Third National Communication of Climate Change in Sri Lanka

Ministry of Environment
Sri Lanka

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Climate Change Secretariat
Ministry of Environment
Sri Lanka

DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

Third National Communication of Climate Change in Sri Lanka

Submission to the UNFCCC Secretariat

by

Ministry of Environment

Sri Lanka

Financial Support by

Global Environment Facility (GEF) through

United Nations Development Programme (UNDP)

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ISBN: 978-624-5817-25-2

October, 2022

MESSAGE OF
THE MINISTER OF ENVIRONMENT

Climate never remained unchanged in the atmosphere during the human history. It is the average daily weather over a long period of time, may be that of few decades or even a century. Climate is what we expect and experience, and it deals with probability. Throughout human history, human beings have been dealing with this climate probability, predicting it possibility of occurrence and making whatever possible adjustments to live with it.

In water-deficit, tropical and sub-tropical countries, the use of irrigation devices of all forms and meticulous water management systems put in place, both damaging consequences of frequent droughts and floods caused to human settlements and many forms of people's livelihoods are compelled the human beings to predict and prepare to live with them.

All inhabitants are not in sensible for adjustments to live with natural hazards. Over the past several decades, we witnessed that unending destructive interference with the nature by the human everywhere in the world, more to satisfy the greed than to frugally meet the basic needs, has increased the severity of climate around us, which is accentuated by the undeniable release of greenhouse gases that imbalances the atmospheric behavior. Isn't that today we reap what the people everywhere in the world have sown?

Melting of ice in polar caps and the mountainous regions in cold temperate lands accumulate more water to the oceans causing sea level to rise. This leads to the inundation of low-lying coastal areas where the millions of people live in engaged with diverse forms of livelihoods. The coastal towns and cities with sparse vegetation that is unable to ameliorate climate at least in some conductive form, for comfortable living and working in them are actually forming "heat islands" today. Further, the variability, severity and the rhythm of occurrence of prolonged droughts and flash floods are becoming more destructive to the sustainable human existence.

Water shortage is a critical factor in the survival of humans, all other living beings and vegetation all round, all of them having a symbiotic relationship. It may be reminded here that Sri Lanka is custodian of a unique hydraulic civilization based on a myriad of big and small reservoir networks meeting the water needs of all those animate and inanimate ones, amidst the existing climatic vagaries, a model which needs international consideration. Besides, such country-specific considerations, the globally expanding climatic vagaries, as evidenced in rising temperature across all climatic regions, requires all big and small nations to join hands in bringing about lasting climate resilience improvements. The foreword march taken by the United Nations Framework Convention on Climate Change (UNFCCC) in this regard is laudable.

Eng. Nazeer Ahamed, (M.P.)
Minister of Environment

MESSAGE OF
THE SECRETARY OF MINISTRY OF ENVIRONMENT

Sri Lanka is one of the most vulnerable tropical island nations to adverse effects of climate change in the world. Prolong droughts, flash floods in lowlands and landslides in highlands due to intensive rainfall, and sea level rise are major adverse impacts that the country is experience during past decades. These adverse impacts directly affect to livelihood of the nations, human health, development programmes, human settlements and infrastructures, and to the environment including biodiversity and ecosystem in different scales.

However, Sri Lanka's GHG emission to global contribution is less than 1% and per capita emission is 1.07 tonne in 2010. In this circumstances, Sri Lanka has endeavored in this Third National Communication (TNC) Report submitting to the United Nations Framework Convention on Climate Change (UNFCCC) in developing the country's greenhouse gas inventory, and identifying knowledge gaps in climate vulnerabilities in moving towards with potential adaptation actions, mitigation options, gaps & constraints, and supports needed for addressing climate related issues in the country.

The measures to be taken are immediate and long-term for building resilience to overwhelmed the adverse effects of climate change. In this context, the country has submitted its nationally determined contributions (NDCs) to the UNFCCC, stating among other things, a greenhouse gas (GHG) emission reduction by 14.5% (4% unconditionally, 10.5% conditionally) in power generation, transport, industry, waste management, forestry and agriculture with respective to business as usual scenario for the period of 2021-2030.

The Ministry of Environment being the focal point to the UNFCCC, is being implemented the national adaptation plan (NAP) since 2016 and the components of which are closely interlinked with the NDCs on adaptation, consists of nine sectors for building resilience to meet the climate change adverse impacts. In the long run, implementation of NDCs and NAP is mindful to keep abreast with fulfillment of the Sustainable Development Goals (SDGs).

As a sequel to the above indicated, I take this opportunity on behalf of the Ministry of Environment to express my appreciation and gratitude to all those who contributed towards the preparation of this report. I also wish to place on record the unfailing services performed by the officials of the Ministry of Environment, particularly by its Climate Change Secretariat for their tireless and invaluable contributions. A special appreciation is warmly extended to the Global Environment Facility (GEF) and the United Nations Development Programme (UNDP) Country Office in Sri Lanka for financial assistance provided for the preparation of this document.

Dr. Anil Jasinghe
Secretary
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FOREWORD

Sri Lanka is a Non-Annex 1 party to the United Nations Framework Convention on Climate Change (UNFCCC) since 1993. Submission of National Communications to the UNFCCC Secretariat is an obligation under the Article 4 and 12 of the Convention. In accordance with the paragraph 1 of Article 4, each Party shall communicate to the Conference of Parties (COPs), through the UNFCCC Secretariat on national circumstances, challenges, gaps and needs on climate change.

Preparation of the Third National Communication (TNC) of Climate Change in Sri Lanka was a process of wider consultation of stakeholders *inter alia* government, private sector, civil society organizations, academia, media and individual experts to ensure inclusiveness, transparency, completeness, relevancy, accuracy and quality. The leadership for the preparation of TNC of Sri Lanka was taken by the Climate Change Secretariat of the Ministry of Environment which is the national focal point to the UNFCCC. Global Environment Facility (GEF) extended the financial support for the preparation of TNC through United Nations Development Programme (UNDP) Sri Lanka.

The TNC of Climate Change in Sri Lanka reflects the present social, economic and environmental circumstances, anthropogenic greenhouse gases emissions by sources and removals by sinks, potential emission reduction actions, climate vulnerability and risks, adaptation actions to be taken for building resilience in most vulnerable sectors, communities and areas, needs of financial assistance, technology transfer, capacity building, awareness and education on climate change, research and systematic observations, prevailing gaps and constraints of addressing climate change, challenges and preparation of national communications.

This report provides a set of robust recommendations that are relevant to facilitate more effective coordination and planning for climate change mitigation and adaptation at national and provincial level, in addition to the implementation of institutional capacities and processes relating to climate change.

The successful completion of the TNC preparation was possible through the effective collaboration of line ministries, departments and other government agencies, private sector, civil societies, academia, national and international experts, UN organizations including UNDP Sri Lanka. In this respect, I highly appreciate those who contributed to complete this national effort including the officials of the Ministry of Environment and Climate Change Secretariat.

Being the national focal point to the UNFCCC, the Ministry of Environment is pleased to present this report to the UNFCCC Secretariat on behalf of the government of Sri Lanka and her people.

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ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Centre
AFOLU	Agriculture, Forestry and Other Land use
AWD	Alternate wetting and drying
BAU	Business as usual
BCEF	Biomass Conversion and Expansion Factor
BEF	Biomass Expansion Factor
BIMSTEC	The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
BOD	Biological Oxygen Demand
BOI	Board of Investment of Sri Lanka
BRT	Bus Rapid Transit
$CaCO_3$	Calcium Carbonate
CBSL	Central Bank of Sri Lanka
CC&S	Carbon Capture and Storage
CCC	Ceylon Chamber of Commerce
CCS	Climate Change Secretariat
Cd	Cadmium
CDC	Centre for Disease Control
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CFC	Chlorofluorocarbon
CFL	Compact Fluorescent Lamp
CH_4	Methane
CIMA	Chartered Institute of Management Accountancy
CKDu	Chronic Kidney Diseases of Unknown etiology
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
COP	Conference of Parties
CPC	Ceylon Petroleum Corporation
CTCN	Climate Technology Centre and Network
Cu	Copper
DAPH	Department of Animal Production and Health
DMC	Disaster Management Centre
DoE	Excise Department of Sri Lanka
DOM	Dead Organic Matter
DoM	Department of Meteorology
DSDs	Divisional Secretariat Divisions
DSM	Demand Side Management
DWC	Department of Wildlife Conservation
EF	Emission Factor
FAO	Food and Agriculture Organization
FIM	First Inter Monsoon
FSMP	Forest Sector Master Plan
GCE A/L	General Certificate of Education - Advance Level
GCE O/L	General Certificate of Education - Ordinary Level

GCF	Green Climate Fund
GDP	Gross Domestic Production
GEF	Global Environment Facility
GHG	Greenhouse Gas
GJ	Giga Joules
GPG	Good Practice Guidance
GSMB	Geological Survey & Mines Bureau
GWP	Global Warming Potential
HFC	Hydroflurocarbon
HH, Com & Agri.	Household, Commercial and Agriculture
HWP	Harvested Wood Product
ICTZ	Intertropical Convergence Zone
IPCC	Intergovernmental Panel on Climate Change
IPCC-GL	IPCC Guidelines
ISO	International Organization for Standardization
ktoe	Kilotonne of Oil Equivalent
LKR	Sri Lankan Rupees
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LRT	Light Rail Transit
LTGEP	Long Term Generation Expansion Plan
LULUCF	Land Use, Land Use Change and Forestry
MALF	Ministry of Agriculture, Land and Forestry
MCF	Methane Correlation Factor
MMDE	Ministry of Mahaweli Development and Environment
MOE	Ministry of Environment
MRI	Medical Research Institute
MRT	Mass Rapid Transit
MSW	Municipal Solid Waste
Mt	Million tonne
N_2O	Nitrous oxide
$NaHCO_3$	Sodium Bicarbonate
NAMA	Nationally Appropriate Mitigation Action
NAP	National Adaptation Plan for Climate Change Impacts in Sri Lanka
NAP - LD	National Action Programme for Combating Land Degradation in Sri Lanka
NARA	National Aquatic Resources Research and Development Agency
NCPC	National Cleaner Production Centre
NCV	Net Calorific Value
NDCs	Nationally Determined Contributions
NEM	North East Monsoon
NEPS	National Energy Policy and Strategies
NGOs	Non-Governmental Organizations
NGRS	National Green Reporting System
NMVOC	Non Methane Volatile Organic Compound
NO_x	Nitrogen Oxides
NSWMSC	National Solid Waste Management Support Center

PCs	Provincial Councils
PCW	Puttalam Cement Works
PFCs	Perfluorocarbons
PMU	Project Management Unit
QA/QC	Quality Assurance/Quality Control
R&D	Research and Development
RCP	Representative Concentration Pathway
SAARC	South Asian Association for Regional Cooperation
SDGs	Sustainable Development Goals
SF_6	Sulphur hexafluoride
SIM	Second Inter Monsoon
SLSEA	Sri Lanka Sustainable Energy Authority
SNC	Second National Communication
SNCCA	Sri Lanka National Centre for Climate Applications
SO_2	Sulphur dioxide
SO_x	Sulphur oxides
SWDSs	Solid Waste Dumping Sites
SWM	South West Monsoon
Tier I	Tier one
TNC	Third National Communication
TVET	Technical, Vocational Education and Training
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WHO	World Health Organization
WMAWP	Waste Management Authority of Western Province
WMO	World Meteorological Organization

UNITS

g	gramme
Gg	Gigagramme
ha	hectare
J	Joule
kg	Kilogramme
km	kilometer
mm	millimeter
0C	degree Centigrade
PJ	Peta Joule
t	tonne (1,000kg)
w	watt
yr	Year

EXECUTIVE SUMMARY

The Third National Communication (TNC) of Climate Change in Sri Lanka consists of seven chapters. The first chapter provides the national circumstances on climate change and associated concerns.

Sri Lanka is located in the Indian Ocean closer to the Indian sub-continent, is exposed to a range of climate vulnerabilities leading to disaster-prone weather extremes, spawned by uncertain monsoons and turbulent atmospheric conditions that frequently arise mostly in the Bay of Bengal and sometimes associated with the Intertropical Convergence Zone (ITCZ). Three-fourths of this island of 65,525 km^2 is below 300 m in elevation and the remaining one-fourth is in the central highlands characterized by mountain ranges, plateaus, peaks above 2,000 m determining the temperature, rainfall and drainage patterns in the country.

There is evidence of temperature rising. Average temperature in Sri Lanka is projected to increase by a maximum of 3.3°C or a minimum of 2.3°C by 2080, over the present level of temperature. Historically, rainfall had been decreasing. Rainfall received during the period of 1961-1990 had been 7% less than the rainfall received during the period of 1931-1960, nevertheless, the amounts and variabilities of rainfall have increased over the recent decades.

The Department of Meteorology has identified short term (2020-2040), medium term (2040-2060) and long term (2070-2090) rainfall changes related to the four monsoons, following the RCP 4.5 and RCP 8.5 scenarios of Fifth Assessment Report of IPCC. As a result, future trends of rainfall are continuous to be increased in the wet zone with increased floods, landslides and coastal lowland submergence. The dry and intermediate zones in the country are expected to have more and more rainfall failures, frequently leading to droughts of varying magnitude and duration.

These anticipated climate changes, among other development constraints, are likely to damage people's livelihoods recurrently. About 30% of the country's population is engaged in agriculture in which the majority works in grain production mostly in the dry and intermediate zones who cultivate cereals and perennial crops which are liable to face water shortages due to drought and destined to face losses in both production and productivity, threatening the food security in the country. Plantation agriculture mostly in the wet zone due to intensive rainfalls, is liable to fall in productivity seriously reducing the country's export earnings.

Nearly two million people engaged in coastal and marine fishing contributing 2% to GDP will face economic hardships together with damages to dwellings and their total coastal environment due to sea level rise. The major consequence of sea level rise due to global warming is coastal inundation and that sea level rise around Sri Lanka appears to be even marginally higher than the global averages and a shoreline retreat of 200,000 to 300,000 m^2 per year not only a threat to coastal fishing and up-coming coastal tourist industry but increased intrusion of salt water in to interior fresh water bodies will also devastate agricultural lands. Myriads of other economic activities associated with small and medium scale industries and services in towns and hamlets within the coastal belt of about 2 km where 40% of the country's population work and live would be economically devastated.

Climate induced disasters are threatening the economic growth. In 2016 alone, the estimated flood-induced damages cost was about LKR 99.8 billion and in 2017, climate-induced disasters' losses were about US$ 1,623 million. These are significant financial constraints for a country like this small island.

A retarded GDP growth limits the annual public expenditure. For example, the GDP share of public expenditure declined from 20% in 2010 to 17.3% in 2014. Public expenditure on the country's healthcare, free education, many other social welfare commitments, development programmes and other public expenditure required, are suffered.

To monitor, supervise and follow-up the above stated economic pursuits together with due and consistent watch on moving climate change in the country and in its environment, the necessary and adequate institutional arrangements are there in national, regional and local levels. The national government comprises of ministries, departments, statuary bodies, state owned enterprises.

There are nine provincial councils and 335 local authorities including 23 municipal councils and 41 urban councils. This is an adequate network of organizations to deal with the ongoing and impending climate changes in the country. However, not all these organizations are well versed in climate change and climate change resilience improvement, because climate change is relatively a new area of government involvement. However, the redeeming feature is that climate is now the concern of all public organizations. An overall coordination effort involving all of them is, therefore, necessary.

The Ministry of Environment has the command through the Climate Change Secretariat, which is duty bound to coordinate climate related overarching activities of ministries, departments, statutory bodies, provincial councils and local authorities, public-private enterprises, NGOs, private sector organizations and individuals and other organizations concerned with social responsibilities.

The second chapter of TNC Report is presented the national greenhouse (GHG) inventory of 2010. It provides the estimates of anthropogenic emissions by source and removals by sink of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The TNC Report also provides information on gaseous emissions such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and information on emissions of precursor carbon monoxide (CO), nitrogen oxide (NO_x). The Guidelines of Intergovernmental Panel on Climate Change (IPCC) were used to calculate emissions from energy, industrial processes and product use (IPPU), agriculture, forestry and other land use (AFOLU) and waste sectors. The emissions in the GHG inventory have been estimated using Tier I method from 2006 IPCC Guideline for the time period of 2000-2010. Emission from each sector was calculated in unit of mass and in CO_2 equivalents using the Global Warming Potential (GWP) values.

Emissions from energy sector amounted in 14,154.16 Gg CO_2-eq, IPPU sector in 448.57 Gg CO_2-eq, agriculture sector in 6,505.67 Gg CO_2-eq, waste sector in 976.22 Gg CO_2-eq, LULUCF sector in 21,460.13 Gg CO_2-eq. The total emissions is 43,544.75 Gg CO_2-eq and the removals of carbon by sink is -39,826.3 Gg CO_2-eq. Hence, the total emission exceeds the sink by 3,718.45 Gg CO_2-eq. The total emission in 2010 excluding LULUCF was 22,084.62 Gg CO_2-eq and it is a 25% increase from the year 2000 that the GHG Inventory prepared for the Second National Communication. Consequently, the per capita CO_2-eq emission has increased from 0.78 tonne in 2000 to 1.07 tonne in 2010.

Vulnerability to adverse effects of climate change is so alarming and the Global Climate Risk Index published by the Germanwatch has ranked the country as the 4th in 2018, 2nd 2019 and 6th in 2020 as the most vulnerable country in the world with an annual loss of US$ 2129 million. The World Bank estimates that 7.7 percent (US$ 50 billion) of GDP, needs to be allocated to face climate disasters by 2050.

The vulnerability and adaptation measures chapter presents the degree of climate change risks due to droughts, floods, landslides and sea level rise affecting agriculture, livestock, fisheries, industry, water sources, health, biodiversity and ecosystems, human settlements and tourism in line with nationally determined contributions (NDCs) and national adaptation plan (NAP), in keeping with different geographical scales such as Districts and Divisional Secretariats. It also proposes robust and flexible adaptation measures towards evidence-based policy and decision making by comparing the existing risk map evidences with climate anomalies of short term (2020-2040), and midterm (2040-2060) durations using the high emission scenarios of Representative Concentration Pathway (RCP 8.5). Impacts and its vulnerability, government policy frameworks, adaptation measures needed are under each sector highlighted.

For climate resilience building, the government of Sri Lanka has identified inter alia: (a). rehabilitation of ancient tank cascade (*Ellangawa*) system in the dry zone covering nearly two-thirds of the island's land area to combat the prolonged drought situations by storing rainwater; (b). enrichment of catchment vegetation and water supply sources of tanks, protection of water sources of the Central Highlands and river basins to ensure perennial water sources while reducing soil erosion; and (c). diverting excess water in the wet zone to the thirsty dry zone over-coming the adverse impacts of the droughts likely to be frequent in long time to come.

The 4th chapter presents the actions already taken and potential mitigation measures that can be implemented to reduce anthropogenic emission of greenhouse gases in energy, industrial processes and product use (IPPU), agriculture, forestry and other land use (AFOLU) and waste sectors. The mitigation analysis of these sectors was totally based on the GHG inventory in the 2nd chapter. Potential mitigation measures were analyzed for the different sectors for the period of 2010-2030. Two types of scenarios constructed as the baseline and the mitigation scenarios.

The baseline scenario reflects a future in which there will be no additional policies or programmes designed to reduce GHG emissions or enhance carbon sinks. A baseline scenario is considered a critical element in the abatement assessment since the benefits and incremental cost of mitigation options are directly linked to the sound definition of the baseline scenario. Therefore, the baseline scenario was constructed based on the trends, plans and policies prevailing from 2010 to 2018. In this scenario, the most recent and current emission levels were projected to future emission levels envisaged for each type of activity up to 2030. The projections were based on assumptions of population growth, GDP and other macro variables obtained from official sources.

The mitigation scenario was structured according to a set of criteria reflecting country specific conditions such as potential for large impacts of GHG reduction, economic impacts, consistency with national development goals, potential effectiveness of implementation policies, sustainability of an option, data availability for evaluation and other sector specific criteria.

The fifth chapter indicates the education, training, awareness and capacity building related to climate change in the country. Increasing climate change awareness among school children is gradually expanding and their climate change knowledge will help themselves while in school and thereafter to understand the climate change impacts and potential solutions. The concern about climate change and its consequences are also being increasingly felt by the government, semi-government, private sector and civil societies. At present there is a growing interest in universities too, either to dove-tail the subject of climate to existing academic disciplines of relevance or to attempt and develop fresh courses. 402 public sector training centers, over 400 private sector and civil societies provide short term training courses on climate change to boost public awareness.

Non-formal training is through an organized training process that occurs outside the formal learning environments. Non-formal training is possible by coming together of the people with similar interests who can then exchange their ideas and viewpoints cross pollinating and enriching their practical knowledge. Non-formal education is a very strong system of training that needs frequent attention of the due authorities to increase public awareness on climate change and people's capacity building to be sure-footedly resilient to climate change.

The sixth chapter revealed the needs of technology transfer, research and systematic observations in addressing climate change. The chapter is started with given a reference to the obligations of the UNFCCC for the both developed and developing countries' responsibilities on technology transfer, research and systematic observations in order for addressing climate change issues. Then, the Technology Need Assessment conducted by the Climate Change Secretariat in 2014 has been highlighted. Technical Assistance for Climate Smart City Programme for Kurunegala city from the Climate Technology Center and Network (CTCN) has also been indicated. Further, supports extended by the regional level interventions and technical cooperation such as SAARC, BIMSTEC, ADPC, Regional Integrated Multi-Hazards Early Warning for Africa and Asia, and SNCCA have been highlighted. The need of educational and outreach activities on climate smart technology in order to change conventional management practices have been recognized.

The need of advanced software, tools and models for effective analysis of long-range weather forecasting for agricultural planning and crop recommendation are highlighted. Also, introduction of effective land and water management techniques for central highlands and other marginal areas to minimize land degradation and to improve land and water productivity due to climate change adverse impacts are recommended.

Several appropriate and potential technologies for building resilience in most vulnerable sectors such as agriculture, livestock, tourism, water and irrigation etc. have been recommended to address the prolonged droughts and flash floods. Improving knowledge of agricultural machinery, training and capacity building among farmers on climate smart technologies are required to promote conservation farming techniques, integrated pest management etc. in areas where vulnerable to climate change.

In order to minimize the adverse impacts of landslides, settlements and land use changes in landslide-prone and other vulnerable areas potential technologies have been recommended. Numerous technology needs to address the impacts of sea level rise in the coastal and marine sectors have been identified. Technology needs to improve the energy efficiency and infrastructure have been identified and potential technologies have been proposed including innovative and existing technologies. Further, separate technology interventions for different settlement categories have been identified for predicted climate scenarios.

Barriers and constraints identified for technology mobilization in adaptation and mitigation sectors have been well recognized and measures for overcome those have been recommended including fiscal policy reforms aiming at reducing costs of infrastructure development.

A large number of research and systematic observations for different sectors of climate change adaptation and mitigation have been identified covering climate change predictions, vulnerability and adaptation measures, potential GHG emission reductions and removals, technology demonstrations and piloting etc.. Finally, a great need has been identified to modernize the data management, data sharing and information dissemination using digital system for easy recording and analysis.

The chapter seven identifies the existing gaps and constraints for the preparation of national communications, and implementation of climate actions. It proposes actions to be implemented to address these gaps and constraints. The preparation of this chapter has been through desk research, expert consultations, sectoral and national level stakeholder consultations. Gaps and constraints indicated in the SNC have been evaluated and updated in this chapter.

The key gaps and constraints identified for addressing climate change impacts and fulfilling the obligations under the UNFCCC are gaps in institutional structure and coordination among different entities working on fulfilling obligations related to climate change activities; gaps in laws, policies, and regulations pertaining to adaptation and mitigation actions; gaps and lack of availability of data for adaptation and mitigation measures that focus on climate change impacts in Sir Lanka; gaps in capacity building and research; gaps in financial resources available and the amount needed to implement the activities related to climate change in the country.

Based on these gaps and constraints, the chapter proposes activities needed to address them. Activities that are highlighted among other are amending policies and regulations and development of a law for implementing activities related to climate change in Sri Lanka; capacity building activities on climate change for stakeholders; development of coordination and institutional structures for effective and efficient implementation of climate action; mobilizing climate finance to address support needs. Assessing the vulnerability and building resilience to meet the adverse effects of climate change, and potential GHG emission reductions, means of implementation (finance, technology transfer and capacity building) for Sri Lanka should be provided.

CHAPTER ONE

National Circumstances

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National Circumstances

1.0 Introduction

Sri Lanka is a tropical island in the Indian Ocean few kilometers off the southern tip of India at 5°54′ - 9°52′ North latitude and 79°39′ - 81°53′ East longitude. Economically, the country is ranked as a lower middle-income country. Nearly a third of the population is still dependent on agriculture related livelihoods which are sensitive to growing impacts of climate change. Her central location in the Indian Ocean closer to main sea lanes presents prospects for trade and service-based growth in the economy. In the recent period, successive governments have declared the intention for transforming the country into an economic hub joining the growth centers in the East and West, taking advantage of the country's unique location. The country's unique geographical position offers both opportunities and challenges.

On the other hand, the same location factor exposes Sri Lanka to a diverse range of vulnerabilities. Sri Lanka frequently experiences disaster prone weather extremes spawned by uncertain monsoons and turbulent atmospheric conditions arising in Bay of Bengal. The country's water resources that fulfill a vital role in economic, social and cultural life are heavily dependent on precipitation patterns determined by these forces. Moreover, being an island nation with densely populated low-lying coastal belt, the country is vulnerable to sea level rise. Sri Lanka's national circumstances are shaped by its physiographic, demographic and socio-economic conditions that are under the strong influence of the institutional setup of the country.

