged in raising public awareness on various issues of climate change together with the Ministry of Environment, Department of Agriculture, Ministry of Health, Central Environment Authority, National Building Research Organization etc. These programs are being conducted island wide, for policy makers, government officers, district level administrators, school children, master teachers, university students, planters, private sector and NGOs utilizing the resource personnel of the above stakeholder institutions. CCCS has conducted 54 such awareness programs during 2002-2008. The financial assistance for conducting these programmes were received from the Government of Netherlands through the Working Group III of the Intergovernmental Panel on Climate Change (IPCC) in 2002, Climate Change Enabling Activity Phase II project launched by the MENR with the financial assistance of GEF/UNDP in 2003/2004, Asia Pacific Network (APN) funded Capacity Building and Environment (CAPaBLE) program in 2005, United Nations Children Funds (UNICEF) in 2006 and UNDP funds in 2008.

The Department of Agriculture provides expertise through well trained resource personnel to work with MD to conduct public awareness programs. The awareness creation among the public in the agricultural sector and water resource management is conducted by the resource personnel of AD. These programs are conducted at schools of agriculture and in-service training institutions of the Department. For increasing awareness among farmer communities and the general public, various kinds of leaflets, brochures and posters on impact of climate change as well as possible adaptation and mitigation strategies have been prepared and distributed by the Department.

The Department of Irrigation conducts a number of programs annually for raising awareness among various groups of people on Irrigation related issues. The existing programs have addressed the influence of climate change in the irrigation sector. Steps have also been taken to make irrigation related awareness among farmers, school children and

youth living under major and minor irrigation schemes managed by the Department of Irrigation particularly on adaptation measures needed to conserve water during drought the periods.

6.3.3 Programmes of Government Institutions

The Marine Environment Protection Authority (MEPA) conducts awareness programs related to ocean pollution and its related issues such as sea level rise. Awareness among school children, potential pollutants, teachers, government officers and NGO's on ocean pollution issues is created through programs organized by MEPA throughout the year. MEPA has conducted many awareness programs during the recent past for school children in southwestern coastal districts from Hambantota to Puttalam. Additionally, insights into the influence of global warming on ocean issues such as rising sea levels, coastal inundation, coral bleaching etc. are being shared through marine pollution protection programs conducted by MEPA.

Tea Research Institute (TRI), Rubber Research Institute (RRI) and Coconut Research Institute (CRI) are involved in creating awareness among school children, government officers and personnel in the plantation sector on the impact of climate change and adaptation strategies in respective sectors. This information is distributed among interested people in the plantation sector in the form of leaflets, brochures and posters. All three institutes have also carried out several awareness programs annually for plantation executives, smallholders and inspectors on the impacts of climate change in the relevant industry, instructing them on how to mitigate the adverse impacts.

The National Aquatic Resources Research and Development Agency (NARA) has taken various steps to make the general public including youth aware of consequences of rise of sea level and bleaching of coastal coral reefs through printed and electronic media. Public awareness programs have been organized to create awareness among coastal communities on various ocean related issues. Leaflets, brochures and posters prepared by NARA on sea level rise and its related issues and video programmes on ocean observation are made use for education and training and creation of awareness among the general public. IOC and UNESCO reports on sea level rise, coastal inundation and its impacts due to climate change are also available for the knowledge enhancement of users.

The Epidemiology Unit and the Environmental and Occupational Health Unit of the Ministry of Health are involved in creating awareness among people on health consequences which arise due to climate change. These programs are conducted mostly at village level through public health officers. Further, the Unit carries out awareness programs on control of Diarrhea, Dengue and other mosquito borne diseases with the changing communicable disease scenario with climate change. The Ministry of Health Services has been developing posters, brochures, leaflets, Weekly Epidemiology Reports (WER Sri Lanka) and booklets on emerging and re-emerging health consequences related to climate change for distribution amongst the general public.

The Sri Lanka Tourism Promotion Bureau (SLTPB) and Earth-Lung Initiative have introduced a theme "A land like no other" in 2008 in order to create awareness on issues of climate change among public. Earth-Lung Initiative also intended to document climate change related best practices and sustainable models implemented in commercial entities with a view to create examples for others to follow. All identified best practices and cleaner production methods are in the process of being documented for distribution to the public via mass media. After the three year program it is hoped to organize school level travel clubs through which school children will be educated on responsible tourism, conservation and protecting the environment.