1.1 Geography

The geography of the country is characterized by three major features; a mountainous region located at the south-central part of the island, lowland plains extend radially from the central highland to the coast and, low-lying coastal fringe runs around the country. Nearly three quarters of the land area lie below the 300 m and the rest is under hilly terrain. The central highland area is characterized by several ranges of mountains, plateaus and peaks. Sri Lanka's tropical location closer to the Intertropical Convergence Zone (ITCZ) and the unique geographical formation characterized by central mountain region determine the country's climatic and drainage patterns significantly. The intermediate plain areas are characterized by undulating landscape with ridges and valleys. The plain, which is broad and flat in north and east and rugged in south-west, is intermittently disturbed by residual rocks. The coastal fringe that lies below the 30 m is characterized by sandy beaches and several other coastal land forms.

Geologically, 90% of lands in Sri Lanka is underlain with metamorphic rocks of Precambrian origin. The Precambrian rock formations are crystalline in nature and are subdivided in to 3 major groups.

1. Highland complex (HC): Occupies a broad belt running across the central part of the island from southwest to north east. The lithology of HC is comprised of quartzites, gneisses, charnockites and pegmatites.
2. Wanni complex (WC): Occupies the north-western part of the island. Made up of complex lithology that includes quartzites, gneisses, granites, charnockites and amphibolites.
3. Vijayan complex (VC): Located in the southeast parts of the island and comprised of gneisses, migmatites and pegmatites.

Wanni complex and Vijayan complex are flanking the Highland complex from two sides. North-western and northern parts of the country are underlain with sedimentary formations of Jurassic and Miocene origin. Geological properties of these rock formations have mainly determined the types of soils, occurrence of groundwater and availability of various types of economically useful minerals.

1.2 Population

A majority of the population still lives in rural areas even though rapid urbanization can be observed around major urban centers and along the main transport corridors of the country. Sri Lanka is a country with highest level of population density in the world. Moreover, population is geographically concentrated in areas that are more susceptible to climate change impacts such as coastal zone. Hence, adaptation measures aimed at facing the impacts of climate change have to take population parameters into serious consideration.

The midyear population in 2016 was estimated as at 21.20 million. This included 10.26 million males (48.5%) and 10.93 million females (51.5%). Of the total population, 15.44 million was in the age category of "15 years or above".

According to the Intergovernmental Panel on Climate Change (IPCC), population growth is a key factor contributing to climate change. It leads automatically to increase in energy consumption thereby contributing to GHG emissions. On the other hand, population growth increases the number of victims to climate change impacts too. High growth and density of population makes the adaptation efforts more difficult due to high demand created for critical resources such as water and other ecosystem services.

Having low population growth rate and relatively low per capita emissions, Sri Lanka's marginal contribution to global GHG emissions can be considered also as low. Nevertheless, its location in a disaster-prone tropical region and high population density makes her citizens vulnerable to climate change in significant manner.

1.3 Climate

Sri Lanka does not experience significant seasonal variation in temperature within a year. As a result, average pattern of climate in a given locality is determined mainly by the seasonal variation in rainfall. However, regional variations in temperature can be observed depending on the altitude of locations. Average annual temperature in lowland areas usually vary over 26.5°C whereas in central highland areas average temperature could significantly be lower than this. For instance, average temperature in Nuwara Eliya at 1,800 m mean sea level is around 15°C.

Based on the temporal distribution of rainfall within a year, four rainfall seasons have been inherited in the country (please see figure 3.2, 3.3, 3.4 and section 3.3.1).

Sri Lanka receives mean annual rainfall around 1,850 mm as a cumulative outcome of all four rainfall seasons that can be considered a relatively high level of rainfall compared with many other countries. In spite of that, country faces problems in water availability due to two major reasons as rainfall in Sri Lanka shows high inter-annual variation, and spatial distribution of rainfall in the country shows high regional variation. The average rainfall in different locations could vary over the wide range of 1,000 mm to 5,000 mm. The south western quarter, especially the western slopes of central highland, can be identified as the wettest region having the mean annual rainfall over 5,000 mm. On the contrary, mean annual rainfall in south-eastern (e.g. *Yala* area) and north-western (e.g. Mannar) coastal areas is usually around 1,000 mm.

1.3.1 Observed and projected changes in climate

Recent studies indicate that the normal pattern of climate is undergoing changes. Two major sources, namely, observed changes and projected changes provide evidence on climate change. Observed changes are based on past meteorological data recorded from different locations of the country over several years. Projected changes are predictions on future trends in climatological parameters that are based on global climate models.

Temperature: Information from many studies suggests that ambient air temperature is rising all over the country (Basnayake, 2007; Chandrapala, 1996; Eriyagama et al., 2010; Nissanka et al., 2011). Mean air temperature anomalies have shown increasing trends in many stations around the country (Basnayake, 2007). Warming trend has been manifested by many number of warm days and nights, fewer number of cold days and nights, increase in mean daytime maximum and mean night time minimum air temperatures and growing number of dry days (Basnayake, 2007; Samarasinghe, 2009; Zubair et al., 2005). It appears that increase in night time minimum air temperature contributes more to average increase in annual temperature than day time maximum air temperature (Basnayake, 2007). Evidence also indicates that the warming trend has become faster in recent years (Basnayake, 2007; Chandrapala, 2007). However, warming trend is not uniform throughout the country and the highest rate of increase was reported from Puttalam area (Chandrapala, 2007). Besides the warming trend observed all over the country, studies have shown increased average air temperature in urban locations due to urban heat island (UHI) effect (Manawadu and Liyanage, 2008). Lack of vegetation cover, high heat absorption by built-up environments and concentration of waste heat emissions from multiple sources are the major factors responsible for this situation.

Rainfall: While there is overwhelming evidence about changes in normal pattern of rainfall all over the country, there is no clear indication over direction of change or nature of emerging patterns unlike in the case of temperature. According to some studies that compared the mean annual rainfall in recent and past periods, average rainfall shows a declining trend (Basnayake, 2007; Jayatillake et al., 2005). It was estimated about 7% reduction of rainfall during the period 1961-1990 compared with 1931-1960 period (Chandrapala, 1996; Jayatillake et al., 2005). The magnitude of these changes could vary depending on the rainfall season and the geographical location. Few studies have also indicated that number of consecutive wet periods has decreased while the number of consecutive dry days has increased (Ratnayake et al., 2005; Premalal, 2009). However, Punyawardena et al., 2013 reported that in central highlands areas, heavy rainfall events have become more frequent during the recent period. In spite of differences in opinion over the overall direction of change, researchers seem to agree that variability of rainfall has increased over time and current pattern of spatial distribution may be changing. Some studies suggest that changes in spatial distribution can lead to shifting of agro-ecological boundaries (Eriyagama et al., 2010; Mutuwatte et al., 2013).

Extreme events: Emerging evidence appears to suggest that intensity and frequency of extreme event relating to rainfall (e.g. heavy rainfall events and total absence of rainfall over lengthy spells) are increasing (Imbulana et al., 2006; Ratnayake et al., 2005). Such extreme events have a direct association with hazards such as floods, landslides and droughts. High rainfall events show a strong correlation with landslides (Ratnayake et al., 2005). In the recent period, Sri Lanka experienced high incidence of extreme events. Extended drought occurred in certain parts of dry zone during 2016-2018 has been reported as the worst since 1970s. This has affected the agricultural production significantly. During the same period, certain locations in wet zone experienced catastrophic events of floods causing heavy life, economic and property damages. In central highlands, extreme rainfall events were often associated with disastrous landslides that caused tragic losses of human life and property damages.

Understanding future climate circumstances is an important step to face the impacts of climate change in successful manner. This requires projection of possible future scenarios of climate and few efforts have been made to project the future climate in Sri Lanka. The recent projections by the Department of Meteorology (DoM) in 2016 can be considered the most important among them. The DoM predicted rainfall and temperature under standard emission scenarios developed by IPCC known as Representative Concentration Pathway (RCP). Projections have been developed under moderate (RCP 4.5) and high emission (RCP 8.5) scenarios using a multi-model ensemble projection (Please see the section 3.3.1).

One regional study conducted by ADB that covered Sri Lanka among six other countries in South Asia made projections under different IPCC scenarios until 2080, indicates that average temperature in Sri Lanka could rise by 3.6°C, 3.3 °C and 2.3°C under A2, A1B and B1 scenarios respectively by 2080 (Table 1.1). It also predicts rainfall of the country could increase by 39.6, 35.5 and 31.3 percent respectively under A2, A1B and B1 scenarios by 2080. According to this projection average number of consecutive dry days per year will also increase progressively over time.

Table 1.1 Temperature and precipitation projections under different scenarios

Climate parameter	2030			2050			2080		
	A2	**A1B**	**B1**	**A2**	**A1B**	**B1**	**A2**	**A1B**	**B1**
Precipitation (%)	7.4	11.0	3.6	15.8	25.0	16.5	39.6	35.5	31.3
Temperature (°C)	1.0	1.1	1.0	1.8	1.5	1.3	3.6	3.3	2.3

Source: Ahmed and Supachalasai (2014)

In addition to changes in atmospheric parameters, changes in oceanic environment especially, sea level rise, too are expected due to climate change. Being an island with densely populated low-lying coastal zone, sea level rise could be expected to create significant adverse impacts in Sri Lanka. Studies suggest that Sri Lanka had undergone sea level variations in number of stages in geological history (Katupotha, 2015).

The sea level rise could lead to inundate low-lying areas in the coastal zone. According to the hazard profiles developed by the Disaster Management Center of Sri Lanka (DMC), the estimated district level inundation due to sea level rise by 2100 could vary from 1,534 hectares in the Colombo district to 14,809 hectares in the Puttalam district (DMC, 2012). A recent study conducted by the UNHABITAT (2017) on climate change in urban areas indicated that certain coastal cities will be moderately exposed to sea level rise. Out of 14 coastal towns examined, 7 (Colombo, Negambo, Mannar, Galle, Trincomalee, Batticaloa and Hambantota) will experience moderate and low level impacts of sea level rise by 2050 such as inundation of low-lying areas and salt water intrusion posing challenges to local authorities perhaps even forcing affected sections of population to migrate.

1.4 Local Knowledge on Climate

There is significant evidence that farmers in many areas of Sri Lanka have knowledge on local climate developed over generations of collective experience. This is a shared knowledge among community members that guide their livelihood decisions. Farmers get access to this shared knowledge through a social process of knowledge transmission that involve fellow community members and elders of the society. The local climate knowledge usually covers detailed understanding about local weather patterns and set of local indicators that provide the basis for prediction of rainfalls. These local climate indicators are usually signs appear in local environment.

A prominent example of local climate knowledge is local agricultural calendar based on two farmer-defined seasons known as *Yala* and *Maha* (please see Section 3.3). Farmers' knowledge about generations of experience about seasonality of annual rainfall is embedded.

Farmers are also assisted by local climate indicators that help to predict forthcoming weather events that can be considered as indigenous weather forecasts. These forecasts may have time lags that may extend from few hours to few months. Farmers use wide range of local indicators to make their predictions and few common indicators reported by researchers include; animal/plant behaviour, observations on wind/sky/clouds, local hydrological phenomena, thermal changes, indicator species and cosmological phenomena.

Evidence suggests that farmers find reliability of local weather predictions is declining. It appears that changes taking place in local climate patterns and environment has made it difficult to observe certain indicators thereby rendering local weather predictions less reliable. For instance, certain observations on animal/plant behaviour have become rare due to clearance of local forest patches. Therefore, such phenomena can no longer be relied upon to make regular decisions. As a result, some parts of indigenous knowledge have become obsolete with limited current use. Another factor that has led to decline in local climate predictions is limited experience and knowledge of young farmers about indigenous knowledge. Also, local knowledge on weather change observations are unable to predict by the communities due to present climate change effects.

1.5 Forests and ecosystems

Sri Lanka is listed as one of 36 'Biodiversity Hot Spots[1]' in the world together with Western Ghats region of India. The country has a rich endowed biodiversity that covers a range of terrestrial and aquatic ecosystems with over 9,400 described species of fauna and flora. The diverse climatic and topographic conditions found within a relatively small area (Section 1.1-1.2) are one source of diversity and richness in forests and ecosystems in the country. Sri Lanka's forests and ecosystems are characterized with high level of endemism that exceed over 20% in certain categories of fauna and flora (Weerakoon, 2012). Forests and ecosystems in Sri Lanka have been classified in the National Atlas of Sri Lanka-2007 (2nd edition) has 10 categories (Table 1.2).

According to the latest forest cover estimate in 2015, the forest cover in Sri Lanka is about 29.7% of the land area. Forests in the south-western quarter have the highest biological diversity. Out of total forest area only 5% is coming under the montane and the sub-montane categories. Besides the rich endowment of biodiversity, forests in central hills and the wet zone play highly important role as upper watersheds of country's radial drainage system.

In spite of natural richness, forests and ecosystems in the country has undergone a rapid process of degradation due to anthropogenic causes. Hence, the situation of forests and ecosystems in the country can be considered as fragile. The key challenges faced by forests and ecosystems in the country are deforestation

1 The term 'hot spot' implies that the biodiversity in the country has high level of endemism that has been threatened.

and degradation of natural forests; degradation of critical habitats such as mangroves and wetlands; risk of extinction of species due to over exploitation; spread of invasive alien species; and human-wildlife conflict.

Table 1.2 Classification of forests and ecosystems in Sri Lanka

Forest type	Characteristic climatic and topographical features	Climatic Zone
Montane Forest	Above 1,500 m elevation. Temperatures ~ 15°C. Rainfall >1,800 mm with no moisture deficit period.	Wet zone (Montane)
Sub Montane Forest	Within elevations of 1,000 to 1,500 m. Temperatures 15°-20°C. Rainfall > 1,800 mm.	Wet zone (Sub Montane)
Lowland Rain Forest	Extending from the coastal plains to 1,000 m. Temperatures >20°C. Rainfall >2,500 mm, no moisture deficit period vegetation.	Wet zone (lowland)
Moist Monsoon Rain Forest	Found at <1,000 m. Temperature >20°C. Rainfall 1,800-2,500 mm with a peak from October - January with a dry period of 3 months.	Intermediate Zone
Dry Monsoon Rain Forest	At elevations of <600 m often on slopes. Rainfall 1,000-1,800 mm from mid-October to January with a dry period of 3-6 months.	Dry zone
Riverine Dry Forest	Found along flood plains and river valleys. Elevation <600 m. Rainfall 1,000-1,800 mm.	Mostly Dry zone
Mangrove Dry Forest	Present along intertidal sheltered coastlines, usually associated with river mouths and lagoons.	Coastal area / Lowland/ Both in wet and dry zones
Grasslands	Four types divided according to climatic zones; *patana* (montane), *talawa* (lowland wet zone), *damana* (lowland dry zone) and *villu* (wetlands).	All climatic zones
Trop. Thorn and Degraded Forests	Mostly disturbed areas flanking dry mixed evergreen forests with thorny shrubs and sparse trees.	Dry zone
Sand Dunes	Raised beaches of sands characterized with stunted vegetation.	Coastal belt in northern and eastern areas

Source: UNREDD Sri Lanka (2017) and Survey Department (2007)

Sri Lanka has experienced gradual decline of forest cover since the second half of the 19th century due to anthropogenic causes. Historically, growth of export-based plantation economy in the wet zone, colonial policy on commercial timber extraction and, land resettlement and irrigation development in the dry zone were among the major drivers responsible for large-scale deforestation and degradation of forests in the country from the mid nineteenth century to the late twentieth century.

The above historical drivers, though not effective today in the same scale, have set the trends for subsequent phases of deforestation and degradation of forests that still continues. Major drivers currently responsible for deforestation in Sri Lanka include infrastructure development activities, encroachment for commercial highland agriculture in dry zone, encroachment for smallholding tea plantations in the wet zone and rehabilitation and resettlement programmes. However, recent estimates based on forest cover assessments indicate that the rate of deforestation has significantly decreased during 1992-2010 (7,147 ha/year) compared with the period of 1956-1984 (42,200 ha/year) (Fernando et al., 2015).

There are threatened ecosystems that need special attention such as inland and coastal wetlands which offer numerous ecosystem services. The Asian Wetland Directory of 1989 identified 41 wetland sites of international important in Sri Lanka, covering 274,000 ha in total (CEA, 2006). This includes 6 wetland sites also identified under the Ramsar Convention for their international significance.

Majority of wetland ecosystems in the country are currently under the threat of degradation due to human activities. Urban wetlands in areas of high population densities are under the threat becoming garbage disposal sites or being converted into build-up areas. Wetlands in coastal zones also are affected by pollution from urban and industrial effluents, infrastructure and tourism development, garbage disposal, shrimp farming and encroachments. Wetlands are important habitats for migratory birds. Rising temperature and regular droughts lead to high evaporation rates and periodical drying up of wetland habitats. Another issue is inundation of brackish water wetlands with freshwater. These fluctuations in environmental conditions make it difficult for migratory birds to stay in these habitats thereby affecting biodiversity of the systems negatively.

Invasive alien species (IAS) have emerged as a major threat to Sri Lanka's ecosystems. The invasive species damage both natural as well as agro-ecosystems by competing, dominating and damaging local species. Further, climate change could possibly increase the threat by favouring invasive species which usually have broad environmental and climatic tolerances, wider geographic ranges, fast growth rates, early maturity for an efficient reproduction, high dispersal ability and increased potential for rapid micro-evolutionary changes.

Intensified human-wildlife conflicts have emerged as another area of concern that affects ecosystems of the country. This is an outcome of extending frontiers of agricultural and human settlements that increases the risk of hostile interactions between humans and wildlife. This has resulted in growing numbers of crop and property damages and life threats to humans as well as wildlife. Among others, human-elephant conflict has attracted attention of many stakeholders, and the Department of Wildlife Conservation has introduced number of programmes to overcome this problem. Significant costs on both sides have been incurred by the conflict. During 2014-2016, 212 human deaths and 4,070 incidents of property damages reported (DWC, 2016). In 2015, the DWC has disbursed Rs. 25.7 million as compensation for wildlife damages to victimize families and spent Rs. 19.1 million to capture and translocation of marauding elephants.

Growing impacts of climate change such as extended droughts are likely to intensify the human-wildlife conflicts. Associated losses to local ecosystems can aggravate the situation further. Hence the problem needs special attention and suitable options of adaptation need to be identified.

1.6 Land resources and land uses

Land resources are critical for economic and social wellbeing of the people. About a third of population is dependent on agriculture whose livelihoods are directly dependent on land resources. The total land area of the country is 65,610 km^2. This land area has been allocated for several land uses that come under the broad categories of urban lands, agricultural lands, forests, water and barren lands. The population growth has reduced the per capita availability of land from 1.8 ha in 1900 to 0.3 ha in 2010.

65% of land area in the country has been utilized for agricultural land use. Urban lands including built up areas occupy less than 1%. Of the agricultural land uses, homestead gardens (15.7%), paddy (12.7%) and plantation (10.5%) are the major crops. Sparsely used croplands (22%) and scrubs (2.1%), which are mainly former shifting cultivation lands, also occupy a significant extent. Over 5% of land is covered either with water (4.6%) or barren lands (1.2%).

The National Action Program for Combatting Land Degradation in Sri Lanka 2015-2024 (NAP-LD, 2014) identified that many land uses in the country are affected by land degradation. Among many forms of land degradation, soil erosion due to agricultural uses and degradation due to non-agricultural activities as mining are the most critical.

Soil erosion in upcountry areas has serious off-site effects such as flash floods, drying up of streams, rapid siltation and capacity reduction of reservoirs. Major on-site effects of soil erosion are loss of top soil, declining soil fertility and landslides. Significant soil erosion can also be observed in low country dry zone areas due to spread of commercial highland farming in encroached land in catchments of irrigation reservoirs.

Mining is another major cause of land degradation in Sri Lanka. Mining can lead to degrade entire profiles of land, causing heavy soil erosion, weakening soil structure and damaging surrounding lands and properties with sediments and dust.

Landslides are another cause of land degradation. The National Building Research Organization (NBRO) has identified number of locations in Nuwara Eliya, Badulla, Kegalle, Ratnapura, Kalutara, Galle and Matara districts as landslide prone areas. Catastrophic events of landslides have taken place in locations such as Meeriyabedda (Badulla district) in 2014 and Samasarakanda (Kegalle district) in 2016. Despite increased vulnerability caused by frequent extreme rainfall events in the recent period, all other land based factors responsible for landslides are human induced. They include clearance of vegetation cover for agricultural and settlement purposes, poorly designed constructions and infrastructure development activities and poor storm water and drainage management. High population densities and growing land scarcity in wet zone areas act as key underline drivers.

1.7 Water resources

Water resources in Sri Lanka are heavily dependent on rainfall. Surveys on groundwater have indicated that groundwater potential in the country is limited (Panabokke, 2008). In a normal year, the country used to get a relatively abundant supply of water from monsoon and inter-monsoon rains. Water available from rainfall is distributed over 103 river basins through a radial pattern of drainage. Despite this relatively positive scenario, however, high inter-annual variation and uneven spatial distribution of rainfall often lead to serious issues of water scarcity. In such circumstances, competing demands from household, agriculture, energy and industrial sectors have to be met under immense difficulties. Growing uncertainties of rainfall due to climate change could worsen this situation further.

As far as spatial distribution of rainfall is concerned, wet zone receives year-round rainfall compared with dry and intermediate zones. The wet zone occupies one third of country's land and houses over 55% of the population. The per capita availability of land in wet zone is far below the country's average and acute scarcity of land is the major limiting factor that wet zone faces. On the other hand, dry zone where the majority of arable land is located constantly faces the challenge of water scarcity caused by uneven spatial distribution of rainfall. The water supply in the dry zone is a time bound matter determined by limited rainfall and high rates of evaporation. On average, dry zone experiences uneven seasonal distribution of rainfall within a year. Unevenly distributed rainfall together with high rate of evaporation creates an acute deficit in water supply nearly for 5 months. Inter-annual fluctuations could lead to further scarcity, resulting in lengthy dry spells or drought conditions. Situation of water scarcity could vary within the dry zone itself, depending on the availability of irrigation facilities and accessibility to groundwater.

Demand for water in Sri Lanka originates from 4 major uses as irrigation, domestic, industry and energy purposes. The water demand projection by Amarasinghe et. al;1999 shows that in 2025, the highest demand for water originates from irrigation in dry zone. As a result, severe water scarcity can be expected at least for one season in 13 out of 16 dry zone districts and moderate water scarcity is expected in the wet zone. Domestic and industrial demand is comparatively low and 62% of it would originate from wet zone. The above projections are applicable under existing low water use efficiency scenario and this can be improved by increasing the water use efficiency in irrigation. For instance, it shows that the country would require around 11 km^3 of water annually by 2025 for both irrigation and domestic/industrial purposes under low water use efficiency scenario. This may be reduced to 6 km^3 if the water use efficiency in irrigation could be increased.

Prospects for meeting water demand from groundwater also have serious limitations. Seven types of aquifers have been identified in Sri Lanka, namely: shallow karstic limestone, coastal sand, deep confined, laterite, alluvial, shallow regolith and deep fractured zone (Survey Department, 2007). Shallow aquifers still play an important role in household supply of water through domestic wells in many areas. Dry zone areas have two sources of groundwater of limited potential; 'shallow regolith aquifer' and deeper fracture zone aquifer (Herbert et al., 1988). The former is found more widespread at depths ranging from 3-12 m and is currently being tapped heavily for agriculture through agro-wells. The latter has more sporadic distribution and is found in deeper zone ranging from 40 m and below. Sedimentary formations provide significant groundwater potential in the northern region, especially in Mannar, Killinochchi and Jaffna districts, which is being heavily exploited for agricultural, household and industrial needs of water (Thushyanthy et al., 2012; Villholth et al., 2010).

Besides the above-mentioned situation relating atmospheric and geological sources of water supply, number of other factors could positively and negatively affect the availability of water resources in the country. Among others, two major factors could be expected to intensify the situation of water scarcity in future, namely, destruction of critical watersheds and water pollution. Two major concerns associated with watersheds in Sri Lanka are degradation of critical upper watersheds, destruction of reservoir catchments and degradation of riverine lowland habitats.

Sri Lanka has a radial drainage pattern where the strategic role of central highlands is critical. Hence, the vegetation cover in central highlands plays a major role as upper watersheds of major river basins originate there. Vegetation cover in upper watersheds regulates the stream flow of rivers, ensuring water availability for many parts of the country. Having opened for establishing of plantation crops from early nineteenth century, continuous degradation of upper watersheds remains a major problem of water management in the country.

The landscape in downstream lowland areas of the dry zone is studded with network of numerous irrigation tanks. Besides high loads of sediments carried from degraded upper watersheds, rapid clearing of surrounding catchments has become a major threat for sustainability of these reservoirs. The entire irrigation network has been organized as cascade systems (locally known as '*Ellnaga*') of small, medium and large tanks that functions as a huge rainwater harvesting system. Besides the critical role played by upper watersheds, proper management of catchments of individual tanks also is highly important for the sustainable functioning of the system.

Sri Lanka has a radial drainage pattern and major rivers that originate in upper watersheds in central highlands passes through lowland plains before reaching the coastal zone. Not only the upper watersheds but lowland riverine habitats also play an important role for ensuring the water availability while offering many ecosystem services such as serving as floodplains and housing biodiversity rich habitats. Lowland riverine habitats have come under threat due to increased human activities such as clearance of vegetation, sand mining and encroachments. Unlike degradation of upper watersheds and reservoir catchments, this is an area that has received less attention of policy makers and researchers in spite of clear signs of habitat degradation are visible.

Studies have predicted undesirable impacts on water resources due to changing patterns of rainfall, rising temperature and increased incidence of extreme events. Destruction and degradation of watersheds and riverine habitats would lead to increase the stress of such undesirable impacts further. Therefore, importance of conservation of upper watersheds, reservoir catchments and riverine habitats as a measure of adaptation to climate change cannot be underestimated.

Water pollution further increases the scarcity of water in addition to being a major environmental problem faced by the country. Few major sources of pollutants responsible for the problem in different areas are solid waste and domestic wastewater, industrial pollutants, fertilizers and agro-chemicals. In urban areas, solid waste and domestic wastewater are the major sources of water pollution. Open dumping of garbage and their dispersal through runoff flow in rainy periods channel pollutants into water sources.

In rural areas where agriculture dominates, fertilizer and agro-chemicals are the major sources of water pollution. Fertilizer and agro-chemicals applied to crops end up in surface or groundwater leading to adverse health conditions and destruction of aquatic biodiversity. Water pollution caused by these major sources lead to reduction of water available for agricultural, domestic and industrial purposes. This would increase the vulnerability of communities that are faced with rising scarcity of water due to impacts of climate change.

1.8 Coastal and marine resources

Sri Lanka has 1,700 km long coastline around the island which in most parts is a low-lying coastal belt. The coastal zone is rich with numerous coastal and marine ecosystems such as mangroves, salt marshes, dunes, beaches, barriers and spits, coral reefs, seagrass beds, lagoons and estuaries and other water bodies. Marine resources of the country lay beyond the coastal zone are comprised of Exclusive Economic Zone (EEZ), Contiguous Zone, Territorial Sea and Historical Waters (Survey Department, 2007).

About 40% country's population is concentrated in townships in the coastal zone. Major economic activities based on the coastal and marine resources include fisheries and aquaculture, tourism, ports and shipping, manufacturing industries, paddy farming, urban utilities and service sectors and power generation facilities. Around 300,000 families make their living out of fisheries in coastal, off-shore and deep-sea areas (Ministry of Fisheries, 2016).

Coastal zone represents the interface between land and sea and therefore it is an area of high ecological importance. Island nations like Sri Lanka stand to face the greatest challenge due to climate change impacts such as sea level rise and ocean acidification. Coastal and marine ecosystems are identified among the most vulnerable ecosystems to climate change adverse impacts. The recent disasters have clearly shown the vulnerability of country's low-lying coastal areas to future rise in sea level too.

Inundation of low-lying areas and salt-water intrusion are the major impacts that can be expected due to rise in sea level. Coastal ecosystems such as mangroves have an important role to play in reducing the impacts of sea level rise, as well as the highest sequestration of CO_2. Hence, loss of ecosystem services due to destruction of mangroves can be identified as a major factor that would increase the vulnerability of coastal communities to sea level rise.

Problems of coastal erosion and destruction of coastal habitats are the most critical issues associated with coastal resources depletion in Sri Lanka. Coastal erosion due to both natural and manmade causes is a serious challenge faced by coastal resources managers. Major impacts of coastal erosion include shoreline retreat, intrusion of salt water into freshwater sources, loss of productive lands and development on salinity in coastal lands.

Physiographic and environmental conditions described in this chapter provides the basis for understanding the nature of climate change impacts in Sri Lanka and physical/natural conditions under which the country has to take actions against those impacts. In essence, it outlines the natural/physical conditions that determine the vulnerability of different economic sectors and communities to the impacts of climate change and the broad scope available for making appropriate adaptation and mitigation choices. More in-depth aspects will be discussed further in respective Chapters on 'Vulnerability and Adaptation Measures' and 'Mitigation Analysis and Options' with relevant technical details. Not only the physiographic and environmental factors, the country's prospects for facing the impacts of climate change are shaped by human factors too, which involves the current situation and trends associated with population, socio-economic conditions and institutional arrangements. These aspects are discussed in the forthcoming sections of this chapter.

1.9 Economic Development

Sri Lanka's economy has reported ups and downs over time under the influence of internal drivers as well as external factors. Sri Lanka adopted the liberal economic policies 1977 onward. Since then, the successive governments followed an outward oriented strategy of export driven growth replacing hitherto followed inward looking import substitution strategy. Transformation from import substitution strategy to the export promotion strategy called for deep structural changes in the economy. The key element of government policy to achieve this was creating conditions necessary to attract foreign direct investments (FDI) for export-driven ventures that can create employment opportunities. The government followed a policy of setting up specialized export processing zones and offering incentive packages for investors. Moreover, the export promotion strategy was complemented by opening the economy for trade and capital flows and adopting a liberal exchange rate regime. Parallel to these structural changes, all governments invested on development of agriculture and rural infrastructure with the aim of connecting rural economies to the domestic and global markets. This has enhanced the market access for agricultural products and facilitated commercialization of rural economies further. The government introduced these changes while continuing the free health and education services to the public and social welfare programmes.

Sri Lanka reported Rs. 9,889,379 million gross domestic product (GDP) at market price in 2019. This amounted to a per capita GDP of 3,852 US$. The service sector, manufacturing sector and, agriculture and forestry sector contributed to the GDP in 2019 as 57.4%, 5.8% and 15.6% respectively.

Climate-induced disasters have emerged as a major threat to economic development, incurring significant economic losses on regular basis in the fast decades. Sri Lanka has been ranked the second in the Global Climate Risk Index 2019 by Germanwatch with annual losses of 3,129 US$ million (PPP) due to climate-induced disasters in 2018. Economic losses and damages due to flood events in May 2016 alone have been estimated at Rs. 99.8 billion that amounted to 0.89% of the GDP.

1.10 Agriculture

The agriculture sector covers broad subsectors of crop production, livestock, fisheries and aquaculture. Table 1.3 provides relative contributions of major subsectors of agriculture sector during the period of 2010-2015. In this section, situation in selected agricultural production activities of paddy, livestock and fisheries is reviewed briefly.

Table 1.3 Contribution to GDP by agriculture in Rs. billion

Year	2010	2011	2012	2013	2014	2015
Agriculture	544.91	569.95	592.44	611.68	639.69	670.11
Share of GDP (%)	8.5	8.2	7.8	7.8	7.8	7.8

Source: Department of Census and Statistics (2016)

Agriculture is the most sensitive sector to climate change among all sectors. Extreme events such as droughts and floods have severely affected the agricultural production and farm assets in the recent period. Not only the extreme events, slow-onset impacts such as rising temperature and sea level rise also affect agriculture which are less visible but equally or more damaging. Given the high share of employment in agriculture, such impacts create significant livelihood outcomes affecting a larger section of population. Vulnerability of agriculture sector is directly connected to impacts on water resources, which is directly dependent on climate conditions. Sri Lanka has invested heavily on agricultural water supply that needs special attention in adaptation to climate change.

Paddy production is the main livelihood of rural population in the country. Total production of paddy has shown a steady growth over the years. It has increased more than five folds from 0.9 million Mt in 1960 to 4.8 million Mt in 2015. Paddy production is closely correlated with expansion of area under cultivation. Cultivation area has increased from 595,000 ha to 1,253,000 ha during the period of 1960-2015. Even though paddy is cultivated in all districts of the country nearly a half of the national production comes from four districts in the dry zone; Polonnaruwa (13.1%), Ampara (12.8%), Anuradhapura (11.2%) and Kurunegala (10.3%). Share of production from dry zone districts exceeds 75% while the contribution from wet zone districts is usually less than 10%.

Despite measures taken to enhance the rice production through various supply-side measures such as irrigation schemes, the production base has remained susceptible to climate related hazards which became intensified recently. As a result, crop failures and production losses have become regular incidents in paddy and other field crops. There are no systematic studies undertaken to assess the losses and damages caused by climate change on agriculture.

In 2015, Sri Lanka imported 631.6 million liquid milk equivalents (LME) of dairy products that amounted to 61% of the total supply in the country (DAPH, 2015). Despite high import dependency, relative share of domestic production of milk has increased gradually to 39% in 2015 from 33% in 2011.

Climate change could affect the local milk production negatively, making it difficult to achieve the national production targets. Factors such as limited area of grazing land, declining yield potential of animals due to heat stress and increased incidence of drought would act as barriers for development of local milk production. Hence, suitable adaptation measures to address climate change impacts are essential for maintaining the growth momentum in the livestock sector.

Being an island with a high density of inland water bodies too, the fisheries sector is expected to play an important role in the economy of Sri Lanka. Fish production in Sri Lanka can be categorized under three major sub sectors; coastal, offshore and deep sea, and inland fisheries and aquaculture. The highest contribution still comes from the coastal sub sector that amounts to 51% of the total fish production. However, rapid growth in deep sea subsector can be observed with more investments on multi-day fishing crafts since 1990s. Supply from domestic sources, is supplemented by substantial amount of imports of processed fish too.

In the recent period, rising incidence of unpredictable weather events have caused significant disturbances to fishing and associated livelihoods, leading to significant damages on life and fishing assets. Moreover, sea level rise and ocean acidification, major physical effects associated with climate change, is likely to create significant impacts over coastal and marine fisheries in the long run. Observed and projected threats highlight the necessity of building resilience in fisheries sector.

1.11 Industry and services

The GDP share of industry has fluctuated in the range of 20.6 - 30.1% during the period of 2010-2016 with an average share of 28%. Assisted by various government incentives and structural facilities such as free trade zones and industrial zones, this sector has attained a healthy growth during last 3 - 4 decades and remained competitive even under adverse conditions in the global economy.

Impacts of climate change on industry are multi-faceted and some industrial activities produce significant level of emissions too. In Sri Lanka's context few major impacts appear to be critical such as availability of agro-based raw materials, industrial water supply and infrastructure vulnerability to extreme weather events. Supply of raw materials for agro-based industries is heavily dependent on climate and rising scarcity of water creates difficulties for industrial water supply. Recent floods in wet zone areas, especially in Kelani river basin, have brought severe damages on industrial facilities. Hence, industrial sector deserves special attention not only in mitigation measures but national efforts in adaptation too.

Services are the dominant sector in the economy that contributed 57% to GDP in 2016. It has shown a slow but steady growth throughout the period, starting from 54.6% in 2010.

Service sector is involved with activities leading to mitigation of as well as adaptation to climate change. While some service sector activities (e.g. transportation) are main contributors to GHG emissions, many of them (e.g. health, tourism) are highly vulnerable to impacts of climate change too. Some services provide the essential basis for designing and implementation of both mitigation and adaptation measures (e.g. public administration and defence, insurance, financial services). Hence, the service sector has multifaceted involvement with climate change.

1.11.1 Transport service

There are 4 major modes of transport operating in Sri Lanka; road transport, rail transport, shipping and aviation. Transport sector covers both passenger and cargo. Total length of the road network in Sri Lanka was 31,450 km in 2016 including expressways. The total length of rail track network in Sri Lanka in 2015 was 1,568 km. Sri Lanka has 4 foreign vessels arriving shipping ports (Colombo, Galle, Trincomalee and Hambantota) and two international airports (Katunayake and Mattala). Road transport has both public and private transport options whereas other modes are mainly public transport modes. Public road transport reported 65,688 million passenger kilometers in 2016 whereas railways covered 7,413 passenger kilometers. The rest come from government owned and regional transport companies. The national airline has flown 12,855 passenger kilometers in 2016. Sri Lanka's vehicle fleet has rapidly been growing. The total fleet of vehicles has increased more than 3 times during the period of 2000-2015.

An important development in transport sector is growing popularity of hybrid and electric vehicles among private car users. Both hybrid and electric vehicles help to raise fuel use efficiency of vehicles in the country thereby contributing to reduce both the fossil fuel dependency and emissions. The Government has promoted the hybrid and electric vehicles by offering import tax incentives. As a result, significant growth in the share of hybrid and electric cars in local vehicle fleet can be observed. In 2015, out of the total of 99,600 petrol cars imported, 40,800 (41%) were petrol hybrids (Department of Motor Traffic, 2016). Besides, promoting low emission vehicles, the government is also making efforts to shift from private to public modes of transport.

Transportation is too a vulnerable sector to impacts of climate change. For instance, regular disturbances to transport sector occurs due to extreme weather events throughout the country. The tendency seems to be rising over time and this creates fiscal burdens for rehabilitation and maintenance of transport infrastructure frequently. Hence, the transport sector also needs the support of appropriate adaptation measures to cope up with projected impacts of climate change in addition to mitigation measures for reducing emissions from transportation.

1.11.2 Healthcare service

Sri Lanka is covered by a network of public healthcare facilities that provides free health care to all. In addition, private healthcare services also show a tendency towards growth, especially in urban areas. The countrywide public health service facilities have helped raising the indicators of maternal child health indicators that are in par with higher middle-income or even higher income countries. Sri Lanka has also shown commendable progress in eradicating some communicable diseases such as Malaria and Tuberculosis. The World Health Organization (WHO) certified Sri Lanka as a Malaria free country in 2016. In spite of these achievements, however, rising incidence of other communicable diseases such as Dengue has been reported during the recent years.

The main challenge in health sector in Sri Lanka is posed by non-communicable diseases. In addition, reports indicate that incidence Chronic Kidney Disease (CKD) is spreading rapidly in certain areas of the country. The key factors that contribute to the increasing prevalence of non-communicable disease include ageing population, unhealthy food habits, and the rise of alcohol and tobacco consumption. Growing incidence of CKD is suspected of resulting from exposure to pesticides pollution.

Sri Lanka has experienced rising incidence of outbreak of diseases that are closely connected with environment and weather patterns such as seasonal outbreaks of dengue from the recent past. Moreover, extreme weather events have resulted in increased numbers of fatalities and injuries. Another potential health hazard that needs close attention is spread of vector borne diseases into new areas with changing patterns of local climate. Sri Lanka has an ageing population and gradual rise in temperature and sudden fluctuations in weather patterns can directly affect the living comfort and health of them. Hence, all observations and projections suggest that Sri Lanka's health system has to face increased challenges due to climate change which demand adaptive solutions.

1.11.3 Education

Sri Lanka has reported significant achievements in education system. Literacy rates of both male and female populations exceed 97%. The net primary enrolment rate was 99% in 2015 while the secondary enrolment rate was also high at 85%. These achievements can be considered as a favorable outcome of education policies pursued by successive governments. Country has launched universal free education policy even before gaining the political independence in 1948 and countrywide system of public schools helped to achieve this target. Country adopted compulsory education for children aged 5-14 in 1998. Besides providing free and compulsory education, the government also offer free textbooks, free uniforms, subsidized transport and free school meals for school children.

Not only the school education, the state also provides free tertiary education in 15 government universities and 5 higher education institutes run by the University Grants Commission. These universities and higher education institutes have 556 academic departments that offer courses on different subject areas including environmental science and climate change (more details in section 5.2). In addition to state universities, there is large number of private higher education institutes that offer degree courses of their own or in affiliation with foreign universities.

Climate change has the potential to create harmful impacts on the education system. Recent extreme events dropped school attendance frequently while occasionally forcing the authorities to close down schools temporarily. Floods caused temporary displacement of children of victimized households, often resulting in losses and damages to their school books and other educational materials. Displaced children had to miss their school attendance for several days and in few occasions bar examinations had to be rescheduled for accommodating children faced with disaster events. Even though not systematically investigated, spread of climate sensitive diseases (e.g. dengue) among school children has apparently increased recently.

On the other hand, education is a key factor that determines the adaptive capacity of the country against climate change too. The national education system can contribute to increase the awareness and develop the skills necessary for facing the threat of climate change, i.e. adaptation and mitigation. In addition, school children are being given disaster awareness, including mock drills to increase the preparedness in disaster prone areas. Children educated in causes and impacts of climate change and appropriate climate actions, while strengthening the country's future capacity for implementing mitigation and adaptive actions, can also be considered as an effective channel for communicating knowledge on climate change to other household members too.

1.12 Energy

A major share of Sri Lanka's primary energy still comes from renewable indigenous sources, namely, biomass and hydro. Accordingly, 42% of primary supply comes from biomass sources, whereas hydro and non-conventional renewable energy (NCRE) account for 8% and 3%, respectively (SLSEA, 2015). Fossil fuel sources contribute to 47%. Fuel wood is the major type of biomass widely used in households, especially in rural areas, for domestic cooking, heating of water etc. Besides, a large number of small and medium industries also use biomass for boilers, driers and kilns, etc. Other forms of biomass energy such as coconut shells, bagasse and paddy husk also play a limited role. The data indicate that the composition of the power and energy mix in Sri Lanka is transforming gradually. The share of renewable energy in the primary energy has slowly decreased while the share of petroleum has increased. It has increased the import dependency of energy sector. Coal and NCRE have come as new entries to energy mix.

Demand for electricity has been steadily increasing over the years. The highest demand comes from the domestic sector followed by the industrial and commercial sectors. The demand from household and commercial sectors has been growing faster than the demand from industry. As a result, the share of electricity in industrial sector has been shrinking even though actual consumption has increased. Rapid growth in demand for electricity and susceptibility of hydro power generation to rainfall uncertainties compelled to increase the capacity of thermal power generation from 1990s onwards. As a result, during the last decade, the share of thermal generation has increased up to over 60% of total annual generation and continues to grow even further.

Sri Lanka's growing dependency on fossil fuels has economic, social and environmental impacts. As far as import volume of petroleum is concerned, it has nearly doubled during the period of 2006-2015 indicating growing demand for petroleum. In terms of the composition of imports, locally refined quantity of petroleum has gradually decreased while the share of refined products has increased. Import of coal, a new entry to the energy mix has increased steadily from 2010 onwards after commissioning of first coal power generation plant.

Growing dependency on fossil fuel creates balance of payment pressures on the economy. The burden of fossil fuel imports is a result of both increased volume as well as price hikes. In Sri Lanka, energy sector plays a critical role in mitigation of and adaptation to climate change. Growing dependence on fossil fuel for power generation has made the energy sector a major source of GHG emissions. As a result, Sri Lanka's nationally determined contributions (NDCs) to the Paris Agreement mainly concentrated on the energy sector. On the other hand, power generation in the country is still dependent on hydro power facilities to a significant extent. Changing patterns of rainfall appear to have a direct impact on them. Rising temperature also could affect water availability in reservoirs. Hence, energy is an economic sector that needs careful attention of both mitigation as well as adaptation policies of the country.

1.13 Tourism

Sri Lanka offers a unique tourism destination in the world where multiple attractions are offered within a relatively small area which can be accessed by few hours travel from one attraction to many other. Key attractions include scenic beaches, archaeological sites, nature based, cultural heritage and events. Each of them has the multiple sites of attractions.

In 2016, total earnings from tourism reached 3.52 US$ billion. At this level tourism has become the third highest earner of foreign exchange to the national economy. Its contribution to total foreign earnings reached

14.2%. Total estimated employment in the tourism sector (both direct and indirect) was 335,659 which is 5.1% increase from the previous year.

By its nature, tourism is highly sensitive to disturbing conditions such as natural disasters and adverse weather conditions. Sri Lanka is frequently experienced adverse effects of climate change. Hence, climate change can adversely affect the demand for tourism, creating difficulties for operational activities of tourism. It can also affect the infrastructure facilities and assets of tourism industry making them vulnerable to climate related hazards. This implies that carefully planned adaptation measures are necessary for maintaining the demand for tourism in Sri Lanka while ensuring efficient operation of the industry under rising impacts of climate change.

1.14 Waste management

Waste management is a major challenge in densely populated urban areas where garbage is generated in large quantities. Many local authorities adopted open dumping as the usual method of disposal. This has given rise to problems of environmental and sanitary hazards. Moreover, local authorities found it increasingly difficult to find suitable dumping sites as lands become scarcer. Studies have established that average composition of municipal solid waste (MSW) generated in households contains 60-70% biodegradable organic waste. Organic content mainly comes from kitchen and garden waste. The rest is consisted of plastic, paper, metal, glass and wood which are reusable and recyclable. Further, studies have also shown moisture content of MSW vary from 70-80% with calorific values around 600-1,000 kcal/kg. Limited daily collection and composition of waste restricts the use of certain alternatives of waste management unviable. For instance, high moisture content and low calorific value restrict the use of incineration while limited collection makes sanitary land filling economically non-viable option. The absence of proper waste management has led to health, social and environmental problems from the point of generation to the point of disposal.

The responsibility of MSW management is vested to the local government by the Pradeshiya Sabha Act, the Municipal Council Ordinance and the Urban Council Ordinance. The waste management plans of the country are formulated and executed based on the data records available with the relevant government agencies such as the National Solid Waste Management Support Centre (NSWMSC) operated under the Ministry of Provincial Councils and Local Government, Western Province Waste Management Authority (WPWMA) and Central Environmental Authority (CEA). Certain steps have been taken by the NSWMSC, Ministry of Environment, the CEA and the WPWMA to improve the situation.

1.15 Governance and institutional set up

The government of Sri Lanka have three levels of administrative structures, namely; the central government, Provincial Councils (PCs) and local Authorities (LAs). Each level of the government comprises elected representative bodies.

The Cabinet headed by the Executive President and the Parliament are the elected representatives of the central government. The central government comprises of a hierarchy of organizations, ministries at the top most level to the village officers at the bottom. At the top level, line ministries take policy decisions on broad subject areas of governance. There may be number of line agencies under each ministry to handle specialized areas of the broad subject of the ministry. Two broad categories of line agencies are government departments and state-owned enterprises (SOEs). The SOEs include statutory boards and institutions such as Authorities, Boards, Institutions as well as public enterprises (e.g. State Banks, Corporations, and Government Companies) that have some independence of handling their finances and managerial functions. The budget expenditures of ministries and departments are directly allocated and controlled by the Treasury. At the local level, the central government is represented by regional/local branches of different line agencies and the uniform hierarchy of district administration comprised of District Secretariats, Divisional Secretariats and *Grama Niladari* (Village Officer) Divisions.

Below the level of central government, there are 09 Provincial Councils (PCs) that are comprised of elected members. Provincial governments are nominally headed by a Governor appointed by H.E. the President. The executive powers are vested with the Chief Minister who is an elected member. Administrative structure of the PCs comprises of provincial ministries and provincial line agencies (provincial departments and authorities).

Special arrangements are available for allocating finance to PCs through the Finance Commission and the Ministry in charge of Provincial Councils and Local Government of the central government.

Local Authorities are the grass-root level administrative set up of Sri Lanka. They have three types of elected government bodies, namely; Municipal Councils (MCs), Urban Councils (UCs) and Pradeshiya Sabhas (PSs). Policy decisions taken by the elected representatives are implemented by government civil servants. Functions and responsibilities of LAs include: public health and sanitation (primary health care, solid waste management, maintaining the drainage system, conservancy and scavenging services etc..); public thoroughfares (maintenance and repair, servicing, actions against damages, utilization for special purposes, etc..); community development (pre-schools, libraries, etc..), and; public utility services (water supply, markets and fares, play grounds, public and children's parks, etc..).

Climate change has been identified as a subject relating to environment within the overall mandate of the Ministry of Environment. The national focal point for the UNFCCC is the Ministry of Environment in Sri Lanka. The national policies, programs and institutional arrangements relating to climate change are fast being developed in the country. The subject of climate change has been assigned to the Climate Change Secretariat (CCS) functioning in the Ministry of Environment.

Addressing climate change issues requires a complex institutional mechanism for coordinating actions of several line ministries and agencies. Hence, the CCS is playing a coordination role among several line ministries and agencies. Other key agencies that come under different ministries that deal with areas relating to climate change are the DoM, DMC and NBRO.

Sri Lanka is yet to introduce dedicated legal provisions guaranteed by a parliamentary act to address climate change issues other than general provisions made available in the National Environmental Act and other sectoral legislations. The formulation of National Climate Change Policy (NCCP) of Sri Lanka in 2012 has been a major milestone of the national agenda on climate change.

In addition, National Climate Change Adaptation Strategy for Sri Lanka (2011-2016), Technology Needs Assessments (2014), National Adaptation Plan for Climate Change Impacts (2016-2025) and the Nationally Determined Contributions (NDCs) in 2016 and 2021 are the key climate change related documents that have been prepared by the CCS.

1.16 Preparation of National Communications

Sri Lanka has prepared two national communications and submitted to the UNFCCC in 2000 and 2012. The preparation of Third National Communication (TNC) was coordinated by the CCS and a project management unit (PMU) was established under the CCS to prepare the TNC.

Overall supervision and guidance for the preparation of TNC was made by the Project Executive Board established with the representation of Ministry of Environment, Department of External Resources, Department of National Planning and UNDP Sri Lanka which was chaired by the Secretary, Ministry of Environment. Teams of consultants and individual experts were appointed for particular tasks to be performed. Consequently, three national experts and team of sector experts were appointed for preparation of GHG Inventory, Mitigation Analysis and Options, and Vulnerability and Adaptation Measures (VAM) separately. Four individual consultants were on board for preparation of chapters on National Circumstances; Education, Training, Awareness and Capacity Building; Technology Transfer, Research and Systematic Observations; Gaps, Constraints and Needs. Further, an expert was on board to make socio economic analysis for the VAM chapter. In order to coordinate between PMU and consultants including experts two Technical Coordinators for adaptation and mitigation separately were appointed. During the data collection, analysis and preparation the TNC report by aforesaid consultants and experts to ensure the accuracy and quality of outputs a seven-member Independent Review Panel (IRP) was established comprising well knowledgeable and experienced professionals in this field. Regular progress review meetings were conducted to assess the progress of each consultancy and the IRP participated for those meetings. Series of workshops and stakeholder consultations were held to gather the required information and data for the preparation of TNC report and validate the outputs. In addition to the national expertise and consultancy occupied, an international consultant was hired for sharing international experience on developing national communication.

Necessity of developing a climate change data portal with data sharing and continuous updating facilities has been identified and highlighted by many stakeholders. Not only the preparation GHG inventory, such a data sharing and updating mechanism would help all layers of stakeholders from grass-root level development workers to highest level policy makers in taking decisions on multiple areas of climate action. The CCS is currently planning to launch this initiative based upon the data collected and generated in preparation of the TNC. Accordingly, all information collected by the consultants from different sources and new information generated in the study were uploaded into a database which will provide the basis for continuous updating and sharing of data.