The Sri Lanka Sustainable Energy Authority (SLSEA) is engaged in educating students, teachers, government officers, private sector and general public on energy conservation through awareness programs, through which attempts are being made to mitigate the emission of GHG into the atmosphere. In 2008 alone, SLSEA has conducted 37 such programmes both in the public and private sector institutions.

The Waste Management Authority of Western Province (WMAWP) has taken steps to educate people in the Western Province on managing waste for a clean environment through various programs such as *"Pivituru Pasala" (for schools), "Pivituru Kakulo" (for pre-schools), "Pivituru Ayatana" (for institutions), "Pivituru Suwapaya" (for health clinics) and "Parisara Mithuro" (for communities)*. Additionally, a program called *"Pivituru Purawara"* (for cities) has been launched with the intention of introducing municipal solid waste management rules formulated in 2008 to the public at the level of local authorities.

The Universities of Moratuwa, Sri Jayawardhanapura, Kelaniya and **Sabaragamuwa** etc. are regularly involved in creating awareness on climate change among University students and the general public in various ways. The Department of Forestry and Environmental Science of the **University of Sri Jayawardhanapura (UOSJ)** has held "International Forestry and Environment Symposium" annually since 2005 to stage a forum for researches, professionals, policy makers and industry to network and share their research findings and experience. Also the Department conducts awareness creation programs on environmental issues among the general public too. The Sabaragamuwa University of Sri Lanka also conducts similar national symposiums on "Natural Resource Management" annually for various categories of people.

The Provincial Environmental Authority (PEA) of the North Western Province (NWP) being an independent body, carries out all environmental related activities within the province similar to the programs carried out by CEA in the rest of the country. It conducts awareness programs to various groups of the society, including political authorities, police officers, government officials, school children, teachers, public sector and the general public on conservation and the sustainable use of environment. Workshops, seminars, environment related competitions, street drams, display of placards and banners are some of activities carried out by PEA of NWP in the province to make people aware on environmental issues. The PEA also celebrates environmentally important international days such as World Environmental day, World Water day and World Wet day.

6.3.4 Non-Government Organizations and the Private Sector

The Sri Lanka Association for the Advancement of Science (SLAAS) through its Environmental Committee and the Committee for the Popularization of Science conducts awareness programs on environmental protection and consequences of climate change annually targeting various levels of people, including school children in higher grades, teachers, university students, health workers and the general public. SLAAS also conducts through its Media Resources Committee, regular awareness programmes including those on climate and climate change for the benefit of science journalists representing almost all print and electronic media institution. The SLAAS also celebrates environmentally significant International days such as World Environmental Day, World Ozone day through seminars, workshops, quiz programs and poster competitions etc. Several competitions on themes related to environment are also conducted for school children annually.

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The Federation of Chamber of Commerce and Industry of Sri Lanka (FCCISL)/ Small and Medium Entrepreneurs Development (SMED) have been involved in creating awareness among industrialists and the public on the importance of reducing GHG emissions and energy saving in Sri Lanka. The energy and environment division of FCCISL/SMED has conducted 30 such programs in 2009 on environmental awareness and identifying and implementing model industries which are environmentally friendly and economically viable. These models are focused on climate change and adaptation strategies in respective sectors such as Desiccated Coconut Industry, Vehicle Service Stations, Rice Mills, Lime Factory/ Mills and Seed Farms.

The National Cleaner Production Centre (NCPC) established under UNIDO to promote the concept of cleaner production in Sri Lanka also conducts awareness programs for various groups of people on the importance of cleaner production and energy efficiency in reducing GHG emission in respective sectors. They also conduct programs to increase climate awareness of officers of Municipal Councils, Urban Councils and Divisional Councils (*Pradeshiya Sabhas*) on cleaner production and energy efficiency. The programmes that have been carried out during 2003-08 period included 17 in schools, 4 in universities, 7 in Chambers of Commerce, 24 in the corporate sector, 11 in local government institutions and 37 in various industries. Further the centre has prepared a significant amount of educational material in all three languages on energy efficiency for the use of the public. The NCPC is linked with international organization such as United Nations Industrial Development Organization (UNIDO), United Nations Environmental Program (UNEP), Division of Technology, Industry & Environment (DTIE), Centre for Environment & Industrial Health (CEIH) and National Productivity Council (NPC) India directly in developing education materials on energy efficiency and climate change. In support of conducting climate change related programs in Sri Lanka, the National Productivity Council of India has been providing resource personnel and educational materials (Leaflets, brochures, Posters etc) for a significant period of time.