1.17 Multi stakeholder engagement

The CCS has to work in close coordination with multiple national agencies to implement the climate actions. It includes government ministries, departments and constitutional bodies, civil society organizations (CSOs), private sector, academia and media.

Presently, number of CSOs that are dedicated to areas of environment and sustainable development also work in climate change related issues. In spite of that some CSOs currently work in coordination with the CCS and other public agencies in areas relating to climate action.

Even though not specifically identified as climate action, the private sector in Sri Lanka has made some positive steps towards this direction. This is particularly visible in energy sector where, private-public partnerships relating to non-conventional renewable energy (NCRE) have emerged through the facilitation of Sri Lanka Sustainable Energy Authority (SLSEA). The Government has opened some avenues for private sector participation in NCRE through the programmes initiated by SLSEA and the long-term generation expansion plans of the Ceylon Electricity Board (CEB). Net metering for solar energy systems supplied by private sector companies is available for domestic users from the two electricity suppliers in the country namely CEB and Lanka Electricity Company (LECO). Some encouraging private sector involvements are emerging in the area of improving energy efficiency in domestic and industrial sectors too. Energy efficient lighting such as CFL and LED are getting popular and private suppliers are already catering to meet the rising demand. Solar Industries Association (SIA) and Renewable Energy Development Association (REDA) are two business organizations that has been established to promote the common interests of private sector companies working in the area of NCRE.

1.18 Climate financing

Sri Lanka's climate financing has three major sources, namely; public, private and donor funding. Public financing through the government budget is the dominant source of funding for both adaptation and mitigation actions while donor funding has supplemented the government efforts through few major projects and several small projects. Public financing for climate action includes both 'direct' as well as 'indirect' climate finance. Direct climate finance is funding aimed at addressing specifically identified climate change related purposes. For instance, annual budget allocation for renewable energy generation and adaptation related areas such as improving the climate forecasting facilities of the DoM and disaster mitigation measures.

As far as direct public financing for climate related purposes are concerned, two major areas can be mainly identified as financing for climate change mitigation (renewable energy, e-mobility, greening industries) and financing for climate change adaptation (disaster management and resilience building). The government is currently allocating significant resources for improving renewable energy sector and demand side management (DSM) programmes in industrial, commercial and household sectors. Also, significant public funding has been allocated for risk reduction and relief on climate-induced disasters that has mainly been channelled through the Ministry in charge of disaster management and line agencies coming under the same.

However, it appears that government has more indirect financing for adaptation in areas such as irrigation and water management, agriculture, health, coastal zone management, biodiversity and ecosystems conservation which are contributing to build resilience unless specifically identified as climate financing. Even though there are no systematic assessments, it appears that indirect financing for climate change adaptation is higher than direct financing given the indirect funding is being allocated.

As far as private climate financing is concerned, significant investments can be found in areas relating to NCRE such as solar power systems and wind power generation and importation of electric vehicles. These investments have revealed the objective of reducing emissions that can be considered as private sector financing for climate change mitigation. Information on private sector financing for climate change adaptation is slightly available however it is apparent that private sector entities are taking voluntary measures to face climate change impacts such as prolong droughts and floods.

The public and private sectors' efforts for adaptation are further enhanced by donor funding. At present, there are few major projects directly aimed at addressing climate change issues. Two examples are World Bank funded 'Climate Resilience Improvement Project (CRIP) and the Green Climate Fund (GCF) granted 'Climate Resilient Integrated Water Management Project (CRIWMP)' implemented by the Department of Irrigation and the UNDP Sri Lanka. The CRIP is addressing adaptation needs in 10 major river basins in the country. The CRIWMP is focusing on enhancing the adaptive capacity in cascaded tank-village systems in the dry zone.

CHAPTER TWO

National Greenhouse Gas Inventory

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National Greenhouse Gas Inventory

2.0 Introduction

In accordance with the Decision 17/CP.8 (FCCC/CP/2002/7/Add.2), Non-Annex 1 parties are required to estimate anthropogenic emissions by sources and removals by sinks of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in their national greenhouse gas (GHG) inventories. Countries listed in the Non-Annex 1 parties are also encouraged to provide information on anthropogenic emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) and emissions of ozone precursors such as carbon monoxide (CO), nitrogen oxide (NO_x) and non-methane volatile organic compounds (NMVOCs). In addition, Non-Annex I parties may also report on other gases not controlled by the Montreal Protocol such as sulphur oxides (SO_x).

Sri Lanka, as a Non-Annex 1 party, used the 2006 IPCC-GLs (IPCC, 2006) in the current GHG Inventory, predominantly considering the Tier-1 approach. It includes the emissions from Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land-Use (AFOLU) and Waste sectors. AFOLU emissions and removals are reported under Agriculture, and Land Use, Land Use Change and Forestry (LULUCF) separately.

However, revised 1996 IPCC-GL was used for the calculation of HFC emissions in IPPU sector and the emissions of precursors, CO, NO_x and NMVOC, in the energy and IPPU sectors as these precursor emissions are not given in the 2006 IPCC-GL. The emission factors (EFs) for certain forestry subcategories were extracted from the Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC, 2003).

The GHG inventory provides emissions by sources and removals by sinks under the above sectors and relevant sub-sectors focusing on the year 2010. In addition, GHG emissions were calculated for the time series 2000-2010. Emissions were calculated in units of mass, and in CO_2 equivalents using the global warming potential (GWP) values given in the IPCC Second Assessment Report (IPCC, 1996).

In the energy sector, emissions from fossil fuel combustion activities and fugitive emissions were estimated. Under the fossil fuel combustion activities, energy industries (including electricity generation and petroleum refining), manufacturing industries and construction, transport and other sectors (i.e. household, commercial and agriculture sectors) were considered. The transportation and storage of CO_2 are not relevant to Sri Lanka and hence not included in the current GHG inventory. Under the IPPU sector, CO_2 emissions from mineral industry and emissions of HFCs were estimated.

The agriculture related emissions include CH_4 from rice cultivation, enteric fermentation and manure management, and N_2O emissions due to soil fertilization and added nitrogen from nitrogen fixing crop residues as well as indirect emissions due to manure management. Carbon dioxide emissions due to liming and urea application, emission estimates of CH_4, N_2O and gaseous emissions such as NO_x and CO due to crop residue burning are also given. The emission estimates associated with LULUCF include the carbon stock change in biomass, dead organic matters, mineral soils and disturbances. Under the waste sector, emissions of CH_4 and N_2O by the disposal of solid waste in sanitary land-fills and open dumping and wastewater treatment facilities were estimated.

2.1 Arrangement for preparation of GHG Inventory

This GHG Inventory was prepared by the Climate Change Secretariat (CCS) of the Ministry of Environment. The Project Management Unit of CCS was primarily responsible for preparation of this inventory, with the support from a Technical Coordinator, National Expert and a Team of Sector Experts.

The followings were considered for the preparation of this GHG Inventory;

1. 2006 IPCC Tier-1 methodology was used. The default emission factors were used due to the concerns on validity and accuracy of certain nationally available EFs.
2. Priority given towards collection and utilization of nationally available activity data.
3. Utilization of pre-determined data templates in line with the worksheets of 2006 IPCC-GL.

4. Maximum use of the nationally available information and capacities through consultation of additional sectoral experts and stakeholders, as needed.

2.2 Overall methodology and summary of sector wise emissions

The GHGs and emissions of precursors were estimated using the IPCC methodology as indicated above and the nationally available activity data.

The methodology from 2006 IPCC-GL based on activity data on carbonate raw material were used to estimate emissions in the sub-categories of IPPU sector, along with default EFs, as national level production data were not available for the final products. For the category of consumption of fluorinated compounds (e.g. HFCs), the Tier-1 methodology of 1996 IPCC-GL was used.

Many of the above industrial processes also emit precursors including NO_x, NMVOC, CO and SO_2. Industries that emit precursors are listed in Table 7.1 (Volume I) of 2006 IPCC-GL. However, EFs for these precursor emissions are not given in the 2006 IPCC-GL and reference has been made to EMEP/CORINAIR Emission Inventory Guidebook (European Environment Agency, 2006) to obtain these EFs.

Most of the data needed for the 2006 IPCC methodology were not properly recorded or available in the country. The Annual Survey of Industries by the Department of Census and Statistics covers all the economic activities including mining, quarrying and manufacturing among others. There was no publication available with the data or information on the actual physical output of the industries or actual energy consumption. Hence, most of the data were collected directly from the relevant industries. Out of the contacted industries, only a few had data collected for prior years to 2010.

The data collected at district level (e.g. for AFOLU sector) or at factory/plant level (e.g. IPPU and waste sectors) were aggregated to derive the final national level estimates. Following the climatic classification in 2006 IPCC-GL, the "Tropical Moist" (covering the conventional dry and intermediate zones) and "Tropical Wet" (covering the conventional wet zone of Sri Lanka) climates were considered under the agriculture and land use-related sub sectors. All the GHG estimates were calculated with units given under 2006 IPCC-GL and the GHG emissions other than CO_2 were converted to CO_2-eq units, considering global warming potential (GWP, 100-year time horizon) of each GHG. Global warming potential of gases were obtained from IPCC Second Assessment Report.

2.3 Quality Assurance / Quality Control (QA/QC)

Greenhouse gas emissions and removals estimated under each sector and specific sub sectors were thoroughly checked periodically at the inventory preparation progressed. The assessment of the accuracy of the estimates were repeatedly checked through the IPCC equations, EFs and the activity data used. The compatibility of the data available from multiple sources and the decision on the final set of activity data to be used were undertaken in consultation with the national and sector experts, Independent Review Panel established by the Project Management Unit (please see section 1.16) and other stakeholders.

The gap filling in the missing data was also achieved through expert and stakeholder consultations. Information on all the data sources, data extraction methods, default emission factors and their sources used, related supportive documents used in the estimation of GHG emissions, etc., were well noted as a quality control measure. In addition, all the worksheets with the data from different sources and the accuracy of the units, etc., were rechecked.

2.4 Uncertainty assessment

Data collected from some sources were not in a regularly collected and updated. The data which were obtained from different sources for a similar parameter had sometimes significant differences. In such cases, the resolution of data differences and the final selection of the data source were determined through sector-specific stakeholder meetings and expert opinion.

In some data of particular sources were not in the format that what the GHG Inventory preparation required. In such cases, back calculation or conversion were made using rates per unit consumed (e.g. electricity bills, total cost of diesel / petrol / kerosene used, etc..).

Uncertainty in the country-specific EFs was primarily due to the availability of multiple values from different studies. Hence, default EFs suggested in the 2006 IPCC-GL which contain improved EFs compared to the 1996 IPCC-GL were considered. In this respect, sector-level uncertainty is detailed in the respective sector.

There is an uncertainty of about 1.25% in converting volumetric data of fossil fuels using density values meant for 15°C when the ambient temperature in the country is around 30°C. There is also uncertainty of about 2-3% in using IPCC values for Net Caloric Value (NCV) when the few measured values exhibit differences compared to those. In the total energy consumption data, the highest contribution was from biomass consumption. However, the consumption data were based on broader assumptions rather than an actual assessment which may cause uncertainties of at least ~10%. Even the NCV of biomass could be different than the values given in 1996 IPCC-GL.

The use of IPCC Tier-1 methodology where a single EF for CH_4 and N_2O was adopted for an entire sub-sector of transport, industries or households, could be a source of error since actual emissions depend on the type of vehicle used or the type of industrial applications.

The major uncertainty associated with the biomass carbon stock change estimation include the use of default wood density and biomass expansion factors that do not reflect the exact country context. Lack of consistency and aggregated nature of the data also creates an uncertainty. Certain activities such as illicit felling carried out in small scale, removal of tree parts for fuel wood and the exact amounts of biomass lost due to data unavailability, and estimation of soil carbon due to lack of information on the land use type before conversion could not be considered.

A common, default EF was used in estimating the CH_4 emissions from flooded land remaining flooded land. However, in order to reduce the uncertainty in the future, country specific EFs should be developed. Further, maintenance of records on the seasonal wetlands including the number of dates inundated and forest fires dates occurred etc. are also recommended.

In the estimation of GHG emissions from Solid Waste Disposal Sites (SWDSs), the use of default Methane Correction Factor (MCF) might lead to a significant uncertainty as the country's existing SWDSs may not exactly match with the standard classification of SWDSs indicated in the 2006 IPCC-GL. Further, the default values of degradable organic carbon (DOC) content in Municipal Solid Waste (MSW) might also lead to uncertainty as the composition of MSW varies with the consumption patterns due to income levels of the country's population.

Also, estimation of GHGs from open burning of MSW due to the use of default values for the fractions of carbon and dry matter content in the burnt waste, combustion efficiency and fraction of carbon oxidized, etc., as those are directly related with the estimation of CO_2. The conversion of waste from its wet weight to dry weight adds an additional uncertainty and this uncertainty varies substantially depending on the accuracy of the weight fractions used.

Further, in the estimation of GHG emissions associated with MSW composting, the use of default emission factors for CH_4 and N_2O might lead to a significant uncertainty, as the ambient temperature is directly related to the rate of composting of waste material in a specific region.

Similarly, in the estimation of CH_4 and N_2O emissions associated with the discharge of domestic wastewater including sewage, a high-level uncertainty can occur due to the utilization of default values that had been developed for Indian region for the degree of urbanization and the degree of treatment utilization by different income groups, etc.

In addition, in the estimation of N_2O emissions from industry wastewater treatment, assumption of a single value for total nitrogen content in the waste water for a given treatment system for the period of 2000-2010 (in the absence of time-specific total nitrogen data) could lead to some uncertainty as well.

2.5 Summary of emissions and emission trends

The sector-wise overall emissions for the country in 2010 are in Table 2.1. The total GHG emission and removals in 2010 are 43,554.75 Gg CO_2-eq and -39,826.30 Gg CO_2- eq respectively. Accordingly, the net GHG emission in 2010 is 3,718.45 Gg CO_2-eq and per capita GHG emission (excluding LULUCF) is 1.07 tonne with midyear population of 20,653,000 in 2010. However, the per capita net GHG emission is 0.18 tonne in 2010.

In 2010, GHG emission profile of Sri Lanka comprises as 64.1% from energy sector including transport, 29.5% from agriculture sector, 2% from IPPU sector and 4.4% from waste sector.

Table 2.1 Summary of GHG emissions and removals in 2010 in Gg CO_2-eq

Sector	CO_2 emissions	CO_2 removals	CH_4	N_2O	HFCs	Total
Energy	12,810.00		950.46	393.70		**14,154.16**
IPPU	435.59				12.98	**448.57**
Agriculture	340.45		2,860.62	3,304.60		**6,505.67**
Waste	122.78		527.94	325.50		**976.22**
Total excluding LULUCF	**13,708.82**		**4,339.02**	**4,023.80**	**12.98**	**22,084.62**
LULUCF-emissions	21,342.40		112.77	4.96		**21,460.13**
LULUCF-removals		-39,826.30				**-39,826.30**
Net Total	**35,051.22**	**-39.826.3**	**4,451.79**	**4,028.76**	**12.98**	**3,718.45**

GHG emission estimates for the period of 2000-2010 excluding LULUCF are shown in Figure 2.1 and including LULUCF in Figure 2.2. It is revealed that the carbon sequestration is higher than the GHG emission up to 2004 in the country and it is reversed onward 2005 (Figure 2.2).

The total GHG emission in 2010 excluding LULUCF was 22,084.62 Gg CO_2-eq and it was a 25% increase compared to 2000. The highest emissions during the time series were observed after 2006 with slight year-to-year variability.

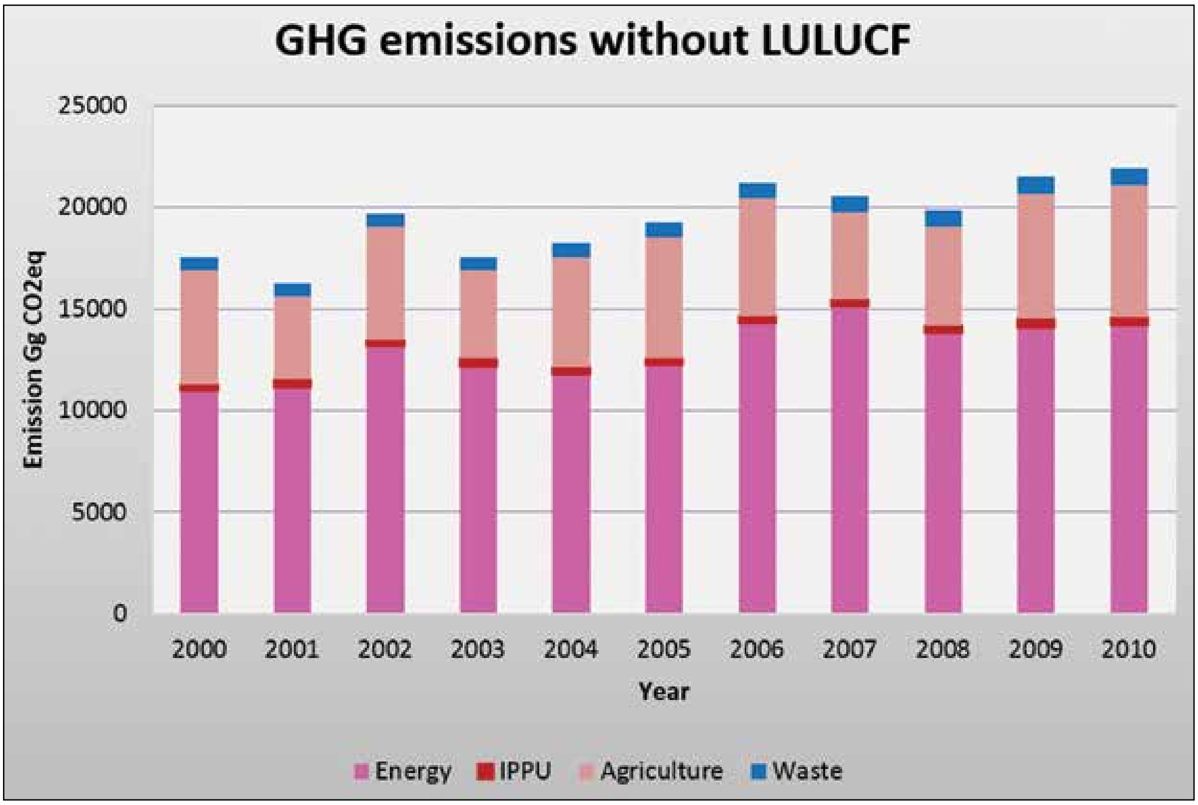


Figure 2.1 GHG emissions by sectors excluding LULUCF from 2000-2010

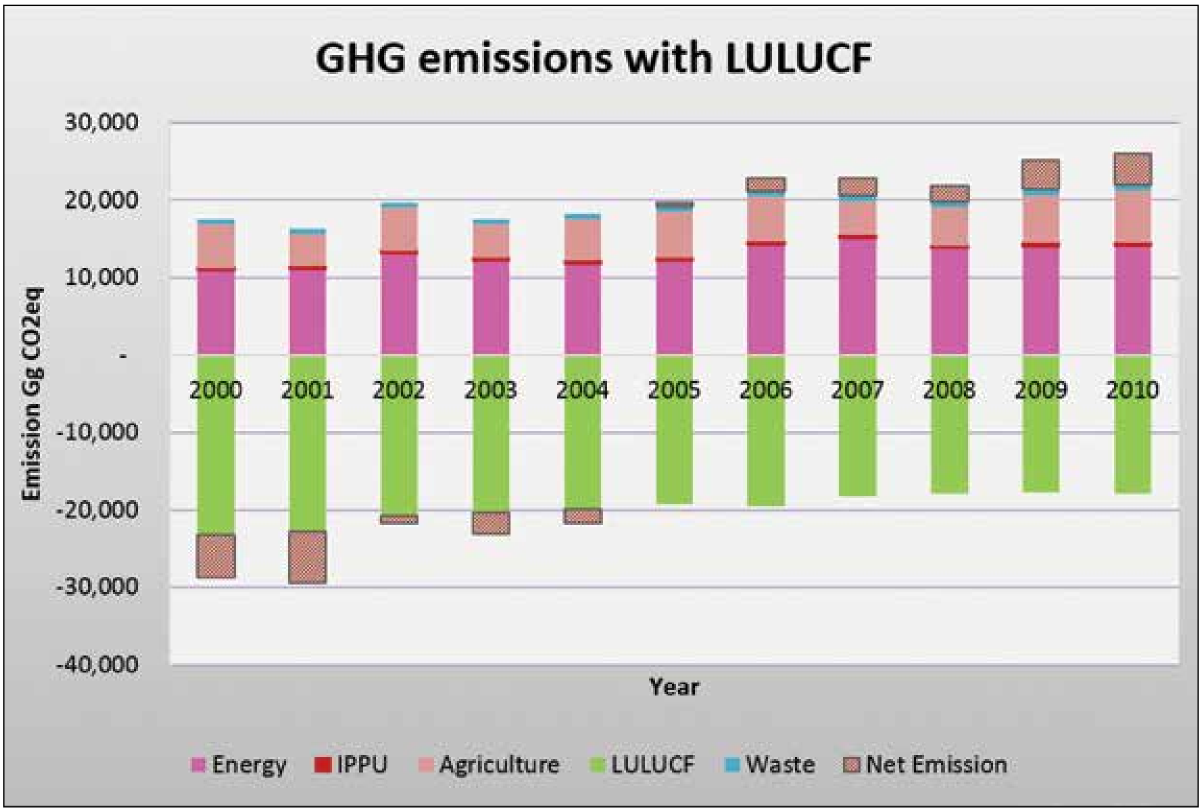


Figure 2.2 GHG emissions by sectors including LULUCF from 2000-2010

The contribution from CO_2 emissions varied between 59% - 66% of the emissions and the contribution from CH_4 emissions was 19% - 21% and that from N_2O ranged between 17% - 20%. The contributions from CO_2, CH_4 and N_2O emissions to the national GHG Inventory in 2010 excluding LULUCF were 62%, 20%, and 18% respectively; 0.0005% of HFC emissions (e.g.12.38 Gg CO_2-eq) was negligible (Figure 2.3).

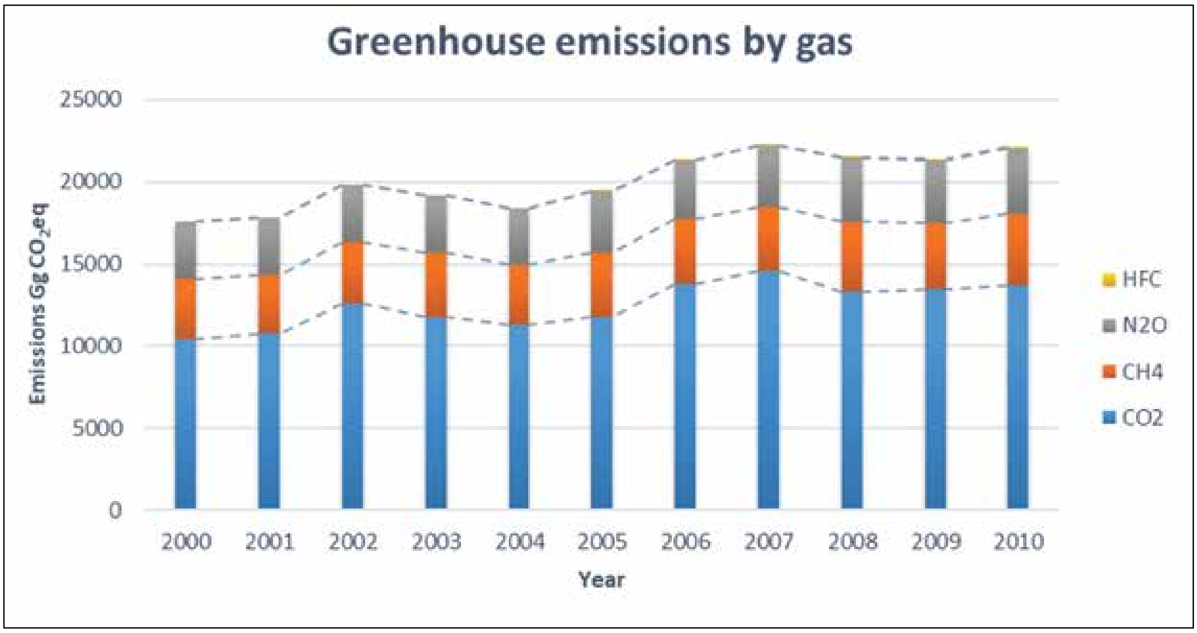


Figure 2.3 GHG emissions by gas (excluding LULUCF) from 2000-2010

2.6 Energy sector

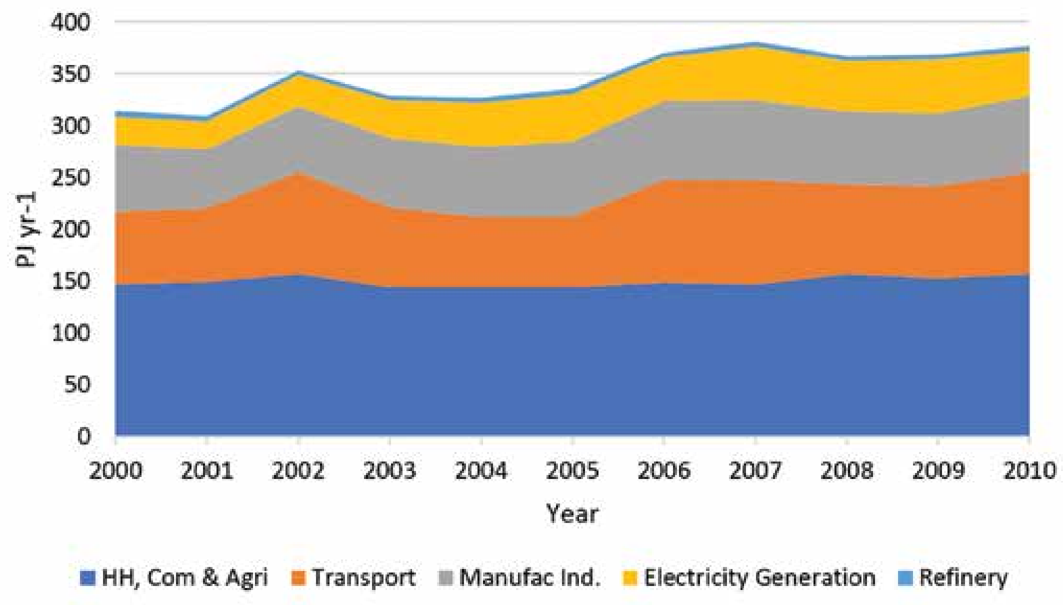
The emissions from sub sectors of energy sector were calculated using the IPCC 1997a, 1997b, 1997c and 2006 Guidelines and the default EFs. The energy sector activity data (i.e energy generation and fuel consumption data) were obtained from the national energy balance statements published by the Sri Lanka Sustainable Energy Authority (SLSEA, 2000-2010). The data included fuel consumption data in electricity generation and other energy needs in industries, transport, household, commercial and agricultural sectors.

The fuel properties published by the Ceylon Petroleum Corporation (CPC) were also considered. Default EFs under the IPCC Tier-1 methodology as well as Net Calorific Values (NCV) for fuels given in the 2006 IPCC-GL were used. Since the carbon content in fuels is given in terms of the energy content of the fuel, it was necessary to convert the amount of fuel burnt expressed in tonnes (t) into Giga-Joules (GJ) using the NCVs.

The EFs corresponding to NO_x, CO and NMVOC emissions from different fuels and sub-sectors were extracted from the 2006 IPCC-GL. The amount of CO_2 emissions is totally dependent on the fuel properties, whereas the emissions of CH_4 and N_2O are dependent on the fuel properties and the combustion burner properties.

2.6.1 Emissions from fuel combustion activities

The energy use in different sub sectors from 2000 to 2010 (Figure 2.4 and Table 2.2) exhibits a growth of 20% in the energy use with the highest growth in electricity generation (60%), followed by Transport (39%), Manufacturing Industries and Construction (16%), and Household, Commercial and Agriculture (7%). However, sub sector contribution in 2010 is shown in the Figure 4.4.



(HH, Com & Agri - Household, Commercial and Agriculture; Manufac Ind.– Manufacturing Industries and Construction; Refinery-Petroleum refining)

Figure 2.4 Growth of sectoral energy use from 2000 - 2010

Table 2.2 Energy use in PJ/yr during 2000 - 2010

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
HH, Com & Agri	146.8	149.1	156.8	144.2	144.1	144.1	148.2	146.7	156.7	152.4	156.8
Transport	70.43	71.15	98.02	77.00	67.87	67.87	98.79	100.99	86.67	88.64	98.02
Manufac Ind.	63.69	56.37	63.27	66.52	67.34	72.57	76.90	76.37	69.74	70.38	73.87
Electricity Generation	27.13	27.81	30.54	36.41	42.15	46.19	42.21	52.25	49.67	52.41	43.39
Refinery	5.86	4.88	4.25	4.14	5.49	4.33	3.92	4.43	3.92	4.67	4.37
Total	**313.9**	**309.3**	**352.9**	**328.3**	**327**	**335.1**	**370**	**380.7**	**366.7**	**368.5**	**376.4**

(HH, Com & Agri- Household, Commercial and Agriculture; Manufac Ind.– Manufacturing Industries and Construction; Refinery-Petroleum refining)

The energy use in transport in 2000 and 2003 was reduced owing to increased price of diesel and gasoline.

The three main GHGs; CO_2, CH_4 and N_2O, and the three precursors; CO, NO_x and NMVOC, and the emissions of SO_2; an aerosol precursor, were estimated (Table 2.3).

The EFs to compute the emissions of CO, NO_x, NMVOC were taken from 1996 IPCC-GL. The emissions of SO_2 were based on the Sulphur content of the fuel as given by the CPC. Emissions of CO_2 from biomass burning in industries and households were added as a memo item, as those emissions are considered to be offset by the CO_2 emissions absorbed during vegetation growth. However, CH_4 and N_2O emissions from biomass burning were reported. Under 2006 IPCC-GL, CO_2 emissions from biomass burnt for energy generation to be reflected as emissions from changes to biomass stocks under LULUCF sector. Following the 2006 IPCC-GL, the emission from international bunkering was also reported as a memo item (Table 2.3).

The energy sector reports an aggregated CO_2 emission of 14,151.45 Gg CO_2-eq (excluding fugitive emission) in Table 2.3 for 2010. The main contributors were Transport (51%), electricity generation (23.6%) and Household Commercial and Agriculture (15%) sub sectors. The sector emissions for the year 2010 were composed of 90% CO_2 (the highest share), 7% CH_4 and 3% N_2O.

Table 2.3 GHG emissions in 2010 and aggregated emissions in CO_2-eq

Sector	Gaseous emission Gg/yr for 2010							CO_2-eq
	CO_2	CH_4	N_2O	CO	NO_x	NMVOC	SO_2	
Energy (Total)	**12,810.11**	**45.24**	**1.27**	**1,037.33**	**102.76**	**142.71**	**95.74**	**14,152.94**
Electricity Generation	3,323.63	0.13	0.03	0.66	8.56	0.22	65.44	3,334.43
Petroleum Refining	320.63	0.04	0.00	NE	NE	NE	17.53	322.36
Manuf. Ind. & Construction	989.01	1.89	0.25	245.47	8.90	3.16	10.71	1,107.69
Transport	7,101.33	0.68	0.41	85.80	69.63	53.93	16.96	7,243.92
HH, Com & Agri.	1,075.50	42.42	0.75	705.40	15.68	84.69	2.63	2,143.04
Fugitive Emission	0.01	0.07	NE	NE	NE	0.71	NE	1.49
Memo items								
International bunkers	1,431.07	0.113	0.031	14.543	22.552	3.057	NE	1,443.05
CO_2 emissions from biomass burning	22,653.92							22,653.92

(Manuf. Ind.– Manufacturing Industries; HH, Com & Agri- Household, Commercial and Agriculture; NE – Not Estimated)

Aggregate emission of sub sectors in energy for the period of 2000-2010 were calculated. Over the decade, the energy related emissions showed an upward trend in Table 2.4 from 10,951 Gg CO_2-eq in 2000 to 14,151 Gg CO_2-eq in 2010 with an overall growth of 29.2%.

Table 2.4 Aggregate CO_2-eq emissions in different sub sectors during 2000-2010

Year	Aggregated CO_2-eq emission Gg/yr										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electricity Generation	2,061	2,122	2,331	2,766	3,199	3,527	3,229	3,984	3,794	4,010	3,334
Refinery	432	360	313	305	405	319	289	326	289	344	322
Manuf. Ind. & Const.	1,091	1,095	1,147	1,248	1,042	1,259	1,258	1,252	1,195	1,143	1,108
Transport	5,237	5,291	7,244	5,720	5,019	5,037	7,324	7,480	6,403	6,558	7,244
HH, Com & Agri.	2,130	2,262	2,143	2,129	2,095	2,095	2,171	2,088	2,139	1,991	2,143
Total	**10,951**	**11,130**	**13,178**	**12,168**	**11,759**	**12,237**	**14,272**	**15,130**	**13,819**	**14,045**	**14,151**

(Manufac Ind. & Const. - Manufacturing Industries and Construction; HH, Com & Agri. - Household, Commercial and Agriculture; Refinery - Petroleum refining)

Though, Manufacturing Industries and Construction, Household, Commercial and Agriculture sub sectors have not shown considerable increased of emissions from 2000-2010, emission from electricity generation sub sector has been increased by 61.8% in 2010 compared to 2000 due to thermal power generation. However, the share of hydro power electricity generation in the energy mix during the period has also been increased (Figure 2.5). Further, it is observed that emissions from transport also have been increased by 38% due to the increase of vehicle population in the road transport sector (Figure 2.6). On the other hand, emissions from refinery have been declined by 25%.

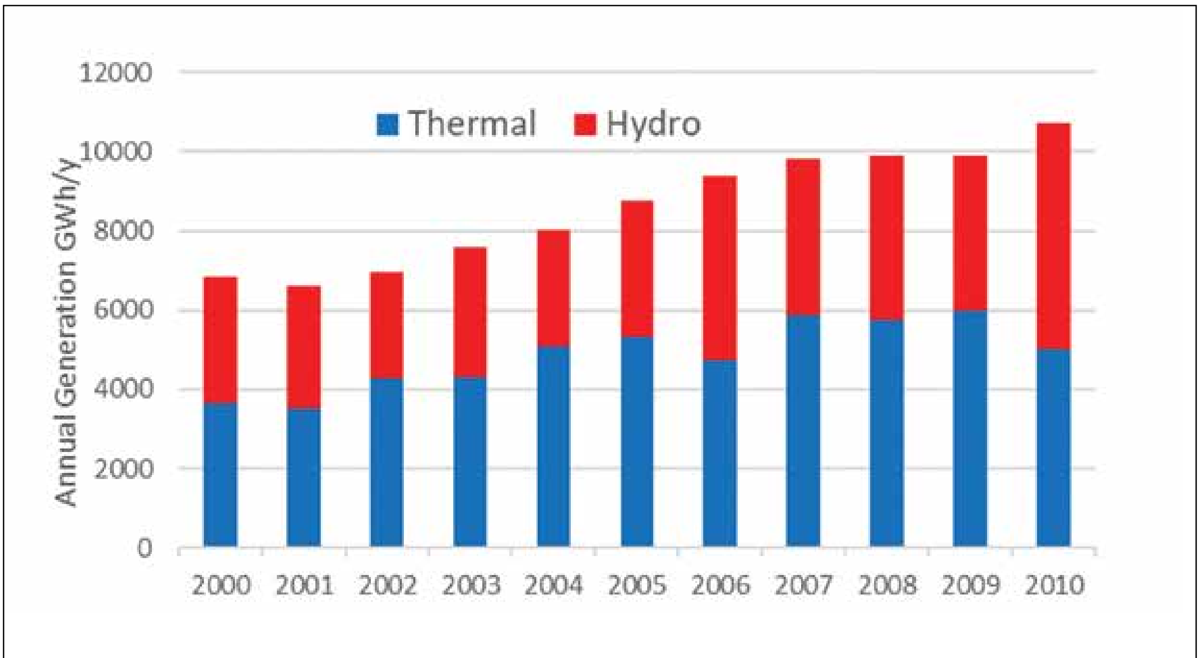


Figure 2.5 Annual electricity generation from thermal and hydro power

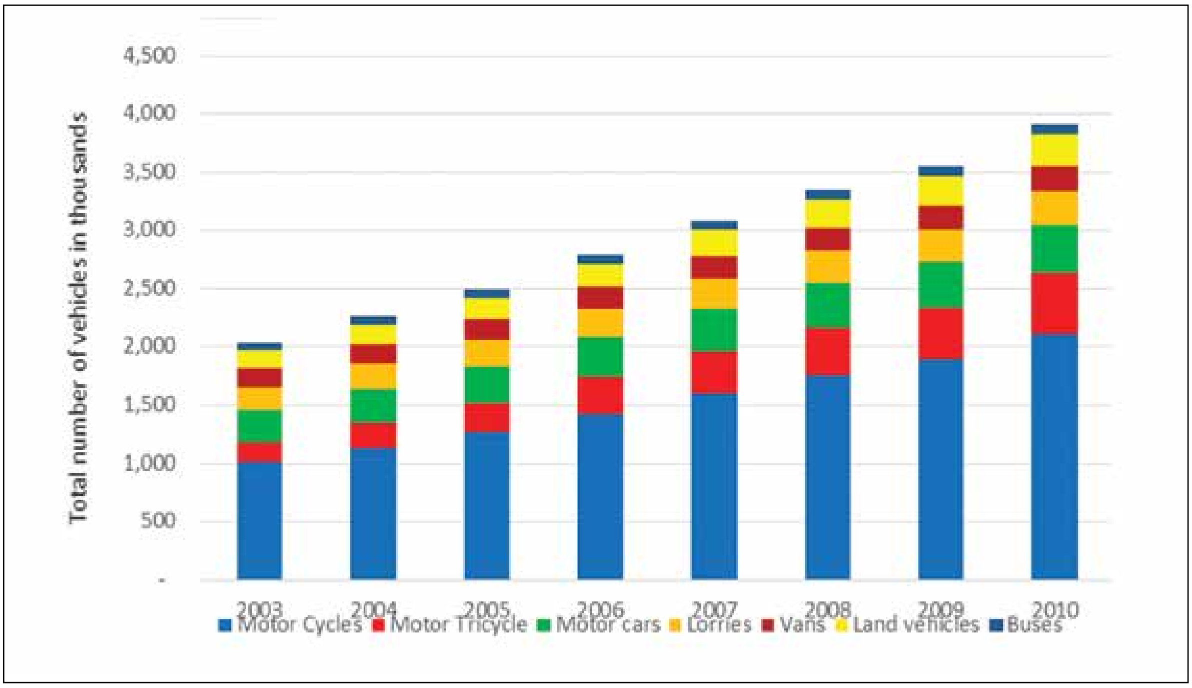


Figure 2.6 Growth of vehicle population from 2003-2010

A breakdown of individual GHGs contribution to the total CO_2-eq emissions from energy sector is shown in Table 2.5. It is clearly shown that the contribution of CO_2 emission is often around 90% of the total GHG emission throughout the time series.

Table 2.5 Total emissions by gas in Gg CO_2-eq from 2000-2010

Year	CO_2	CH_4	N_2O	Total (CO_2-eq)	CO_2 (%)
2000	9,880	868	325	11,072	89
2001	9,943	867	320	11,130	89
2002	11,862	940	375	13,178	90
2003	10,979	852	337	12,168	90
2004	10,574	857	328	11,759	90
2005	11,026	859	333	12,219	90
2006	13,006	886	380	14,272	91
2007	13,863	884	383	15,130	92
2008	12,505	943	371	13,819	90
2009	12,740	930	375	14,045	91
2010	12,810	949	393	14,151	91

2.6.2 Fugitive emissions

Fugitive emissions refer to intentional or unintentional release of GHG during extraction, processing and delivery of fossil fuels to the point of final use. The emissions were computed for transport of oil in pipelines and in bowsers using the emission factors given in 2006 IPCC-GL, it was however found negligible.

2.7 Industrial Processes and Product Use (IPPU) sector

A major source of emissions is the industrial processes that chemically and physically transform materials such as carbonates that release a significant amount of CO_2. During these processes CO_2, CH_4 and N_2O can be produced. In addition, HFCs and PFC soften used in products such as refrigerators, foams or aerosol cans, as alternatives to Ozone Depleting Substances (ODS), have been considered as possible sources of emissions in industrial processes and product use (IPPU) sector.

2.7.1 GHG emissions in sub sectors of IPPU

Under IPPU sector, mainly cement, ceramics, lime, glass, chemicals, metal, solvent application, surface coating, wood preservative application, spirit manufacturing and fluorinate compounds were considered as sub sectors to calculate emissions for 2010. These sub sectors could be further categorized into two as mineral industries and non-mineral industries. The mineral industry category includes cement industry, ceramics industry, lime industry and glass industry. These industries emit CO_2 when the carbonate molecules dissociate on combustion releasing CO_2.

The data on mineral production in the country are given in the Mineral Yearbooks published by the Geological Survey and Mines Bureau (GSMB). Although the annual data on total production of limestone and dolomite used in mineral industries are given in the Mineral Yearbooks, segregated data on quantities consumed in different industries were not available.

In the case of cement, ceramics and glass industries, there are only few factories available in the country and the data on raw material used by them were annually available. The lime industry in Sri Lanka is pursued as a cottage industry and therefore, data on dolomite and limestone consumed in lime industry were not available. Hence, the data for lime industry (Table 2.6) were obtained after deducting the sum of the amounts consumed in the agriculture sector (reported by the National Fertilizer Secretariat) and cement, ceramics and glass industries (reported by individual industries) from the total production given in the GSMB Yearbooks, based on the assumption that what was produced in a year gets consumed during the same year.

2.7.2 Cement industry

The cement industry of Sri Lanka is limited to few factories. Only one factory produces clinker for cement production using locally extracted limestone and dolomite. The others import clinker to manufacture cement. Data were obtained directly from the clinker manufacturer on the consumption of raw material as well as production quantities during the period of 2000-2010. The total amount of cement produced by each manufacturer was available, however disaggregated data by different categories were not available to apply the IPCC Tier-1 Methodology. As recommended in the Tier-2 Methodology, manufacturer's data on clinker production was used in calculating CO_2 generated, which was taken as 0.52 times the clinker produced as given in Equation. 2.4 of Mineral Industry Emissions Chapter of 2006 IPCC-GL. Since, this Emission Factor takes into account the liming added, no contribution from dolomite combustion was considered. To manufacture cement, clinker is burnt in kilns. The manufacturer who uses local raw material to produce clinker and contributes to CO_2 generation is presented in Table 2.7 using EF as 0.52 tCO_2/t Clinker.

Table 2.6 Consumption/Production of dolomite in different industries (tonne)

Year	Consumption/ Production in tonne						
	Fertilizer Usage	Cement Industry	Ceramic Industry	Glass Industry	Consumption Sub total	Total Production	Estimate for Lime Industry
2000	31,940	23,593	1,326	3,359	60,218	75,272	15,054
2001	39,143	25,834	1,342	3,573	69,892	94,169	24,277
2002	35,192	22,316	1,541	3,234	62,283	64,584	2,301
2003	36,631	25,708	1,502	3,818	67,660	82,950	15,290
2004	16,100	42,341	1,579	4,152	64,172	88,434	24,262
2005	35,161	56,305	1,293	4,381	97,140	137,187	40,047
2006	68,032	67,635	1,652	4,329	141,649	180,225	38,576
2007	71,722	75,238	2,124	1,555	159,639	190,000	39,361
2008	61,152	85,620	1,707	7,729	156,208	162,000	5,792
2009	103,307	71,516	1,606	8,294	184,723	273,673	88,950
2010	68,586	61,305	1,436	8,709	140,035	181,692	41,657

Source: Fertilizer Secretariat, Cement Industry, Ceramic Industry, Glass Industry, GSMB

Table 2.7 Emissions of CO_2 from cement production

Year	Manufacturer - Quantity (Tonne)			CO_2 (Gg)
	Cement Production	Clinker Production	Clinker Imported	
2000	531,625	378,286	119,634	196.71
2001	509,168	447,904	23,460	232.91
2002	866,176	469,081	304,033	243.92
2003	849,641	524,238	228,052	272.60
2004	961,732	507,787	322,338	264.05
2005	1,037,056	494,330	371,874	257.05
2006	1,122,465	481,827	417,538	250.55
2007	1,247,491	528,064	437,876	274.59
2008	1,190,800	520,605	410,126	270.71
2009	1,032,905	620,981	230,765	322.91
2010	1,304,213	637,157	443,356	331.32

Source: Direct data collection from the manufacturer

2.7.3 Lime industry

Burning limestone or dolomite to manufacture lime releases CO_2. As indicated in the above Table 2.6, the amount of dolomite used in the lime production was obtained after deducting the quantities consumed in other industries including fertilizer, cement, ceramics and glass from the total production of dolomite. In addition, to the calcium carbonate ($CaCO_3$) obtained from inland corals for the period of 2000-2007 and sea shells for the period of 2000-2009 and emissions from the lime industry are given in Table 2.8.

2.7.4 Glass industry

Sri Lanka has only one major glass manufacturing factory, which produces glass out of mineral raw material including soda ash (Sodium bicarbonate $NaHCO_3$) and dolomite. The consumption data of soda ash, dolomite and calcite were provided by the factory. The emission estimates are given in Table 2.9. Emission factors for soda ash, dolomite and calcite were used as 0.415, 0.477 and 0.44 tCO_2/t respectively.

Table 2.8 Production of lime and CO_2 emissions

Year	Limestone Production (kt)				Dolomite (kt)	EF tCO_2/t		CO_2 (Gg)
	Limestone	Inland	Sea Shells	Total	(Estimated)	Limestone	Dolomite	
	A	B	C	D	E	F	G	H=D*F+E*G
2000	256.6	5.0	3.0	264.6	15.05	0.44	0.477	123.60
2001	411.2	1.0	4.0	416.2	24.28	0.44	0.477	194.69
2002	155.2	3.0	2.0	160.2	2.3	0.44	0.477	71.57
2003	311	1.6	1.7	314.3	15.29	0.44	0.477	145.59
2004	224.1	2.4	1.1	227.6	24.26	0.44	0.477	111.73
2005	141.6	2.2	1.9	145.7	40.05	0.44	0.477	83.23
2006	196.9	5.3	1.2	203.4	38.58	0.44	0.477	107.90
2007	96.9	1.3	10.0	108.2	39.36	0.44	0.477	66.39
2008	138.6	-	1.0	139.6	5.79	0.44	0.477	64.17
2009	318.3	-	1.0	319.3	88.95	0.44	0.477	182.91
2010	148.3	-	-	148.3	41.66	0.44	0.477	85.10

Source: Mineral Year Books 2000 & 2004, GSMB

Table 2.9 Consumption and CO_2 emission of soda ash, dolomite and calcite in glass industry

Year	Consumption in tonne			Emission of CO_2 Gg			Total Emission of CO_2 Gg
	Soda ash	Dolomite	Calcite	Soda ash	Dolomite	Calcite	
2000	4,393	3,359	2,326	1.82	1.60	1.02	4.45
2001	4,672	3,573	2,474	1.94	1.70	1.09	4.73
2002	4,229	3,234	2,239	1.76	1.54	0.99	4.28
2003	4,993	3,818	2,643	2.07	1.82	1.16	5.06
2004	5,730	4,381	2,874	2.25	1.98	1.26	5.50
2005	5,730	4,381	3,033	2.38	2.09	1.33	5.80
2006	5.661	4,329	2,997	2.35	2.07	1.32	5.73
2007	2,026	1,555	2,456	0.84	0.74	1.08	2.66
2008	10,068	7,729	5,330	4.18	3.69	2.35	10.21
2009	10,804	8,294	5,720	4.48	3.96	2.52	10.96
2010	11,345	8,709	6,006	4.71	4.15	2.64	11.50

Source: Primal Glass Company

2.7.5 Ceramics industry

Calcite and dolomite, which are carbonate are the raw materials used in the ceramic industry. When burnt, they emit CO_2. The data on calcite consumed in the manufacture of ceramics products are available in GSMB Year Books. The data on dolomite consumption, however, were obtained directly from the ceramics industry which comprises few companies. The CO_2 emissions released during the combustion of both calcite and dolomite are shown in Table 2.10.

2.7.6 Chemical industry

The Chapter 3 of 2006 IPCC-GL Volume III lists several chemical industries that could produce GHG emissions. However, only a limited number of those industries operate in the country and no reliable data were available. Hence, emissions from this category were considered as not occurring.

2.7.7 Metal industry

Sri Lanka has several metal rolling industries operating with imported raw material, but the data are available in respect of only one industry which produces about 50,000 tonnes of rolled products annually. However, NMVOC released from these industries are below 0.01 Gg and hence not reported.

Table 2.10 CO_2 emissions of calcite and dolomite combustion

Year	Calcite consumption Tonne	Dolomite consumption Tonne	EF for Calcite Consumption (t CO_2/ t calcite)	EF for Dolomite Consumption (t CO_2/ t dolomite)	Emission of CO_2 t	Emission of CO_2 Gg
	A	B	C	D	E=(A*C+B*D)	F=E/1000
2000	4,320	1,326	0.44	0.477	2,533.1	2.53
2001	3,510	1,342	0.44	0.477	2,184.3	2.18
2002	4,700	1,541	0.44	0.477	2,803	2.8
2003	5,510	1,502	0.44	0.477	3,141	3.14
2004	4,830	1,579	0.44	0.477	2,878.4	2.88
2005	4,340	1,293	0.44	0.477	2,526.4	2.53
2006	5,160	1,652	0.44	0.477	3,058.6	3.06
2007	10,070	2,124	0.44	0.477	5,444.1	5.44

Year	Calcite consumption Tonne	Dolomite consumption Tonne	EF for Calcite Consumption (t CO_2/ t calcite)	EF for Dolomite Consumption (t CO_2/ t dolomite)	Emission of CO_2 t	Emission of CO_2 Gg
	A	B	C	D	E=(A*C+B*D)	F=E/1000
2008	6,310	1,707	0.44	0.477	3,590.8	3.59
2009	13,100	1,651	0.44	0.477	6,551.4	6.55
2010	15,870	1,436	0.44	0.477	7,667.7	7.67

Source: Industry Data of Mineral Year Book 2000 and 2004, GSMB

2.7.8 Solvent application

Solvents are used for a variety of purposes including their use as a cleaning agent and in manufacturing surface coatings. Data for import of dry-cleaning agent tetrachloroethylene (C_2Cl_4) were sourced from the internet (https://www.indexmundi.com/trade/imports) while data for other general purposes solvents were obtained from the database of SLSEA. Their emission factors were obtained from EMEP CORINAIR documents B622 and B621 respectively. The emissions of NMVOC generated from solvent application are given in Table 2.11.

2.7.9 Surface coating applications

Surface coatings are a significant source of NMVOCs, particularly from solvent-based coatings and thinners used to thin surface coatings. In recent years, the technology for manufacturing surface coatings has changed from solvent-based coatings to water-based coatings which do not emit NMVOCs. Hence, there has been a gradual decline in the manufacture of the solvent-based coatings. There are several industries formulating surface coatings in the country. However, data for the period 2000-2010 could be obtained only from a relatively small segment of factories that produce surface coatings. A value of 2 ml was assumed for each of solvent-based paints and thinners and NMVOC emissions were calculated using emission factors given in EMEP CORINAIR document B610. An average value 0.88 kg/l was assumed for density. The results are shown in Table 2.12.