The Private Sector too has been contributing its share in conducting environment awareness programmes including those on climate change, for their employees as well as for the general public including students who visit their factories. Among these programmes are the following.

A major garment manufacturing company, has launched a programme to increase the awareness of their work force on promotion of carbon trading, Clean Development Mechanism (CDM), Green work environments, Green jobs, Black to brown to green technologies, ISO 14001 & LEED certifications in order to get their support on environmental preservation & pollution control. Also school children and interested parties, visiting their factories have been educated on measures of environment protections that have been taken in their Garment industry. To raise the awareness among the work force and the general public, a magazine "VIYAMAN" has been published quarterly on climate change, environment protection and pollution control etc.

Another leading construction company in Sri Lanka applies environment friendly methodologies during constructions in compliance to ISO 14001. The company is mainly concerned with the awareness of the in-service work force on the protection of environment. Therefore regular training/ awareness programs are conducted on energy saving, water conservation and treatments, environmental pollution control and involvement in corporate social responsibility (CSR) programs as measures to be taken for environment conservation.

A leading telecom company, subsequent to a massive awareness campaign amongst its own staff, has now converted their entire business operation into a paperless office saving millions of trees as a direct result of this shift.

Non Government Organizations (NGOs) such as Sarvodaya, Energy Forum (EF), Practical Action (PA) etc. have carried out programmes on impact, vulnerability and adaptation and mitigation of climate change for the creation of awareness at grass roots community. Sarvodaya's mainly concern has been on the protection of environment while the Energy Forum focuses on mitigation strategies related to the reduction of GHG emission in sectors of energy and waste. The community at village level in Hambatota and Kalmunei has been educated by Energy Forum to produce compost out of domestic waste and to generate renewable energy (village hydro, bio gas, solar energy, dendro power) from local resources. These measures are considered as mitigation options in reducing the emission of GHG in to the atmosphere.

Green Movement of Sri Lanka

This organization is also extensively involved in creation of awareness among general public on climate change and its consequences through awareness materials, seminars, workshops, round table discussion and organizing poster campaigns, film shows and dramas in addressing climate change and its issues among public and policy makers.

6.4 Capacity Building

Several initiatives have been taken by various organizations to their build capacity to undertake measures that would enable them to comply with the provisions of the climate change convention. Some of these are described here.

6.4.1 GEF Enabling Activity (Phase II) Project

The US $ 118,000 GEF grant received in 2001 enabled Sri Lanka to undertake a series of climate change related studies which would help in building the capacity of young researchers to undertake climate change studies. The programme had two research components, a senior scientist component and a junior scientist component. The junior scientist was expected to work under the guidance of a senior scientist. Under this project, capacity of 38 junior scientists and 20 senior scientists were developed to undertake climate change related studies. In addition, the project under capacity building component, conducted several training programmes for the junior scientists to build their capacity to undertake climate change related studies, and also for the senior scientists to disseminate their research findings to others (MENR, 2004b).

6.4.2 Second National Communication Project

During 2008-2010, Sri Lanka received a sum of US$ 420,000 from GEF for enabling activities for the preparation of Second National Communication (SNC) to the UNFCCC. GEF also provided US$ 200,000 to Sri Lanka during 2004 – 2005 for a project on National Capacity Self Assessment for Global Environmental Management too. Under this project capacity assessment and action plan for developing capacity for compliance with global conventions on biodiversity, climate change and land degradation was carried out.