Table 2.11 Emissions of NMVOC from solvent applications

Year	Consumption of DC agent kg	Emission Factor	Emission NMVOC Gg	Consumption of solvents Kt	Emission Factor	Emissions NMVOC Gg	Total Emissions CO_2 Gg
2000	NA	-	-	69.83	1.0	69.83	69.83
2001	NA	-	-	53.90	1.0	53.9	53.90
2002	NA	-	-	37.84	1.0	37.84	37.84
2003	NA	-	-	2.74	1.0	2.74	2.74
2004	NA	-	-	0.02	1.0	0.02	0.02
2005	44,012	0.8	0.035	0.02	1.0	0.02	0.06
2006	46,938	0.8	0.038	0.02	1.0	0.02	0.06
2007	79,192	0.8	0.063	4.40	1.0	4.4	4.46
2008	97,961	0.8	0.078	2.67	1.0	2.67	2.75
2009	98,483	0.8	0.079	0.92	1.0	0.92	1.00
2010	53,921	0.8	0.043	2.69	1.0	2.69	2.73

(DC - Dry Cleaning, NA- Not Available)

Source: CORINAIR B622, CORINAIR B621, SLSEA

Table 2.12 Emission of NMVOC in 2010 from surface coatings in 2010

Year	Consumption (ml)		Density (kg/l)	Consumption (Gg)		Total (Gg)	Emission Factor NMVOC/kg	Emission CO_2-Gg
	Solvents based paints	Thinners		Solvents based paints	Thinners			
2010	2.0	2.0	0.88	1.76	1.76	3.52	700	2.46

Sources: EST, CORINAIR B610

2.7.10 Wood preservative applications

Wood preservatives are widely used to protect wood from insect attacks. Once applied, about 90% of the quantity will be evaporated over time. Based on the data available for the period after 2010, a value of 1 Mega Litre (Ml) consumption was assumed for 2010 to make the inventory complete. The Emission Factor given in EMEP CORINAIR document B646 was used and the resulting estimates are given in Table 2.13.

Table 2.13 Emission of NMVOC from wood preservative application

Year	Consumption	Density	Consumption	Emission Factor	Emission
	Ml	kg/l	Gg	NMVOC g/kg	Gg
2010	1.0	0.88	0.88	900	0.79

Source: CORINAIR B646

2.7.11 Food and Beverage Industry

2.7.11.1 Bakery industry

Non-Methane Volatile Organic Compounds (NMVOCs) are released during the production of bakery products. The annual production of bread was estimated on the basis of per household consumption of bread amounting to 5.1kg per household per annum as given in the Household Income and Expenditure Survey, 2009-2010 published by the Department of Census and Statistics. The emission factor was taken as 4.5kg NMVOC per tonne of bread (EMEP CORINAIR B465). The estimated emissions are given in Table 2.14.

2.7.11.2 Spirit manufacturing industry

NMVOCs are released during the production of spirits as well as during production of liquor from coconut, palmyrah toddy and sugar cane molasses. Data on the production of spirits were obtained from the Excise Department of Sri Lanka. The emission estimates are given in Table 2.15.

Table 2.14 Production of bread and emission of NMVOCs during bread production

Year	Population ('000)	Number of Household	Bread (kt/y)	Emission Factor (kg/t) (bread)	NMVOCs emission CO_2-Gg
2000	19,102	4,776	292.26	4.5	1.32
2001	18,797	4,699	287.59	4.5	1.29
2002	18,921	4,730	289.49	4.5	1.30
2003	19,173	4,793	293.35	4.5	1.32
2004	19,435	4,859	297.36	4.5	1.34
2005	19,644	4,911	300.55	4.5	1.35
2006	19,858	4,965	303.83	4.5	1.37
2007	20,039	5,010	306.60	4.5	1.38
2008	20,217	5,054	309.32	4.5	1.39
2009	20,450	5,113	312.89	4.5	1.41
2010	20,653	5,163	315.99	4.5	1.42

Source: Department of Census and Statistics

Table 2.15 Production of spirits and emission of NMVOCs

Source	Unit	2008	2009	2010
Coconut	Ml	4.46	2.29	2.51
Palmyrah	Ml	0.13	0.07	0.04
Sugar cane	Ml	7.87	9.36	7.15
Spirits total	Ml	12.46	12.43	9.70
NMVOCs	Gg	1.87	1.86	1.45

Source: Annual reports, 2008, 2009 and 2010, Excise Department of Sri Lanka

2.7.12 Consumption of fluorinated compounds

Among the fluorinated compounds are HFC compounds which are used as substitutes in the refrigeration and air-conditioning industry, foam blowing industry, aerosol manufacture and as a suppressant. Hydrofluorocarbon compounds are imported into Sri Lanka through refrigerators and air-conditioners, and in the form of cylinders to service and replenish HFCs in refrigerators and air-conditioners, particularly in motor vehicle air-conditioners. Hence, the imported amounts are assumed to be the emitted amounts for the same year as recommended in 1996 IPCC-GL. HFCs are imported into Sri Lanka since 2005 mainly by three importers. Some of the HFC products come as blends of several HFC components. The Global Warming Potential (GWP) of Second Assessment Report of IPCC values for the blends were obtained by apportioning the GWP values of each constituent HFC according to their composition. Accordingly, HFC 134a, 407A, 40C, and 410A had GWP values of 1,300, 3,260, 1,525.5 and 1,725 respectively. The resulting emission estimates expressed as CO_2 equivalent values are shown in Table 2.16.

Table 2.16 Emissions associated with the consumption of Hydrofluorocarbons and their blends

Year	HFC Consumption (Kg)				Emission (tCO_2-eq)				Total tCO_2-eq
	134a	404A	407C	410A	134a	404A	407C	410A	
2005	4,860	327	-	-	6,318	1,066	-	-	7,384
2006	26,646	-	-	-	34,639	-	-	-	34,639
2007	7,084	-	226	-	9,209	-	344	-	9,553
2008	23,006	436	-	-	29,908	1,421	-	-	31,329
2009	31,020	872	-	226	40,326	2,843	-	390	43,559
2010	9,520	-	-	-	12,376	-	-	-	12,376

Source: HFC importer's data, 2000-2010

Among the other fluorinated substances, only SF_6 was imported to use in power transformers as a dielectric. However, their imported quantities were not available.

2.7.13 Consolidated inventory of the IPPU sector

The consolidated GHG inventory for the IPPU sector for 2010 is given in Table 2.17. It comprises CO_2 emissions from cement industry, lime industry, glass industry, ceramics industry and NMVOCs emissions from several other industries manufacturing surface coatings, solvents, bread production, sugar production and liquor industry producing spirits. The consumption of HFCs and their blends also contribute significant amounts of HFCs and these are shown in terms of their CO_2-eq values as recommended in 2006 IPCC-GL.

Table 2.17 Consolidated emissions from the IPPU sector in 2010

Code	GHG Category	Annual emissions (Gg)		
		CO_2	HFC (CO_2-eq)	NMVOC
2	**IPPU Sector**	**435.59**	**12.38**	**9.16**
2A	Minerals Industry	435.59		
2A1	Cement Production	331.32		
2A2	Lime Production	85.10		
2A3	Glass Production	11.50		
2A4	Ceramics Production	7.67		
2D	Other production			5.98
2D3	Solvents			2.73
2D4	Surface coatings			3.25
2F	Consumption of halocarbons and SF_6		12.38	
2G	Other manufacturing industries			3.18
	Bread			1.42
	Sugar			0.31
	Spirits			1.45

2.8 Agriculture, Forestry and Other Land Use (AFOLU) sector

GHG emissions and removals were estimated for the above sector by considering Agriculture, and Land Use, Land Use Change and Forestry (LULUCF) separately.

2.8.1 Agriculture

GHG emissions in agriculture mainly consists of enteric fermentation, manure management, rice cultivation and burning of crop residues, liming and urea application in managed soils.

2.8.1.1 Methane emissions from enteric fermentation

In Sri Lanka, livestock comprises mostly cattle and buffaloes. goats, swine and sheep constitute only a small part of the country's livestock. About 85% of the cattle and buffalo population is indigenous and the rest of the population is improved breeds. The indigenous population feed on grasses, while improved breeds are supplemented with higher quality feeds. The improved (European and Indian) breeds possess higher digestive efficiencies with reduced CH_4 emissions (Lokupitiya, 2016). Low quality feeds cause higher amounts methane emissions during the digestive process in ruminant livestock (cattle, sheep and goats). The amount of methane emitted through digestive processes of livestock depend on the animal's body size, metabolism, activity levels and quality of the feed (IPCC, 2006).

Final methane emissions were estimated for the two main IPCC categories: dairy (i.e. mature cows that are producing milk in commercial quantities for human consumption) and other cattle (i.e. cows not currently lactating, bulls and calves). It was assumed that the emissions from calves younger than three months were negligible and excluded in the calculations. Their population was assumed to be 20% of the total calf population. Sheep and goat were considered as one category for the purpose of estimating methane emissions.

Parameters such as livestock categories, size of their population and EFs used for the estimation of emission from enteric fermentation and manure management are given in Table 2.18.

Table 2.18 Emission estimate for enteric fermentation and manure management in 2010

Species/Livestock Category	Number of animals	EF for Enteric Fermentation	CH_4 emissions from Enteric Fermentation	EF for Manure Management	CH_4 emissions from Manure Management
		(kg/head/yr)	(Gg CH_4/yr)	(kg/head/yr)	(Gg/CH_4/yr)
1. Cattle					
1.1 Cattle (Improved)					
1.1.1 Milking cows	78,653	58	4.56	6	0.47
1.1.2 Non-milking	30,939	27	0.84	2	0.06
1.1.3 Calves	17,054	27	0.46	1	0.02
1.1.4 Mature Bulls	39,212	27	1.06	2	0.08
1.2. Cattle (Local)					
1.2.1 Milking cows	445,698	58	25.85	6	2.67
1.2.2 Non-milking	175,321	27	4.73	2	0.35
1.2.3 Calves	96,642	27	2.61	1	0.10
1.2.4 Mature bulls	222,199	27	6	2	0.44
2. Buffaloes					
2.1 Buffaloes (Improved)					
2.1.1 Milking	15,312	55	0.84	5	0.08
2.1.2 Non-milking	6,061	55	0.33	5	0.03
2.1.3 Calves	6,011	55	0.33	1	0.01
2.1.4 Mature Bulls	7,273	55	0.40	5	0.04
2.2. Buffaloes (Local)					
2.2.1. Milking	154,818	55	8.52	5	0.77
2.2.2 Non-milking	61,279	55	3.37	5	0.31
2.2.3. Calves	60,786	55	3.34	1	0.06
2.2.4 Bulls	73,537	55	4.04	5	0.37
3. Sheep	7,910	5	0.04	0.22	
4. Goats					
4.1 Improved breeds	373,465	5	1.87	0.22	0.08
5. Swine	83,785	1	0.08	6	0.50
6. Poultry					
6.1 Chicken	14,018,320			0.025	0.35
6.2 Ducks	13,485			0.03	
Total			**69.28**		**6.79**

2.8.1.2 Methane emission from manure management

Methane emission from manure management is relatively low in the country, as manure is mostly deposited by the animals on grazing land. The manure is not managed or treated in any way that results in anaerobic methane emission. There is a dearth of data on the amount of manure used in biogas production. Since, emissions due to manure management is very low, IPCC Tier -I method and default emission factor given in the Table 10.4 of 2006 IPCC-GL for Indian sub-continent were used. The emission estimated for the sub-categories of manure, amount of methane emitted from manure management was lower than that from enteric fermentation. Quantities of methane emitted from enteric fermentation and manure management during 2000-2010, calculated using the livestock data reported by the Department of Census and Statistics, are given in Table 2.19.

Table 2.19 Methane emission consolidated from enteric fermentation and manure management

Year	Annual methane emission from livestock sector ($GgCH_4$)										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Enteric Fermentation	68.49	68.62	69.48	69.55	69.79	70.30	70.58	72.11	71.87	72.97	76.07
Manure Management	6.15	6.20	6.26	6.30	6.28	6.34	6.43	6.59	6.57	6.46	6.79
Total	**116.47**	**111.33**	**115.75**	**123.51**	**111.89**	**121.23**	**121.51**	**117.85**	**131.12**	**125.97**	**134.56**

During the period of 2000 - 2010, methane emission from livestock farming has increased by 11% and 10.4% from enteric fermentation and manure management respectively.

2.8.1.3 Rice cultivation

The total paddy land extent in Sri Lanka is approximately 0.8 million ha. The paddy cultivated area spread over dry, intermediate and wet zones of the country and these lands fall under both rain-fed and irrigated farming. Crop duration for all the rice varieties was taken as 100 days. In the calculation of methane emissions for this inventory, the default emission factor of 1.3kg CH_4 $ha^{-1}day^{-1}$ given in 2006 IPCC-GL was used. For different water regimes, scaling factor of 0.52kg CH_4 $ha^{-1}day^{-1}$ was used for irrigated rice with intermittent flood with multiple aeration; factors of 0.28kg $CH_4 ha^{-1}$ day-1and 0.25kg CH_4 ha^{-1}day-1were used for normal rain-fed farming and drought prone rain-fed areas predominantly in the dry and intermediate zones respectively.

Methane emissions from paddy fields in different climatic zones under irrigated and rain-fed farming calculated for the period 2000-2010 are shown in Table 2.20. The large share of emissions was from the dry zone (DZ) and intermediate zone (IZ) where the country's highest rice production is recorded.

Table 2.20 Methane emissions from rice cultivation in different climatic zones

Year	Annual methane emission from rice fields in different climatic zones (Gg/yr)						
	Area (ha)- Irrigated DZ & IZ	**Methane Emission- Irrigated DZ & IZ**	Area (ha)- Rain fed DZ & IZ	**Methane Emission- Rain fed DZ & IZ**	Area (ha) - Wet Zone	**Methane Emission- Wet Zone**	**Total**
2000	617,751	41.76	85,138	1.88	175,107	4.34	**47.98**
2001	543,608	36.75	81,236	1.80	168,304	4.17	**42.72**
2002	592,575	40.06	82,440	1.82	177,551	4.39	**46.27**
2003	698,464	47.22	106,037	2.34	177,712	4.40	**53.96**
2004	537,412	36.33	81,813	1.81	160,296	3.97	**42.11**
2005	668,527	45.19	100,526	2.06	168,122	3.68	**50.93**
2006	668,490	45.19	93,212	2.06	148,788	3.68	**50.93**
2007	600,580	40.60	77,087	1.70	139,046	3.44	**45.74**
2008	780,138	52.74	91,809	2.03	181,045	4.48	**59.25**
2009	678,993	45.90	110,404	2.44	188,164	4.66	**53.00**
2010	756,887	51.17	119,773	2.65	188,621	4.67	**58.49**

2.8.1.4 Emissions from burning of crop residues

Carbon monoxide (CO) is the biggest GHG emission generated from burning rice residues, followed by methane (Table 2.21). Although there was significant biomass burning (~40-50% of rice straw) before 2000, mostly in certain parts of the dry zone, the practice was considerably reduced due to promotional campaigns and outreach/extension programs by the Ministry of Agriculture on the use of rice straw as mulch in paddy soils. The burning of rice straw has reduced to 6.7% in the wet zone, 16 % in the dry and intermediate zones (Somaratne and Lokupitiya, 2018); hence, these values were used to estimate the amount of rice straw burnt in the calculation of non-CO_2 GHG emissions. The emission factors used as CH_4 : 2.7g, CO : 92g, N_2O : 0.07g, NO_x

: 2.5g (kg dm burnt)$^{-1}$ according to the 2006 IPCC-GL. Emissions of CO_2 from biomass burning is not counted. The emissions of other GHGs and precursors are shown in Table 2.21.

2.8.1.5 CO_2 emissions from Liming and Urea application on managed soils

Lime and urea applied on soils release CO_2 due to dissolution and breakdown processes within soil. Limestone application in soils is practiced in up-country vegetable cultivations to improve the soil fertility. Dolomite is used in perennial crops mostly in tea plantations in the wet zone. The data recorded by GSMB and emission factors of Limestone: 0.12, Dolomite: 0.13 given in 2006 IPCC-GL were used to calculate the emissions in Table 2.22.

Urea is the main nitrogenous synthetic fertilizer used in the agriculture sector of the country. The IPCC default value of 0.2 tonnes of carbon per tonne of urea was used in the calculations. Table 2.23 shows the growth of CO_2 emission from urea application in rice fields, tea plantations and other crops. The highest share (72%) in 2010 came from rice fields, 21% from tea plantations and the remaining 7% was applied on other crops. Emissions from the urea application in rice and tea cultivation showed a growth of 69% while application in other crops showed 46% decrease and the total emission showed 57% growth from 2000 to 2010 (Table 2.23).

Table 2.21 Emissions of non-CO_2 GHGs and precursors from field biomass burning

Year	Area Burnt (ha)	Emission Gg/yr				
		CH_4	N_2O	CO	NO_x	CO_2-eq
2000	624,096	1.35	0.04	45.93	1.25	39.33
2001	557,840	1.21	0.03	41.06	1.12	35.08
2002	601,604	1.3	0.03	44.28	1.27	37.68
2003	648,864	1.4	0.04	47.76	1.3	40.75
2004	551,261	1.19	0.03	40.57	1.1	34.77
2005	677,201	1.46	0.04	49.84	1.36	42.65
2006	666,465	1.44	0.04	49.05	1.33	41.86
2007	594,542	1.28	0.03	43.76	1.18	37.36
2008	765,504	1.66	0.04	56.34	1.53	48.18
2009	698,865	1.51	0.04	51.44	1.4	44.15
2010	771,228	1.67	0.04	56.76	1.54	48.37

Table 2.22 CO_2 emission from limestone and dolomite applications in cropland

Year	Quantities of applied limestone (tonnes)	Emissions from the application of limestone (Gg CO_2)	Quantities of applied Dolomite (tonnes)	Emissions from the application of Dolomite (Gg CO_2)	Total (Gg CO_2)
2000	10000	4.4	31,940	15.22	19.62
2001	10000	4.4	39,143	18.66	23.06
2002	10000	4.4	35,192	16.77	21.17
2003	10000	4.4	36,631	17.46	21.86
2004	10000	4.4	16,100	7.67	12.07
2005	10000	4.4	35,161	16.76	21.16
2006	10000	4.4	68,032	32.43	36.83
2007	10000	4.4	71,722	34.19	38.59
2008	10000	4.4	61,152	29.15	33.55
2009	10000	4.4	103,307	49.24	53.64
2010	10000	4.4	68,586	32.69	37.09

Table 2.23 CO_2 emission from Urea application in rice, tea and other crops

Year	Urea applied to rice fields (tonnes)	Emission from rice fields (Gg CO_2)	Urea applied to tea lands (tonnes)	Emission from tea lands (Gg CO_2)	Urea applied other croplands (tonnes)	Emission from other croplands (Gg CO_2)	Total Emission (Gg CO_2)
2000	177,729	130.33	58,000	42.53	27,800	20.39	193.25
2001	192,718	141.33	59,000	43.27	31,600	23.17	207.77
2002	233,739	171.41	61,000	44.73	31,100	22.81	238.95
2003	202,000	148.13	59,000	43.27	27,000	19.80	211.20
2004	222,000	162.80	71,000	52.07	30,000	22.00	237.87
2005	266,000	195.07	76,000	55.73	29,000	21.27	272.07
2006	265,000	194.33	56,000	41.07	24,000	17.60	253.00
2007	244,000	178.93	58,000	42.53	18,000	13.20	234.66
2008	359,000	263.27	65,000	47.67	15,000	11.00	322.94
2009	251,000	184.07	112,000	82.13	14,000	10.27	276.47
2010	300,251	220.18	98,000	71.87	15,000	11.00	303.05

2.8.1.6 Nitrous Oxide emissions from managed soils

Nitrous Oxide emissions from managed soils comprised both direct and indirect emissions. The direct emissions include those from nitrogen (N) inputs (i.e. synthetic fertilizers and organic N additions, including the annual input of manure N, N inputs from N-fixing and non-N fixing crop residues, N in mineralized soil organic matter causing an annual carbon loss), managed organic soils and direct emissions from urine and dung inputs from grazing animals. Indirect emissions include the N_2O emissions from atmospheric deposition of N volatized from the N inputs added on managed soils and emissions due to any N leached/runoff from managed soils.

Tier-I methodology of 2006 IPCC-GL and default emission factors were used in estimating direct and indirect emissions. Direct emissions from N inputs were estimated separately for flooded rice and other croplands, and then added together. Direct emissions from managed organic soils, the urine and dung deposited on pasture, range, and paddock and indirect emissions from N inputs were estimated according to 2006 IPCC-GL. Managed soils in the country included both mineral soils and organic soils. Since it is difficult to obtain the amounts of applied quantities of organic manure to managed soils, several assumptions were made. The amounts of dung/droppings per head per day from each category of animals were assumed (i.e. poultry 0.05 kg, cattle and buffalo 25 kg, swine 7 kg and goat 3 kg) and converted to respective dry weight. The corresponding values of total N applied were calculated based on N content and total number of animals. The direct application of N consists of chemical fertilizer and manure from chicken, ducks and swine were assumed. Also, N from paddy straw and leguminous crops was used to calculate the N application from crop residues, and the value of 20 kg N ha^{-1} was used in calculating total N application from legume crops.

The highest direct N_2O emission was estimated as 2,049 Gg CO_2-eq/yr in 2010 and the lowest was estimated for 2004 (1,813 Gg CO_2-eq/yr). Indirect N_2O was lower than that of direct emission and the highest estimated emission was 1,234 Gg CO_2-eq/yr (2010) while the lowest was 934 Gg CO_2-eq/yr 2001.

Urine and dung inputs from livestock (cattle, buffalo, goat and sheep) on grazed soils were considered in calculating the direct N_2O emissions, whereas manure from poultry and piggery were considered for direct emissions from manure application (Table 2.24).

Table 2.24 Direct and indirect N_2O emissions from managed soils and manure in Gg N_2O/yr

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Direct-soil	6.33	6.32	5.88	5.98	5.85	6.16	6.02	6.48	6.37	6.29	6.61
Indirect-soil	3.08	3.01	3.2	3.3	3.11	3.62	3.36	3.21	3.99	3.7	3.98
Manure	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
Total	**9.43**	**9.35**	**9.1**	**9.3**	**8.98**	**9.8**	**9.41**	**9.72**	**10.39**	**10.02**	**10.62**

2.8.1.7 Consolidated emissions for the agriculture sector

The consolidated inventory estimates for the year 2010 is provided in Table 2.25. The largest share of CH_4 emissions came from enteric fermentation.

Table 2.25 Consolidated emissions from agriculture sector in 2010

GHGs Sources Categories			CO_2 Gg	CH_4 Gg	N_2O Gg	CO Gg	NO_x Gg
3	**Agriculture**		**340.14**	**136.23**	**10.66**	**56.76**	**1.54**
	3A1	Enteric fermentation		69.28			
	3A2	Manure management		6.79			
	3C1	Field biomass burning		1.67	0.04	56.76	1.54
	3C2	Liming	37.09				
	3C3	Urea application	303.05				
	3C4	Direct N_2O emission from managed soil			6.61		
	3C5	Indirect N_2O emissions from managed soil			3.98		
	3C6	Indirect N_2O from manure management			0.03		
	3C7	CH_4 emissions from rice cultivation		58.49			

2.8.2 Land Use, Land Use Change and Forestry (LULUCF)

This section mainly consists of the change in carbon stocks in living biomass in forests (gain and loss of biomass), dead organic matter, forest soils, harvested wood products, forest fires and carbon stock change in croplands. Under the other land use related emissions, CO_2 emissions relevant to biomass, crop lands, grasslands, wetlands, settlements and other lands etc.

Carbon dioxide emissions relevant to biomass, dead organic matters and soil carbon stock changes in forest and croplands, and CO_2 and non-CO_2 emissions from other land uses due to human influence were estimated under the land use related emissions. In addition, emission estimates of methane, N_2O and other emissions such as nitrogen oxide and carbon monoxide due to forest fires are provided.

GHG emission for different sub categories under LULUCF were estimated following the 2006 IPCC-GL and IPCC GPG-LULUCF (IPCC, 2003). Required data for emission calculation were mainly obtained from the national reports (annual, periodic and non-periodic) of relevant ministries, the Department of Census and Statistics, Central Bank of Sri Lanka, Forest Conservation Department, State Timber Corporation, Land Use Policy Planning Department, Research Institutions and universities. Further, required data were collected at districts level and aggregated appropriately to derive the final estimates.

Forest plantations less than 20 years old were taken as land converted to forestlands. Existing natural forest areas and the plantation areas established 20 years prior to the inventory year (2010) were considered as forestland remaining forestland. It was assumed that there is no carbon stock change in the undisturbed natural forest areas and the inventory estimations were made only for forest plantations and the restored degraded forest areas. The extent and quantities of the above categories and related GHG emission are comprehensively described in following sections.

2.8.2.1 Change in carbon stocks in living biomass in forests

Carbon stock changes in living biomass include the annual biomass gain in forests due to growth (both above-ground and below-ground) and any losses due to timber and fuelwood harvesting and disturbances. Overall, there was a net carbon sink of 2,706 Gg CO_2 in the living forest biomass in 2010 in Table 2.26.

a. Gain in carbon stocks in living biomass due to growth

In estimating the carbon gain in biomass, the values for annual net increment in volume and basic wood density were extracted from the GPG-LULUCF (IPCC, 2003). For the species that did not have default values indicated in the 2003 IPCC-GL, average values for the relevant genus was considered. IPCC default values for tropical forests was considered for the Biomass Expansion Factor (BEF_1) and below-ground biomass to above-ground biomass Ratios (R). The fraction of carbon in biomass was assumed to be 0.47 based on the 2006 IPCC-GL.

When there were no data on the age of forests, it was assumed that such land belonged to the category of Forest Land Remaining Forest Land. Based on the 2006 IPCC classification, forest lands located in the dry and intermediate zones in Sri Lanka were considered as Tropical Moist Climate; the forest land located in the wet zone were considered as Tropical Wet Climate.

b. Losses in biomass carbon stocks

Carbon losses due to wood removal, fuelwood removal and disturbances were calculated using 2006 IPCC-GLs and GPG-LULUCF (IPCC, 2003). Due to a moratorium imposed on logging inside natural forests since 1990 (Bandaratilake, 2001), the contribution of natural forests toward meeting the country's timber demand has been negligible. Hence, no estimates of timber removal were made under the natural forest category. Although the projected timber volumes for the inventory period are available in the Forestry Sector Master Plan (Ministry of Agriculture, Lands and Forestry, 1995), the present timber supply from forest plantations is much lower than the projected figures in the Forestry Sector Master Plan (Ruwanpathirana, 2011). In estimating the carbon loss in wood removals, Equation 2.12 in 2006 IPCC-GL was used with harvested wood volumes by species; the Biomass Conversion and Expansion Factor for Removals ($BCEF_R$; 2006 IPCC-GL), was replaced with the default values for Biomass Expansion Factor (for removals; BEF_2) and the density given in the GPG-LULUCF (IPCC, 2003). The R (Root to Shoot Ratio) values were extracted from GPG-LULUCF (IPCC, 2003) as well. For the recorded volumes without species, an average wood density of 0.55 tonnes dry matter (dm) m^{-3} was assumed.

Losses of biomass carbon in forest fires were considered under the losses due to disturbances. Although there are no significant threats to natural vegetation from forest fires. Forest fires are significant in forest plantations, especially in Pine and Eucalyptus plantations (Ariyadasa, 2002). Since, these fires are almost short-term surface fires, no impact on the below-ground biomass was assumed from fire, thus making R (Equation 2.14; 2006 IPCC-GL) equal to zero. The fraction of biomass left to decay was taken as 0.5 (2006 IPCC-GL).

Carbon stock change resulting from annual biomass gain and removals in living biomass (considering both the above-ground and below-ground biomass) for forestland during the period of 2000-2010 are given in Table 2.26. The estimates for the period of 2000-2010 showed that forest biomass has been acting as a net carbon sink (Table 2.26). However, a clear trend of declining the CO_2 sink over time was evident, as well as a similar gradual decline in the CO_2 gain by the forest biomass was also evident in Figure 2.7, indicating the need for further restoration of forests and reforestation.

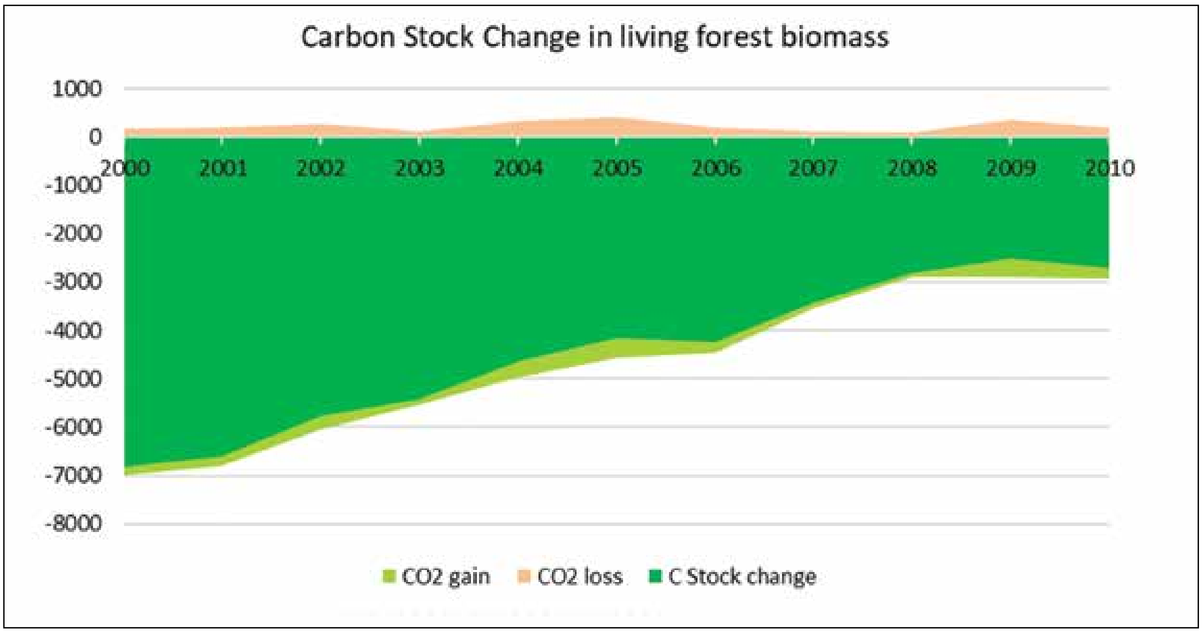


Figure 2.7 Carbon gain and net carbon stock change in living forest biomass (Gg CO_2), 2000-2010

2.8.2.2 Carbon stock change in dead organic matter and soil carbon in forest land

a. Carbon stock change in Dead Organic Matter (DOM)

Dead Organic Matter (DOM) and soil carbon in forest land comprises of dead wood and forest litter. Annual carbon stock change in dead wood pool depends on the carbon inputs from any biomass left from the removed harvests, natural mortality and biomass killed by fire or other disturbances, and carbon release from decay process. Annual changes in the litter stocks in forest floor also contribute to the overall stock change in the forest DOM.

According to the Tier-1 methodology under 2006 IPCC-GL, it is assumed that the DOM carbon stock in Forestland Remaining Forestland (i.e. remaining as forestland for over 20 years) is in equilibrium with no change over time. Therefore, only DOM in land converted to forest lands (i.e. forest plantations younger than 20 years) was estimated. The Tier-1 method assumes that all carbon contained in biomass is emitted directly to the atmosphere during a land-use conversion event and none is added to dead wood and litter pools. Therefore, carbon addition was not considered for the dead and litter pool from a disturbance. Based on the Tier-1 methodology and emission factors given in Table 2.2 of 2006 IPCC-GL, estimates were made for the litter pool excluding fine woody debris with <10 cm diameter; litter carbon stock/s relevant to tropical broadleaf forests (i.e. 2.1 tonnes C ha^{-1}; 2006 IPCC-GL) were used. The net carbon stock change in DOM in forestland is given in Table 2.27.

Table 2.26 Annual carbon stock change in living forest biomass in Gg CO_2

Carbon exchange in Gg CO_2	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Carbon gain in forest biomass											
Land converted to forestland in DZ & IZ	-2453.59	-2084.43	-1795.62	-1387.19	-1087.99	-789.07	-630.09	-325.25	-636.71	-304.14	-262.61
Forestland remaining forestland in DZ & IZ	-893.17	-1367.72	-1067.59	-1151.9	-1181.7	-1234.62	-1268.9	-1295	-334.86	-637.35	-648.61
Enrichment planting in DZ & IZ	-	-	-	-	-	-	-	-	-	-	-5.8
Land converted to forestland in WZ	-2634.91	-2270.22	-2026.87	-1743.37	-1341.64	-1105.88	-1090.76	-373.26	-1623.24	-245.29	-219.65
Forestland remaining forestland in WZ	-1002.11	-1074.1	-1154.44	-1234.93	-1329.88	-1392.2	-1452.8	-1554.98	-305.96	-1694.73	-1721.16
Enrichment planting in WZ	-0.36	-0.726	-5.14	-6.87	-25.41	-37.25	-	-	-	-	-54.33
Total CO_2 gain	**-6984.1**	**-6797.2**	**-6049.7**	**-5524.3**	**-4966.6**	**-4559**	**-4442.6**	**-3548.5**	**-2900.8**	**-2881.5**	**-2912.2**
Carbon loss in wood removal											
Plantations < 20yrs	46.24	40.02	62.81	14.74	59.45	38.16	56.99	44.44	33.02	13.67	5.76
Plantations >20 yrs	45.41	24.32	33.55	2.98	29	23.72	25.24	19.18	19.18	145.82	18.27
Carbon loss in fuel wood removal											
Plantations < 20 yrs	14.84	30.78	20	23.18	29.36	15.32	19.93	14.83	11.27	23.48	29.15
Plantations > 20 yrs	46.06	26.88	20.66	23.95	27.31	22.57	18.53	9.99	9.99	21.84	25.83
Carbon loss in disturbances (i.e. forest fires)											
Plantations < 20 yrs	5.58	80.14	139.45	44.98	177.85	304.69	71.65	27.47	12.07	163.68	127.2
Total CO_2 loss	**158.13**	**202.14**	**276.47**	**109.83**	**322.97**	**404.46**	**192.34**	**115.92**	**85.53**	**368.49**	**206.21**
Carbon stock change ($GgCO_2$)	**-6826**	**-6595.1**	**-5773.2**	**-5414.4**	**-4643.6**	**-4154.6**	**-4250.2**	**-3432.6**	**-2815.2**	**-2513**	**-2706**

*'-'Indicates uptake/removals, and '+' (denoted with no sign) indicates emission to the atmosphere; DZ=Dry Zone; IZ=Intermediate Zone;
WZ= Wet Zone

b. Carbon stock change in forest soils

Carbon stock changes in mineral soils were estimated under this category. As mentioned above, it was assumed that the soil carbon in Forestland Remaining Forestland (i.e older than 20 years) is in equilibrium. Therefore, the soil carbon exchange was calculated only for the land converted to forestland. Since there are hardly any managed organic soils (12-20% or more organic matter by mass; IPCC, 2006) in forests, soil carbon stock changes were estimated only for the mineral soils in Land Converted to Forestland. The land use prior to conversion was considered as degraded/abandoned cropland that had low input and intensive management. Considering the existing soil conditions in the country, a default reference carbon stock of 47 tonnes C ha^{-1} (in a depth of 0-30 cm; IPCC, 2006) for tropical moist Low Activity Clay (LAC) soils were considered for all three climatic zones in Sri Lanka. Net carbon change in soil carbon in forestland is depicted in Table 2.27. The DOM and soil carbon in forestland were a net sink over the period of 2000-2010.

c. Carbon stock changes in harvested wood products

Harvested Wood Products (HWP) include all wood materials (including bark) that remain in harvested sites (IPCC, 2006). The methodology includes the HWP inputs from what is produced within the country, imports/exports and any loss of carbon due to decay of the existing HWP, taking the production information from several decades ago (extrapolated to the beginning of the last century). Emissions from harvested wood products were not estimated due to lack of data.

2.8.2.3 Non-CO_2 emissions due to forest fires

Non-CO_2 emissions due to forest fires were estimated for this inventory. Overall emissions from forest fires include CO_2 and other GHG emissions resulting from incomplete combustion of forest materials. Out of these non-CO_2 GHG emissions, methane, carbon monoxide, nitrous oxide and nitrogen oxide were estimated using 2006 IPCC methodology. Default values given for secondary tropical forests: mass of fuel available for combustion (M_B = 180), combustion factor (C_f = 0.55) and emission factors (CO-104, CH_4-6.8, N_2O-0.2 and NO_x-1.6) were considered. The non-CO_2 emissions from forest fires were relatively low. Carbon monoxide was the highest emission. Then non-CO_2 emissions for 2000-2010 are given in Table 2.2

Table 2.27 Carbon stock change in DOM and mineral soil in Gg CO_2

Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total land area converted to forestland (ha)	134,436.8	116,251.2	103,381.3	84,025.9	65,295.9	49,913.3	46,846.68	35,325	31,779.2	26,969.82	24,198.71
Carbon stock change in Dead Organic Matter	**-51.75**	**-44.76**	**-39.8**	**-32.35**	**-25.14**	**-19.22**	**-18.03**	**-13.6**	**-12.23**	**-10.38**	**-9.32**
Area converted to forestland in DZ and IZ (ha)	62,867.7	52,942.7	45,906.8	36,283.4	28,983.4	21,603	18,199.88	16,705.15	15,326.05	14,912.86	13,429.65
Carbon stock change in Soil carbon- DZ and IZ	**-302.49**	**-254.74**	**-220.88**	**-174.58**	**-139.45**	**-103.94**	**-87.57**	**-80.38**	**-79.16**	**-71.75**	**-64.62**
Area converted to forestland in Wet Zone (ha)	71,569.1	63,308.5	57,474.5	47,742.5	36,312.5	28,310.3	28,646.8	18,619.85	16,453.15	12,056.96	10,769.06
Carbon stock change in Soil carbon -WZ	**-344.36**	**-304.61**	**-276.54**	**-229.72**	**-174.72**	**-136.22**	**-137.84**	**-89.59**	**-73.74**	**-58.01**	**-51.82**
Total stock change	**-698.6**	**-604.11**	**-537.22**	**-436.65**	**-339.31**	**-259.38**	**-243.44**	**-183.57**	**-165.13**	**-140.14**	**-125.76**

Table 2.28 Non-CO_2 emissions from forest fires

GHG and precursors from forest fires	Emissions in Gg										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Area Burnt (ha)	36	516.7	899.1	290	1146.7	1964.5	461.9	177.1	77.8	1055.3	820.1
CO	0.37	5.32	9.26	2.99	11.81	20.23	4.76	1.82	0.80	10.86	8.52
CH_4	0.02	0.35	0.61	0.19	0.77	1.32	0.31	0.12	0.05	0.71	0.55
N_2O	0.00	0.01	0.02	0.01	0.02	0.04	0.01	0.00	0.00	0.02	0.02
NO_x	0.01	0.08	0.14	0.05	0.18	0.31	0.07	0.03	0.01	0.17	0.13

2.8.2.4 Carbon stock change in croplands

a. Crop lands remaining crop land

Only perennial crops were considered for calculation of annual change of carbon stocks in the crop lands. Emissions from the main perennial crops such as tea, rubber, coconut were estimated. The emissions from other perennial export crops were estimated as a separate category (Table 2.29). Although there is a significant land area reported for other horticultural crops, they were not considered due to unavailability of exact areas and data on biomass removal from these land uses category.

Land extent under tea was grouped into low-, mid-, and up-country tea. The land extents for tea in 2010 was 101,225 ha, 65,458 ha and 37,916 ha respectively. In Sri Lanka, all the tea growing regions are considered under the tropical wet climate. Net carbon stock changes for tea and rubber were estimated using respective default emission factor given under 2006 IPCC-GL for Tier-1 methodology (Table 2.29). Rubber are replanted once in 30 years and a considerable amount of biomass is removed when the entire rubber plantation is uprooted and removed. Since these are mature trees, a default sequestration factor of 50kg C ha^{-1} (IPCC, 2006) was used in calculation of the carbon removed by the uprooting for replanting. In calculating carbon assimilation, the default value for tropical wet condition (i.e. 10 tonnes C ha^{-1}/yr) was used (IPCC, 2006).

As per the Agriculture Census in 2002 and 2013, the extent of coconut cultivation shows 394,836 ha and 440,451 ha respectively. A consolidated average extent over a 5 year period (i.e. 20,734 ha) was used throughout the reporting period as the area under young coconut (< 5 years).

However, there is no data available on biomass removal from mature coconut plantations (total trunk removal). Due to lack of data, area under the mature coconut plantation was not considered for calculation of change in biomass carbon stocks. In calculating the carbon assimilation, the default value for tropical wet condition was used (IPCC, 2006).

b. Home gardens as Cropland Remaining Cropland

Home gardens are a mixed perennial cropping system that provide food, fruits, timber, spices and medicinal herbs. According to the estimates of the Forestry Sector Master Plan- FSMP (MALF, 1995), home gardens covered about 858,000 ha in 1992 and the extent has been increased by 1% annually. Since there is no proper data available for the inventory period, the above assumption based on the FSMP was used to derive the area under home gardens for the period considered in this report.

According to the FSMP estimates, home gardens provide about 0.95 m^3 of sawn logs and 0.5 m^3 of poles per ha per year, or about 41% of national saw logs and 26% of the biofuel demand (MALF, 1995).

The Tier-1 emission factor in 2006 IPCC-GL was used for calculating the biomass gain. In estimating the biomass removal, a wood density of 0.54 g/cm^3 and biomass expansion factor of 3.4 was considered along with relevant data for fuel wood and timber removals, as given in the FSMP. A 10% increase in carbon gain and a 6.3% increase in carbon loss was observed for the country giving a net increase in the carbon gain from 1,245.71 to 2,029.12 Gg from 2000 to 2010 (Table 2.30).

Table 2.29 Net carbon stock change (CO_2 Gg /yr) in cropland remaining cropland and land converted to cropland

Cropping system	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Tea	-5586.3	-5576.30	-5538.32	-5460.64	-5505.45	-6385.87	-6515.52	-6321.06	-6380.81	-6328.58	-6175.69
Rubber	-4805.90	-4822.01	-3699.03	-4018.69	-3849.98	-3601.00	-3752.02	-3434.50	-3364.47	-3394.38	-3520.81
Coconut (< 5 years)	-760.94	-760.94	-760.94	-760.94	-760.94	-760.94	-760.94	-760.94	-760.94	-760.94	-760.94
Other perennial crops	-3366.25	-3361.11	-3214.45	-3065.96	-3057.84	-2884.97	-2914.26	-3062.89	-3391.95	-3463.96	-3551.61
Home gardens	-1245.71	-1316.15	-1388.15	-1461.19	-1534.83	-1610.05	-1691.39	-1774.34	-1857.93	-1942.69	-2029.12
Total	**-15765.1**	**-15836.5**	**-14600.9**	**-14767.4**	**-14709**	**-15242.8**	**-15634.1**	**-15353.7**	**-15756.1**	**-15890.6**	**-16038.2**
Biomass	73.00	72.01	103.10	135.09	74.76	140.82	247.06	295.84	413.87	250.48	375.99
Soil Carbon	1.96	1.96	2.71	2.71	2.01	3.79	6.67	7.98	11.18	6.75	10.14
Total	**74.96**	**73.97**	**105.81**	**137.8**	**76.77**	**144.61**	**253.73**	**303.82**	**425.05**	**257.23**	**386.13**

Table 2.30 Annual carbon stock change in home gardens in CO_2 Gg/yr

Carbon gain and loss	CO_2 Gg/yr	
	2000	2010
Home gardens in dry & intermediate zone	- 4,604.68	-5,086.44
Home gardens in wet zone	- 14,490.26	-16,006.27
Total CO_2 gain	**- 19,094.94**	**-21,092.71**
Carbon loss from timber logs and poles	3,626.14	4,005.52
Carbon loss due to fuelwood	14,223.09	15,058.07
Total CO_2 loss	**17,849.23**	**19,063.59**
Carbon stock change	-1,245.71	- 2,029.12

There is no significant change in the area under annual crops in the recent past. In addition, there is no significant change in soil carbon content in the croplands that have remained as croplands for over 20 years. Therefore, no change in soil carbon stocks for cropland remaining cropland was observed.

c. Land Converted to Cropland

No significant conversion of other land uses to agriculture lands was observed during the reporting period. However, new planting areas of tea, rubber and cinnamon were reported. During the inventory preparation, these new planting areas were considered as cleared shrub lands. Therefore, considering the above assumption, carbon stock changes of biomass and soil were calculated using emission factors of 2006 IPCC-GL (Table 2.30). The proportion of carbon stock change associated with this conversion of the shrub land to new planting areas was found to be very insignificant.

2.8.2.5 Grasslands

There is no specific information on the extent of the land converted to grassland. 33,306.56 ha of grasslands were considered as grasslands remaining grassland and assumed to be at steady state with no net charge in biomass carbon stocks where carbon accumulation through plant growth balances the losses through grazing, decomposition and fire. Following the Tier-1 methodology of 2006 IPCC-GL for carbon stock changes in biomass and DOM were not estimated, assuming they are at equilibrium (IPCC, 2006). Emissions from burning of grasslands/savannas were not estimated here separately as both forests and grasslands were considered under forest fires.

2.8.2.6 Wetlands

According to the Ramsar definition, the wetlands in Sri Lanka can be categorized as inland natural freshwater, marine & salt water and man-made wetlands. In this section, only the emissions from managed and man-made wetlands that are relevant to anthropogenic activities were considered. Of the total peatland area of 2,500 ha in the country, a large extent remains permanently flooded. Only a few higher dry ground areas are developed for cultivation. The use of peat in horticulture or any other purpose is not a common practice in Sri Lanka. Thus, on-site CO_2 and non-CO_2 emissions from managed peatlands due to peat extraction were not estimated.

The statistics of the Survey Department indicate that the wetland extent of the country's tanks and reservoirs in 2010 was 139,033.5 ha. This was considered as the flooded land remaining flooded land, in the emission calculation. In estimating the CH_4 emissions from flooded land remaining flooded land, Tier-I method of 2006 IPCC-GL was used, with an emission factor of 0.095kg CH_4 $ha^{-1}day^{-1}$ (i.e. the estimated mean value for the tropical climates). The total CH_4 emissions from flooded land remaining flooded (i.e. major reservoirs) was estimated at 4.82 Gg CH_4 /yr. Emissions from land converted to wetlands (such as seasonal tanks) were not estimated as there were no clear records available for the period of 2000 to 2010.

2.8.2.7 Settlements and other lands

The carbon stock changes in biomass, DOM and soil in the land remaining in settlements and other lands (i.e. lands with bare soil, rock etc.,) or the land converted to those land use categories were not estimated due to lack of relevant data availability.

2.8.2.8 Consolidated emissions and removals for LULUCF

The consolidated emissions and removals for the forestry and other land use sector for 2010 is presented in Table 2.31.

Table 2.31 Consolidated emissions and removals of forestry and other land use sector, 2010

GHGs Sources and Sink Categories			CO_2 emissions* (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	CO (Gg)	NO_x (Gg)
3	**Forestry and Other Land Use Sector**		**21,342.4**	**- 39,826.3**	**5.37**	**0.02**	**8.44**	**0.13**
	3B1a	Forestland remaining Forestland	44.1	- 2,429.9				
	3B1b	Land converted to Forestland	162.11	- 608.22				
	3B2a	Cropland remaining cropland	20,750.06	- 36,788.21				
	3B2b	Land converted to cropland	386.13					
	3B4a	Wetland remaining wetland			4.82			
	3C1a	Biomass burning in forest land			0.55	0.02	8.44	0.13

* Total CO_2 emissions are lower than the emissions from biomass burnt, reported under the energy sector where the total emissions are derived from sustainable and unsustainable (i.e. illegal felling) biomass sources with no proper source categorization and it is a high uncertainty.

2.9 Waste sector

The waste sector releases CO_2, CH_4 and N_2O gases from solid waste disposal, biological treatment of solid waste, incineration, open burning of waste and wastewater treatment and discharge (IPCC, 2006). Solid waste disposal is commonly carried out through land filling, composting, incineration and conversion of waste to energy. The most common GHG produced from Municipal Solid Waste (MSW) disposal in Solid Waste Dumping Sites (SWDSs) is methane. In addition, CO_2 and NMVOCs as well as small amounts of N_2O produce in the disposal sites. The primary source of CO_2 from waste is the decomposition of organic matter derived from biomass sources. Based on 2006 IPCC-GL, CO_2 emission from biogenic waste was not considered under the waste sector.

The solid waste generated in the country usually includes MSW, industrial, commercial, health care and other waste such as sludge and e-waste. MSW generally refers to the waste collected by municipalities or other local authorities. The sludge refers to the waste generated from various wastewater treatment processes and it mainly includes biological and chemical sludge. Most of the chemical sludge generated from industrial wastewater treatment and biological sludge generated from health care wastewater treatment fall under hazardous waste category, as per Sri Lanka's regulations on waste management.

The most common form of MSW disposal taken place in the country during the period of 2000-2010 is the open dumping on uncontrolled SWDSs and in low lying areas and informal burning in the absence of sanitary landfills or fully engineered landfills in the country. In the areas where there were no SWDSs managed by the local authorities, waste disposal was carried out mainly on open lands, low lying areas and through open burning. Only a small portion of waste was composted and used for biogas generation. In addition, disposal of hazardous waste generated from different activities such as healthcare, wastewater treatment and other industrial activities has taken place through incineration in some establishments (using incinerators dedicated for waste destruction) and co-processing in the cement kiln at Puttlam Cement Works (PCW) at a limited level.

2.9.1 Emissions from solid waste disposal

During the period of 2000-2010 waste management was not appropriately organized due to lack of suitable waste disposal facilities in the country whereas six uncontrolled SWDSs were in operation. The prevalent method of waste disposal in Sri Lanka is open dumping accounting for more than 85% (AIT, 2014). Thus, the recorded data on waste disposal were also available only for few years, and not for all the years from 2000-2010.

The MSW database (MENR, 2005) indicates that the average MSW collection in 1998 was 2,544 tons and 2004 was 2,838 tons per day. The estimated amount of average MSW collected across the country in the year 2010 (estimated based on the past data available) was about 3,365 tons per day.

The waste generated by 46.9% of the country is burnt openly and the majority of population are not served by waste collection facilities (DCS, 2012). For the purpose of preparation of this inventory, the category of SWDSs available in the country was considered as unmanaged, shallow type SWDSs.

The estimated methane emission in SWDSs during the period of 2000-2010 shows an increase from 6.70 Gg/yr to 11.03 Gg/yr of CH_4 in Table 2.32.