6.4.3 Assessment of Impacts of and Adaptation to Climate Change Project

Under the project on Assessment of Impacts of and Adaptation to Climate Change (AIACC) in the Coconut and Tea sectors, Sri Lankan scientists were trained in developing crop models on coconut and tea which were used in estimating the yields of the crop under varying conditions of temperature and rainfall as projected corresponding to different

emission scenarios, GCM models and time slices (Ratnasiri, 2006). A team of Sri Lankan scientists received this training at the Indian Agricultural Research Institute at New Delhi. The software necessary for the development of future climate scenarios in the country based on IPCC Third Assessment Report projections was supplied by the International Global Change Institute of the University of Waikato in New Zealand who visited Sri Lanka twice to train the scientists in its use.

6.4.4 Crop Modeling Studies on Coconut

As a follow up to the AIACC Project, a scientist from the Coconut Research Institute followed a post-doctoral programme at University of Wageningen, The Netherlands in 2007-2008 to build her capacity to undertake crop modeling studies on Coconut, particularly with respect to temperature changes and training in the use of modern automated greenhouses for data collection on crop growth. Following this study, CRI is in the process of developing a climate-driven process-based model to predict coconut yield. Collection of critical information necessary for model development and to develop sub models explaining processes related to yield of coconut is in progress.

6.4.5 Centre for Climate Change Studies

The Centre for Climate Change Studies (CCCS) was established in 2000 within the MD to build capacity of local scientists to promote studies and undertake research on climate change. The Centre conducted programs on climate change from 2000 to 2009 to the general public, government officers, the private sector and the education sector with practical knowledge of responding to climate threats. The Centre has been carrying out a large number of awareness programmes for the benefit of school children, members of the public and public servants from all parts of the country.

6.4.6 Climate Change Secretariat

The government in 2008 established the Climate Change Secretariat (CCS) with the objective of strengthening the institutional capacity to undertake tasks that would help in complying with the Climate Change Convention. These tasks included preparation of the greenhouse gas inventory, assessing needs for technology transfer and identifying measures for mitigating emissions and options for adaptation to climate change. Some of these activities were carried out under the Enabling Activity Project described in Section 6.4.1. The Secretariat is severely understaffed to carry out its normal functions mandated to it.

6.4.7 Skill Needs Development

There is an urgent need to acquire capability to undertake crop modeling exercises with respect to perennial crops such as tea and coconut which operate in a more transparent and user-friendly manner, and also to undertake socio-economic modeling. Information on crop models developed by various parties need to be made available freely, or at least at an affordable price, enabling interested scientists in developing countries to acquire them. There are several crop models for annual crops and hydrology models already available and our scientists need to be trained in their use. Perhaps, this skill could be acquired and kept in a central place such as the CCCS which could maintain a stock of models enabling scientists in other organizations to use them whenever necessary. The Centre also could serve as a depositary for data such as island-wide soil properties, solar radiation levels, and climate data necessary for running these models. An important strategy would be to develop the skills within the country necessary to develop software programming

necessary to build simulation models. It would be then be possible to manage the model running by the local institutions and be self-reliant.

6.5 Information Networking

Networking of climate change related information in Sri Lanka is at a very nascent stage and even the existing limited networks are not utilized properly for the exchange of climate change related information. It is also observed that Sri Lanka does not have a specific policy for climate change related data management, sharing, access to information and networking. The Lanka Government Network (LGN) managed by the Information Communication and Technology Agency (ICTA) is the only extensive network available to provide information on government services to the general public. However, LGN contains very limited amounts of information on the climate of Sri Lanka. Individual institutions that maintain climate change related data, information and networks; share and access this information informally as there is no policy on information and data exchange. However, information on climate change issues included in all websites in Sri Lanka is accessible through the internet and websites. Some of the organizations who collect climate related data release their data only on a payment.

6.5.1 The National Meteorological Centre (NMC)

The Department of Meteorology, through its NMC has been linked to the network of Global Telecommunication System (GTS) via internet for global distribution and receiving of meteorological and climatic data/ information. This network operates round the clock. NMC disseminates synoptic meteorological data three hourly through this network to GTS Hubs in New Delhi for global distribution. Further, the network of 33 Automatic Weather Stations (AWS) installed in Sri Lanka has been linked to the NMC through satellite communication. Additionally, the network of 20 automatic rain gauges installed in disaster prone areas has been connected to NMC through a cellular communication network for automatic transfer of data at regular intervals.

6.5.2 Network on Sea Level Monitoring

The **National Aquatic Resources Research and Development Agency (NARA)** maintains three tide gauge stations at Colombo (West Coast), Trincomalee (East Coast) and at Kirinda (Southern Coast). These are connected to international networks GLOSS, IOTWS and UHLC through Global Telecommunication System (GTS) and the internet. Transmission of sea level data at these gauging stations to global sea level monitoring centers is done automatically through these networks as scheduled.

6.5.3 Other Public Sector Information Networks

The Central Environment Authority (CEA), the Council for Agricultural Research Policy (CARP) and the National Science Foundation (NSF) function as focal points for information exchange and networking in their respective fields. **ENVINET** (environmental network) and **AGRINET** (agricultural network) are the networks operated by CEA and CARP respectively for environmental and agricultural purposes. The National Science Library and the Resource Centre of NSF has been functioning as the focal point for a network **SLSTINET** (Sri Lanka Science & Technology Information Network) with membership of over 100 libraries connected through this service. Further, the NSF is a partner of a network called **LEARN** (Lanka Educational and Research Network) developed for education and research purposes and operated from

USA. These networks can also be utilized for the sharing of climate change related information.

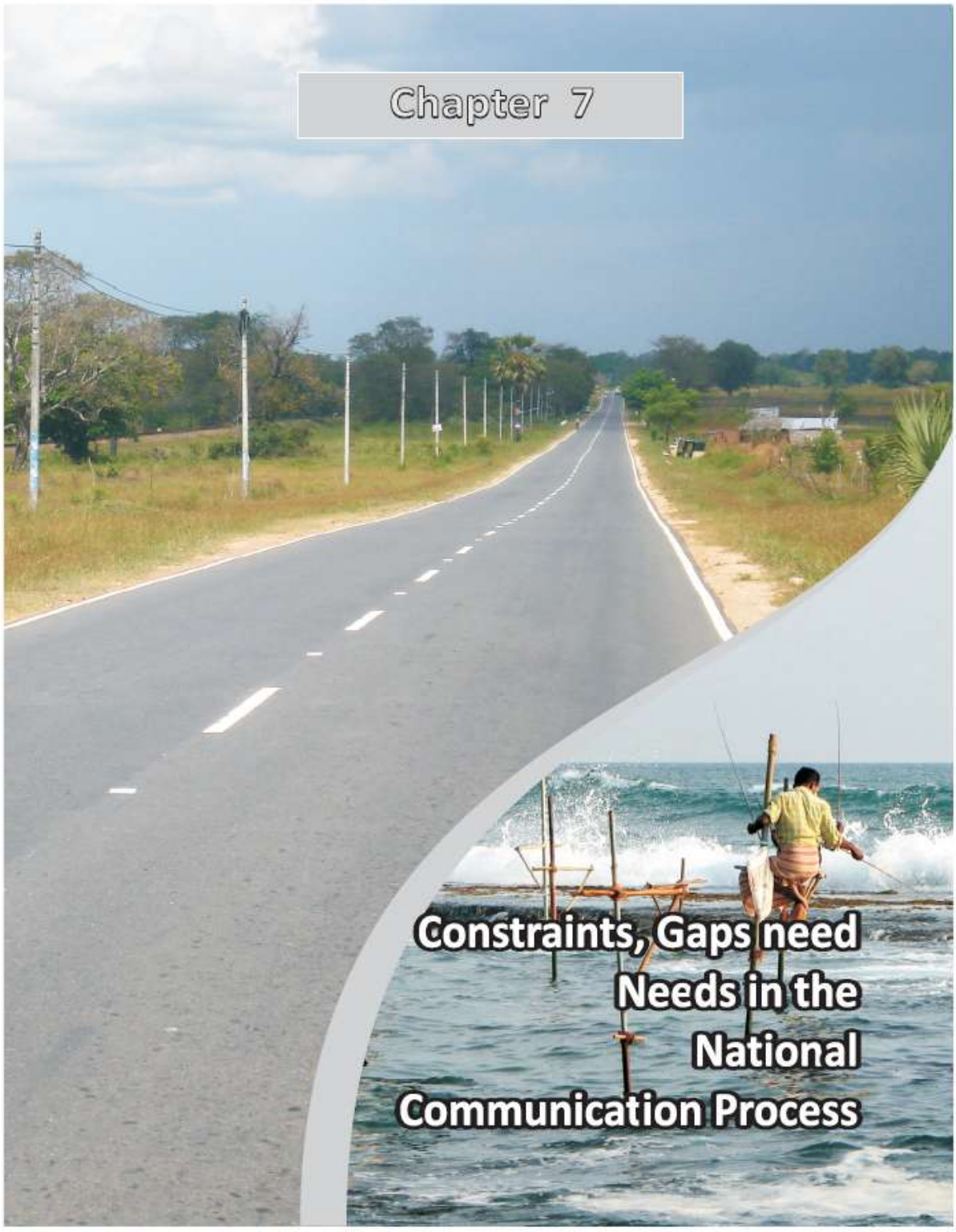
6.5.4 Non-Government Organization Networks

In the Civil Sector, **Practical Action** maintains a climate change specific database and website that allows all civil organization access to information related to climate issues as well as allows registered civil groups to update the web site with information that is gathered from their work in the field. This database can in the future be an information distribution point for all Civil Sector Organization (CSO) data related to climate control.

6.5.5 Access to and use of information technologies

At present climate change information is widely shared and used regionally and internationally through electronic networks. With the expansion of high speed internet facilities in Sri Lanka many institutions in the government and private sectors as well as NGOs are able to utilize the facility in an extensive manner. Starting from dialup internet connections, Sri Lankan users are capable of using high speed Broadband and Wireless Internet (Wireless Broadband) facilities. Users are in a position to use appropriate network topologies, advanced system security, operating systems, software and high capacity databases for their networks.

The Lanka Government Network (LGN) managed by the Information Communication and Technology Agency (ICTA) is an extensive network available to provide information of government services to the general public. LGN has a very sophisticated high speed network with a comparatively large database linking many Ministries, Government Departments, Divisional Secretariats and Provincial Councils. However, LGN contains very limited amounts of information on the climate of Sri Lanka and have access to users within the LGN network. Others may also be able to access information by dialing 1919 through the help desk established at the offices of the LGN. These institutions provide data to users on request in the form of hard copy or digital format.



Chapter 7

Constraints, Gaps need Needs in the National Communication Process

Constraints, Gaps and Needs in the National Communication Process

7.1 Constraints

7.1.1 GHG Inventory Preparation

The preparation of the GHG inventory needs a large number of activity data from a wide range of sectors, coming under the purview of many ministries and government organizations. Sri Lanka has a separate organization responsible for collecting socio-economic data and publishing them, and that is the Census and Statistics Department. Data on agricultural activities including extents and production of crops, livestock population and other socio-economy sectors were sourced from the department's Statistical Abstracts published annually. However, desegregated data in many areas need to be sourced from elsewhere. Also, the classifications and outputs given may not meet the requirements for inventory preparation.

In the energy sector, the calculation of the inventory using Tier I method does not pose any problem. All that is required are the gross amount and the type of fuel consumed in each sector, from which the emissions of each GHG could be calculated using a single emission factor covering the entire sector. However, if Tier II were to be used, that would pose a problem. For example, in the Transport sub-sector, which is the highest emitter of GHG, not only the data on different types of vehicles in use in a given year needs to be known, but also fuel consumed by each of the type of vehicle need to be known. Such information can only be estimated based on statistical modeling whose accuracy is not known. This applies mostly for the estimation of non-CO_2 emissions which depend on the end-user combustion process.
The emission of CH_4 from agricultural activities such as rice cultivation and ruminant animal rearing require desegregated data which are lacking. The district-wise extents of rice sown and harvested each season are published annually, even giving the break down for irrigated and rain-fed extents. However, the calculation of CH_4 using IPCC methodology requires desegregation into fully flooded extents, intermittent flooded extents and flood- and drought-prone extents, and this information is not available. Hence, CH_4 emission from rice cultivation is carried out based only on rough estimations and the results have a wide uncertainty.

The enteric fermentation in ruminant animals is another significant source of CH_4 emissions. The calculations are totally dependent on IPCC default emission factors which may deviate from the real situation widely. The cattle population is owned mostly by small farmers who may not practice modern diary management systems. The type of feed given to these animals and the general management conditions could vary widely from those practiced elsewhere, and there is a need to determine experimentally emission factors even for a small sample of the local cattle population to validate the data adapted from IPCC.

Country specific data are also required in the Land Use Change and Forestry sector, both for extents of land converted from one type to another, and emission factors, particularly for non-CO_2 gases. Hitherto, a large fraction of the land and the coastal region were not accessible to government officials for the purpose of collecting data. With the situation of

the North and the East coming to normalcy, it is expected that better information retrieval could be undertaken in the future.

7.2 Gaps

7.2.1 Vulnerability Assessment

The UNFCCC Guidelines require Non-Annex I Parties to provide information on vulnerable areas that are most critical. Strictly, the assessment of vulnerability requires first to determine the impacts that climate change causes on the relevant area and next the determination of adaptive capacity of that area. The degree of vulnerability would then be the degree of impacts less the degree of adaptation capacity. The total vulnerability could be determined by applying the degree of vulnerability to the total area concerned, from which it would be possible to rank the vulnerability of different sectors and determine the most critical vulnerable sector.

Even though the term "vulnerability" is used frequently in this report, there has been no quantitative estimation of the degree of vulnerability to decide on the sectors most critically vulnerable to climate change. The field data available at the time of writing the report were not adequate to make a meaningful estimation of the degree of vulnerability quantitatively in different sectors. Hence, no effort was made to identify vulnerable areas that are most critical.

Decision 17 of COP8 specifies that Non-Annex I Parties are encouraged to provide information on their vulnerability to the impacts of and their adaptation to, climate change in key vulnerable areas. Information should include key findings, and direct and indirect effects arising from climate change, allowing for an integrated analysis of the country's vulnerability to climate change. Temperature rise is directly related to the increase of greenhouse gases. However, the reason for changes in rainfall pattern could also be due to a change of general circulations and walker circulation responsible for el.nino phenomenon. Therefore, in order to identify actual reasons, it is important to study the global circulation pattern and some of the global tele-connections with Sri Lankan rainfall data. It is important to train some scientists in the Meteorology Department to carry out these analyses.

7.3 Technology and Financial Needs

Under this section, needs for adaptation measures, needs for transfer of technologies, needs for development of endogenous technologies and the need for financial assistance are discussed.

7.3.1 Needs for Adaptation Measures

The Adaptation Strategy for Sri Lanka developed by an ADB sponsored study recently in the areas of agriculture and fisheries; water; health; urban development, human settlements and economic infrastructure; and biodiversity and ecosystem services, 51 project concepts have been identified including the lead agencies responsible for their implementation (Section 3.7.3). In order to implement these projects over the 6-year (2011–2016) duration, additional expenses necessary, beyond current and on-going expenditure, have been estimated at US$ 427 million.

7.3.2 Needs for Technology Transfer

In identifying technology needs for transferring to Sri Lanka, only those technologies currently not available in the country and not freely available commercially were considered. These have been listed in Section 5.3.

7.3.3 Development of Endogenous Technologies

There have been several projects developed locally such as biogas plants, gasifier plants, mini- and micro-hydro plants and automatic rainfall gauging systems but no technical or financial assistance was received bilaterally or multi-laterally for this purpose.

7.3.4 Need for Financial Assistance

There is an urgent need for receiving adequate financial assistance to undertake programmes and projects for compliance with UNFCCC provisions in mitigation, adaptation and in other areas. This is particularly so in view of the recently adopted decisions of the UNFCCC that all Parties including non-Annex I Parties should endeavour to undertake mitigation measures. Access to proposed funding mechanisms to be established to assist non-Annex I Parties in achieving any mitigation targets and adaptation measures should be made easy and time bound, enabling these countries to contribute effectively for achieving the objectives of the UNFCCC.

7.4 Financial Assistance

Sri Lanka has received financial assistance from GEF through several implementing agencies UNDP, UNIDO and WB, for activities enabling it to comply with the provisions of UNFCCC. In addition, a few climate-change related programmes have been supported by other international funding agencies in recent years. These are summarized in Table 7.1.

Table 7.1 Financial Assistance received/ approved for climate change related activities

Period	Source	Implementing Agency	Description	Amount US$
2002-2004	GEF	UNDP	Enabling Activities II for capacity building and undertaking research studies	118,000
2002-2004	GEF	UNEP/ START	Project on Assessment of Impacts of and Adaptation to Climate Change in Coconut and Tea Sectors	195,000
2007-2010	GEF	UNDP	Preparation of SNC on Climate Change	420,000
2009-2010	ADB	ADB	Strengthening Capacity for Climate Change Adaptation	750,000
2011-2016	GEF/UNDP FAO	UNDP	Promotion of efficient use of biomass	4,000,000

This, however, is not an exhaustive list, as several more projects related to climate change are being done in the country with foreign funding.

Annex I

Thematic Working Groups Members

No	Name	Designation	Institute
GHG Inventory			
1.	Mr. Abesekara.R. S.	Director	Dept of Agriculture(WP)Ministry of Agriculture& Agrarian Services
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4.	Ms. Beling A.S.	Senior Manager (Environment)	Boad of Investment
5.	Mr. Dissanayake. A.M.U.	Director	Dept of Census & Statistics
6.	Dr.Fernando S.	Manager(TWC)	National Science Foundation
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8.	Mr. Jayasekara C.	Head	Renewable Energy Division ,Sustainable Energy Authority
9.	Mr. Lokubalassoriya.R.H.R.	Deputy General Manager(TDB)	Ceylon Electricity Board
10.	Dr. Nissanka S.P.	Head	Dept. of Crop Science, Faculty of Agriculture University of Peradeniya
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12.	Mr. Senevirathne A.K.	Addl. Secretary	Ministry of Industrial Development

13	Mr. Surasinghe D.	Senior Assistant Secretary	Ministry of Local Government & Provincial Council
14	Mr. Wasantha L.	Cleaner Production consultant	National Cleaner Production Centre
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15	Prof.Hettiarachchi S.S.L.	Professor	University of Moratuwa
16	Mr. Kariyawasam.S.H.	Deputy Director	Dept. of Meteorology
17.	Mr. Pallewela R.	Manager/Research	Practical Action in South Asia
18	Mr.Premalal.K.H.S.	Deputy Director	Dept. of Meteorology
19	Mr.Premarathne. A.	Director	Planning Division, Dept. of Coast Conservation
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21	Prof. Samarawickrama S.P.	Professor	University of Moratuwa
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24	Mr. Vidanage.S.	Programme Coordinator	International Union for Conservation of Nature
25	Dr. Wijesinghe.P.R.	Consultant Epidemiologist	Ministry of Health Care & Nutrition
26	Dr. Wijesundara S.	Director	NRM, Ministry of Agriculture& Agrarian Services
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28	Dr. Gunawardena P.	Senior Lecturer	University of Sri Jayawardenapura

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31	Mr. Jayasinghe. P	President	Bio Energy Association of Sri Lanka
32	Mr. Jayathilake. H.W.K	Asst Conservator of Forest	Dept. of Forest
33	Mr. Midigaspe.S.	CE	Environment unit ,Ceylon Electricity Board
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38	Ms. Hewawasam.V.	Research Assistant	Ministry of Environment
39	Mr. Jayathilake A.	Director	ARM & IA Division ,Ministry of Environment
40	Mr. Joseph P. G.	Director	Ministry of Science and Technology
41	Dr. Niranjan F.	Senior Research Officer	Sri Lanka Council for Agriculture
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43	Mr. Sumanaweera S.	AGM	Water Supply & Drainage Board
44	Mr. Wickramarachchi.B.	Senior Engineer	
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45	Ms. Dhanawardena M.P.R.	Chief Project Officer	National Institute of Education

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47	Ms. Ediriweera. A	Deputy Director	Federation of Chamber of Commerce
48	Ms. Fernando. S	Environment Management Officer	Ministry of Health Care & Nutrition
49	Mr. Jayathunge J.A.K.N.	Addl. Secretary	Ministry of Power & Energy
50.	Mr. Kumara D. C.	Chief Operation Officer	Green Movement of Sri Lanka
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53	Mr. Nandarathne S. M. K. B.	Director	Disaster Management Centre
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62	Mr. Silva.K.A.I.D.	Director	Policy Planning /Ministry of Environment
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Annex II

Other Participants for Workshops

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