Table 2.32 CH_4 emission in Gg/yr from the disposal of MSW in SWDSs

Year	MSW Disposed to SWDSs (Mil. tonnes/yr)	CH_4 Correction Factor	Fraction of Degradable Organic Content which actually degrades	CH_4 emission from SWDSs	
				CH_4 (Gg/yr)	CO_2-eq (Gg/yr)
2000	0.136	0.6	0.77	6.70	140.70
2001	0.139	0.6	0.77	6.84	143.64
2002	0.142	0.6	0.77	6.97	146.37
2003	0.144	0.6	0.77	7.11	149.31
2004	0.147	0.6	0.77	7.25	152.25
2005	0.207	0.6	0.77	10.20	214.2
2006	0.210	0.6	0.77	10.37	217.77
2007	0.214	0.6	0.77	10.53	221.13
2008	0.217	0.6	0.77	10.70	224.7
2009	0.221	0.6	0.77	10.87	228.27
2010	0.224	0.6	0.77	11.03	231.63

2.9.2 Emissions from biological treatment of solid waste

The most widely practice method of treatment of readily biodegradable organic waste is composting in Sri Lanka. The windrow composting was the most widely used in the processing of MSW and about 5% of the collected MSW are processed in various households and central composting systems (AIT, 2014). Anaerobic digestion was practiced in a few places on an individual basis for biogas generation.

Composting of waste material is an aerobic process and it converts large fraction of Degradable Organic Carbon (DOC) in the material into CO_2. Inside the anaerobic portions of the compost pile CH_4 is formed and released in small quantities. Composting produces N_2O emissions in small amounts depending on the nitrogenous compounds contained in the waste, which has been considered in the emission calculations.

The estimated emission of CH_4 and N_2O from composting of readily biodegradable MSW for the period of 2000-2010 shows an increase from 2.34 Gg/yr to 3.10 Gg/yr of CH_4 and 0.14 Gg/yr to 0.19 Gg/yr of N_2O respectively. The default emission factors used for these estimates are 0.24g N_2O/kg for nitrous oxide and 4g CH_4/kg for methane (Table 2.33).

Table 2.33 CH_4 and N_2O emissions in Gg/yr from composting of MSW

Year	Mass of Organic Waste composted (Kg '000)	Composted			
		CH_4 (Gg)	CO_2 -eq (Gg)	N_2O (Gg)	CO_2-eq (Gg)
2000	584.91	2.34	49.14	0.14	43.40
2001	595.89	2.38	49.98	0.14	43.40
2002	606.87	2.43	51.03	0.15	46.50
2003	617.84	2.47	51.87	0.15	46.50
2004	628.82	2.52	52.92	0.15	46.50
2005	690.24	2.76	57.96	0.17	52.70
2006	711.28	2.85	59.85	0.17	52.70
2007	732.32	2.93	61.53	0.18	55.80
2008	753.37	3.01	63.21	0.18	55.80
2009	774.41	3.10	65.1	0.19	58.90
2010	764.09	3.18	66.78	0.19	58.90

2.9.3 Emissions from incineration and open burning of solid waste

As a result of unavailability of incineration facility for solid waste and hazardous waste including pharmaceutical waste, waste oil and industrial sludge, data for GHG emission calculation were not available for the period of 2000-2010.

Open burning is the most commonly practices method of disposal of MSW in rural areas and sub urban areas where there are no proper waste management facilities available. In addition, open burning of dry waste including yard trimming are practiced in the urban areas too.

The estimated emission of CH_4, N_2O and CO_2 from open burning of MSW during the period of 2000-2010 shows an increasing trend from 0.56 Gg/yr to 0.81 Gg/yr of CH_4, 0.01 Gg/yr to 0.02 Gg/yr of N_2O and 96.39 Gg/yr to 122.78 Gg/yr of fossil CO_2 (Table 2.34). The default emission factors used for estimating methane (6,500 gCH_4/tonne) and nitrous oxide (150 gN_2O/tonne) of waste quantity.

Table 2.34 CH_4, N_2O and CO_2 emissions in Gg/yr from open burning of MSW during 2000-2010

Year	MSW (tonnes/yr)	CH_4	CO_2-eq	N_2O	CO_2-eq	CO_2
2000	86.00×10^3	0.56	11.76	0.01	3.1	96.39
2001	87.03×10^3	0.57	11.97	0.01	3.1	98.16
2002	88.07×10^3	0.57	11.97	0.01	3.1	99.94
2003	89.10×10^3	0.58	12.18	0.01	3.1	101.71
2004	90.13×10^3	0.59	12.39	0.01	3.1	103.49
2005	99.96×10^3	0.65	13.65	0.01	3.1	106.70
2006	104.92×10^3	0.68	14.28	0.02	6.2	109.92
2007	109.88×10^3	0.71	14.91	0.02	6.2	113.14
2008	114.85×10^3	0.75	15.75	0.02	6.2	116.35
2009	119.81×10^3	0.78	16.38	0.02	6.2	119.57
2010	124.77×10^3	0.81	17.01	0.02	6.2	122.78

The summary of the estimated emissions of CH_4, N_2O and CO_2 associated with MSW handling for the year 2010 is given in the Table 2.35.

Table 2.35 The summary of CO_2, CH_4 and N_2O emissions in Gg/yr from MSW handling

Year	Open burnt	Disposal Sites		Composted		Open burnt		Composted		Open burnt	
	CO_2	CH_4	CO_2-eq	CH_4	CO_2-eq	CH_4	CO_2-eq	N_2O	CO_2-eq	N_2O	CO_2 -eq
2000	96.39	6.70	140.70	2.34	49.14	0.56	11.76	0.14	43.40	0.01	3.10
2001	98.16	6.84	143.64	2.38	49.98	0.57	11.97	0.14	43.40	0.01	3.10
2002	99.94	6.97	146.37	2.43	51.03	0.57	11.97	0.15	46.50	0.01	3.10
2003	101.71	7.11	149.31	2.47	51.87	0.58	12.18	0.15	46.50	0.01	3.10
2004	103.49	7.25	152.25	2.52	52.92	0.59	12.39	0.15	46.50	0.01	3.10
2005	106.70	10.20	214.20	2.76	57.96	0.65	13.65	0.17	52.70	0.02	3.10
2006	109.92	10.37	217.77	2.85	59.85	0.68	14.28	0.17	52.70	0.02	6.20
2007	113.14	10.53	221.13	2.93	61.53	0.71	14.91	0.18	55.80	0.02	6.20
2008	116.35	10.70	224.70	3.01	63.21	0.75	15.75	0.18	55.80	0.02	6.20
2009	119.57	10.87	228.27	3.10	65.1	0.78	16.38	0.19	58.90	0.02	6.20
2010	122.78	11.03	231.63	3.18	66.78	0.81	17.01	0.19	58.90	0.02	6.20

2.9.4 Emissions from wastewater treatment and discharge

The sources of the wastewater generated in the country includes domestic, industrial and commercial. In urban areas where treatment plants are available, domestic wastewater including sewage are treated and discharged while pre-treated industrial wastewaters generated from the industries located in the industrial zones established under the Board of Investment of Sri Lanka (BOI) are disposed into the common treatment plants of the respective industrial zones.

In the rest of the urban areas, sewage generated is disposed into onsite septic tanks through water sealed latrines and the majority of domestic wastewater is disposed into soakage pits. Industries located in the non-industrial zones across the country are expected to treat their wastewater to comply with the effluent disposal standards stipulated by the respective regulatory authorities. CH_4 emissions from common treatment facilities were considered negligible as those are of aerobic biological treatments followed by simple chemical treatments.

In order to estimate GHG emissions of wastewater treatment of sugar and brewery were considered. In the estimation of CH_4 emission, the industry-specific activity data together with the respective default vales of maximum CH_4 producing capacity of 0.25kg CH_4/kg, Chemical Oxygen Demand (COD) and CH_4 Correction Factor (MCF) of 0.2 indicated in the 2006 IPCC-GL were used in the calculation of CH_4-EF for the treatment pathway.

The brewery industry considered for the GHG estimation treats its process wastewater using anaerobic digestion, and the emitted biogas is burnt in a flaring mechanism before releasing to the environment. Therefore, GHG emissions from the brewery industry was considered negligible.

The summary of emissions of CH_4 and N_2O associated with the treatment and discharging of wastewater for the period of 2000-2010 is given in the Table 2.36. The estimated emissions of CH_4 and N_2O associated with the treatment and discharge of domestic wastewater reported for the period of 2000-2010 showed an increase from 9.10 Gg/yr to 10.12 Gg/yr for CH_4. However, a decrease of CH_4 from 0.0034 Gg/yr to 0.0014 Gg/yr from industrial wastewater treatment is shown. The emissions of N_2O associated with domestic wastewater has increased from 0.6 Gg/yr to 0.84 Gg/yr. The N_2O emissions associated with industrial wastewater was insignificant.

Table 2.36 CH_4 and N_2O emissions from wastewater discharge in Gg/yr

Year	CH_4 emissions				N_2O emissions			
	Domestic WW Discharge		Industrial WW Treatment (Sugar)		Industrial WW Treatment		Domestic WW Discharge	
	CH_4	CO_2-eq	CH_4	CO_2-eq	N_2O	CO_2-eq	N_2O	CO_2-eq
2000	9.10	191.08	0.0034	0.0714	0.002	0.62	0.60	186.0
2001	9.19	193.08	0.0030	0.0630	0.002	0.62	0.62	192.2
2002	9.29	195.12	0.0017	0.0357	0.002	0.62	0.63	195.3
2003	9.39	197.19	0.0045	0.0945	0.002	0.62	0.65	201.5
2004	9.49	199.28	0.0022	0.0462	0.002	0.62	0.68	210.8
2005	9.59	201.40	0.0008	0.0168	0.002	0.62	0.71	220.1
2006	9.41	197.58	0.0009	0.0189	0.002	0.62	0.70	217.0
2007	9.80	205.75	0.0020	0.0420	0.002	0.62	0.72	223.2
2008	9.90	207.93	0.0024	0.0504	0.002	0.62	0.75	232.5
2009	10.01	210.18	0.0019	0.0399	0.002	0.62	0.76	235.6
2010	10.12	212.43	0.0014	0.0294	0.002	0.62	0.84	260.4

2.9.5 Consolidated emissions of the waste sector

The consolidated emissions for waste sector for 2010 is presented in the Table 2.37.

Table 2.37 Consolidated emissions of the waste sector in 2010

Waste Category No.	Waste Category	Net Annual Emissions (Gg)		
		CH_4	N_2O	Fossil CO_2
4	**Waste**	**25.14**	**1.052**	**122.78**
4A	Solid Waste Disposal on SWDSs	11.03	-	-
4B	Biological treatment of solid waste	3.18	0.19	-
4C	Open burning of Waste	0.81	0.02	122.78
4D	Wastewater treatment and discharge			
	Domestic wastewater discharge	10.12	0.84	-
	Domestic wastewater treatment (STP)	-	4.57×10^{-5}	-
	BOI Industry wastewater treatment	-	0.002	-
	Sugar industry wastewater treatment	1.44×10^{-3}	-	-

CHAPTER THREE

Vulnerability and Adaptation Measures

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Vulnerability and Adaptation Measures

3.0 Introduction

Sri Lanka is in the frontline of climate change, frequently facing repetitive climate induced disasters with multiple impacts on economic development. A multitude of natural hazards such as droughts, floods, landslides, cyclones, storms and sea-level rise threaten the country. According to Desinventar database of Disaster Management Centre, Sri Lanka, around 15 million people have been affected by droughts (8,047,354), floods (7,187,921) and landslides (190,000) from 2008 to 2018 in Figure 3.1.

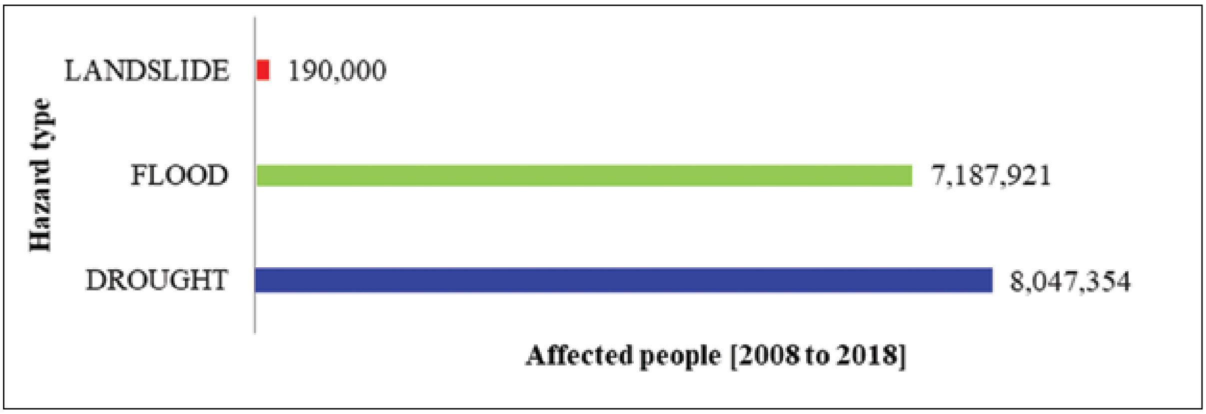


Figure 3.1 Number of affected people by droughts, floods, landslides (2008-2018)

The incidence of disasters caused by climate hazards has increased by 22 folds during the last decade compared to 1973-1983 (UNDRR, 2019). The post disaster needs assessments (PDNAs) in 2016 and 2017 estimated the loss and damage due to floods and landslides as the LKR 175 billion. The Global Climate Risk Index 2019 published by the Germanwatch has ranked Sri Lanka as the second most vulnerable country to extreme climatic events in the world (Eckstein et al., 2019). The World Bank estimates that 7.7% of GDP will need to be spent to manage climate related disasters by 2050 (WB and EU, 2017).

3.1 Scope

This chapter assesses climate change risks (present and predicted) posed by prevalent hazards which include floods, droughts, sea level rise and landslides in vulnerable sectors of agriculture, fisheries, livestock, water resources, health, biodiversity & ecosystems, coastal & marine, human settlements and tourism. These sectors are consistent with the Nationally Determined Contributions (NDCs) and National Adaptation Plan for Climate Change Impacts in Sri Lanka (NAP). A focus on the different climate risks in different administrative boundary levels provides an opportunity to propose appropriate, robust and flexible adaptation measures. Further, it enables an understanding of climate scenarios supporting to assess possible impacts and potential adaptation measures at national and sub-national levels. The methodology used to do so is described in 3.2.

3.2 Methodology

Identifying of risks and adaptation measures was a consultative process with the participation of sector experts and the officials of relevant institutions. The National Expert Committee on Climate Change Adaptation (NECCCA) as well an Independent Review Panel provided guidance during the assessment. The risk assessment was recommended and guided by the NECCCA, based on the methodology proposed by the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The assessment examined:

1. **Past and future climate analysis:** Past trend analysis was conducted using data of 19 surface weather stations maintained by the DoM in Sri Lanka from 1980 to 2015. Future climate predictions have been investigated using short-, medium- and long- term time horizons; using downscaled (25km grid resolution) RCP 4.5 and RCP 8.5 climate projections as per the section 4.2 of AR5.

2. **Socio-economic analysis:** Socio-economic analysis was based on secondary information obtained through desk review, participatory techniques and consultations. The analysis focused on socio-economic impacts due to climate change as well as impacts due to implemented adaptation measures. Projection-based Futuristic Vision was used to guide the analysis.

3. **Approach used for developing climate change risk maps:** The AR5 Climate Risk Framework has been adopted for this study and the following risk formula given in the GIZ Resource Guide was used for risk calculations (GIZ and EURAC, 2017).

Risk = (Hazard × Weightage of Hazard (wH) + Exposure × wE + Vulnerability x wV) /(wH+wE+wV)

Hazard is the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury and other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Exposure is the presence of people (population), livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. Population vulnerability is derived from historic death toll whereas economic vulnerability is derived from historic economic losses.

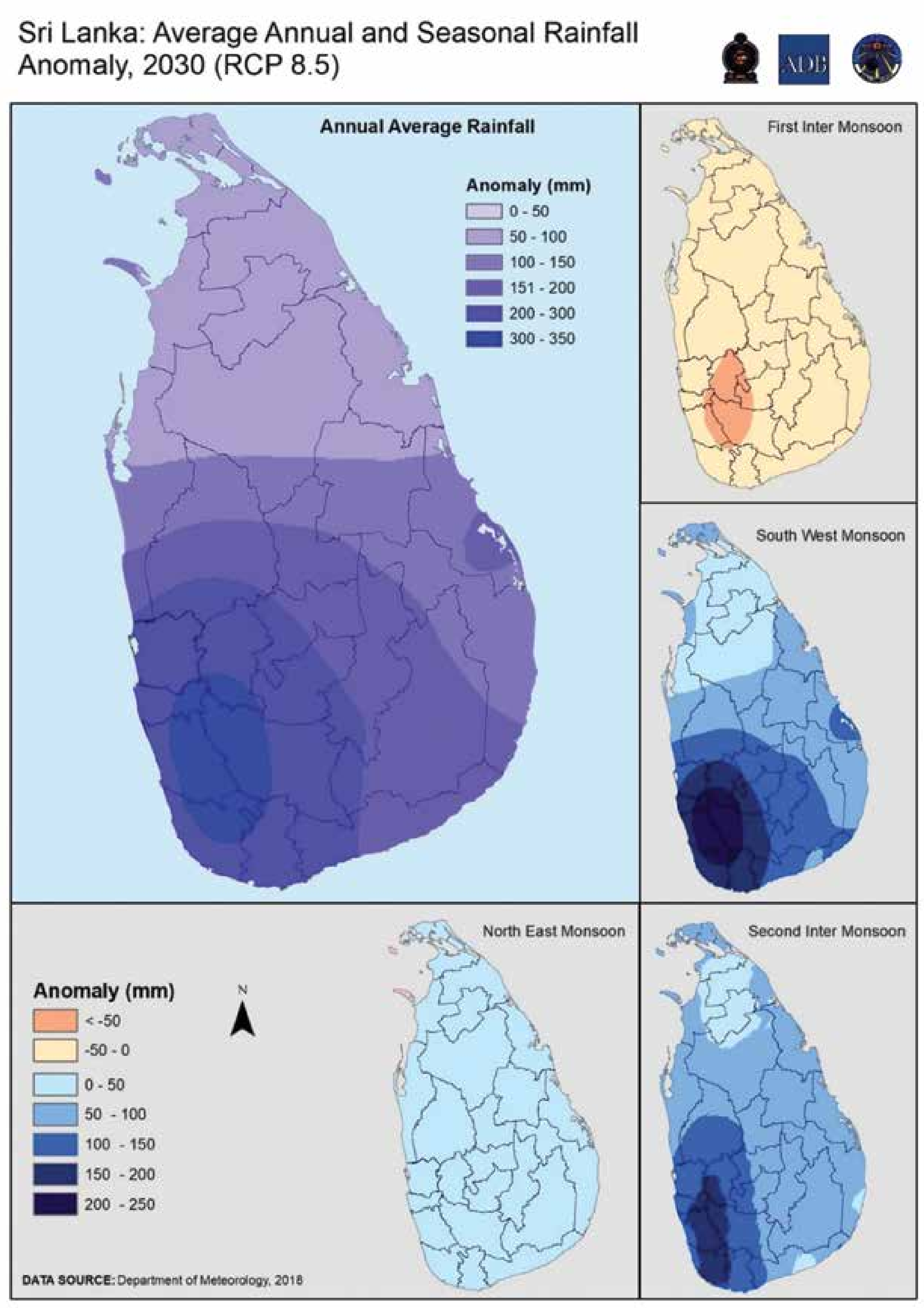
Weightage is the process of attaching a numerical modification (weight) to an indicator to emphasize the importance of this indicator against other indicators. Weighting (eg: adding a multiplier or divisor to the respective factor) is used to enhance or reduce the influence of that factor in its interaction within the composite indicator.

Indicators for each risk component were selected through stakeholder consultations and considering data availability and sub-sectoral impacts. Weightages for selected indicators were assigned through expert opinions. Data required for each indicator were collected in line with mapping boundaries. Proxy data were used where direct data were not available. Data normalization techniques were used for data standardization. The Weighted Arithmetic Aggregation Technique was used for risk calculation and mapping. In mapping, the Equal Interval Technique was used to classify different risk categories: low risk (0-0.33), moderate risk (0.33-0.66) and high risk (0.66-1). Areas with data deficiency, non-applicable and less than the threshold value in appropriate sectors and sub-sectors with specific parameters are indicated in hollow color (white).

In the health sector, the climate change risk of Dengue, Leptospirosis and Leishmaniosis were assessed based on the boundaries of MOH (Medical Officer of Health) divisions. To calculate the Temperature Humidity Index (THI) for cattle in the livestock sector, the formula defined by Mader, et al. (2006) was used. For the biodiversity sector, Maximum Entropy (MaxEnt) modelling version 3.4.1 (Phillips et al., 2004 and 2006; Phillips and Dudick 2008; Elith et al. 2011) was used to predict current and future habitat suitability in line with available species distribution data. High resolution contour mapping was used to assess the risk to sea level rise along the coastal areas and potential one meter inundation areas using LiDAR data. A map of 1:50,000 Landslide risk-prone area prepared by NBRO was used to interpret landslide risk.

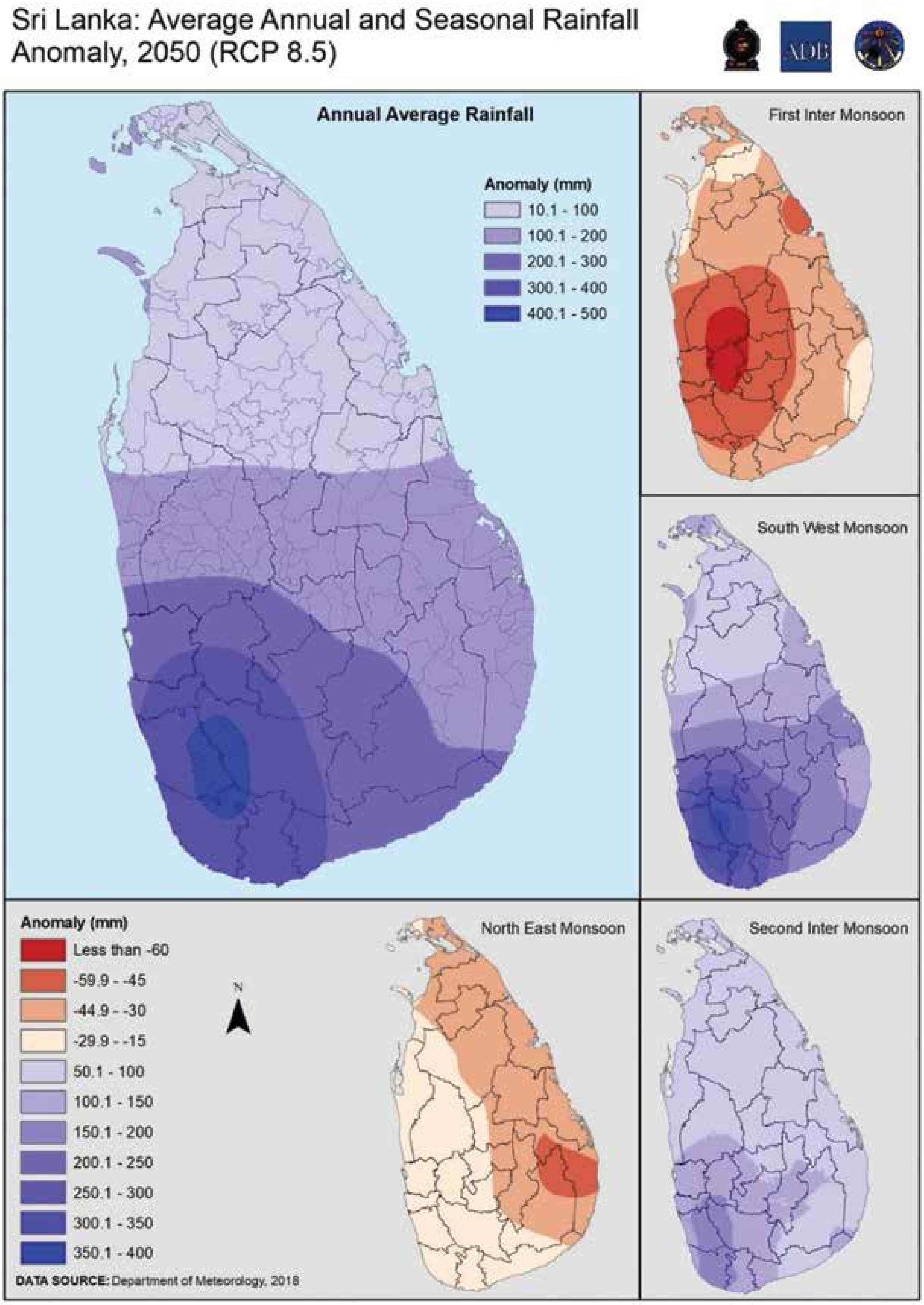
The prepared risk maps reflecting the current status of the sectors was compared with 2030 and 2050 RCP 8.5 rainfall and temperature anomaly maps prepared by the project of Updating Climate Change Vulnerability Assessment and Piloting Mainstreaming Climate Change Adaptation into National Development Activities implemented by the DoM, Sri Lanka (Figure 3.2-3.5).

For each sector, appropriate future anomalies of temperature and rainfall maps for 2030 and 2050 under RCP 8.5 were compared with risk maps prepared by this assessment (Figure 3.2-3.5). Although, the assessment applied all the risks into relevant sectors, only the maps with significant risks are included in this report. Adaptation measures were proposed through a participatory approach, based on risk maps and climate projections. Indicators for women, children and other vulnerable groups including the elderly, differently-abled and pregnant women were also considered in developing the indicator list and proposed appropriate robust and flexible adaptation opportunities.



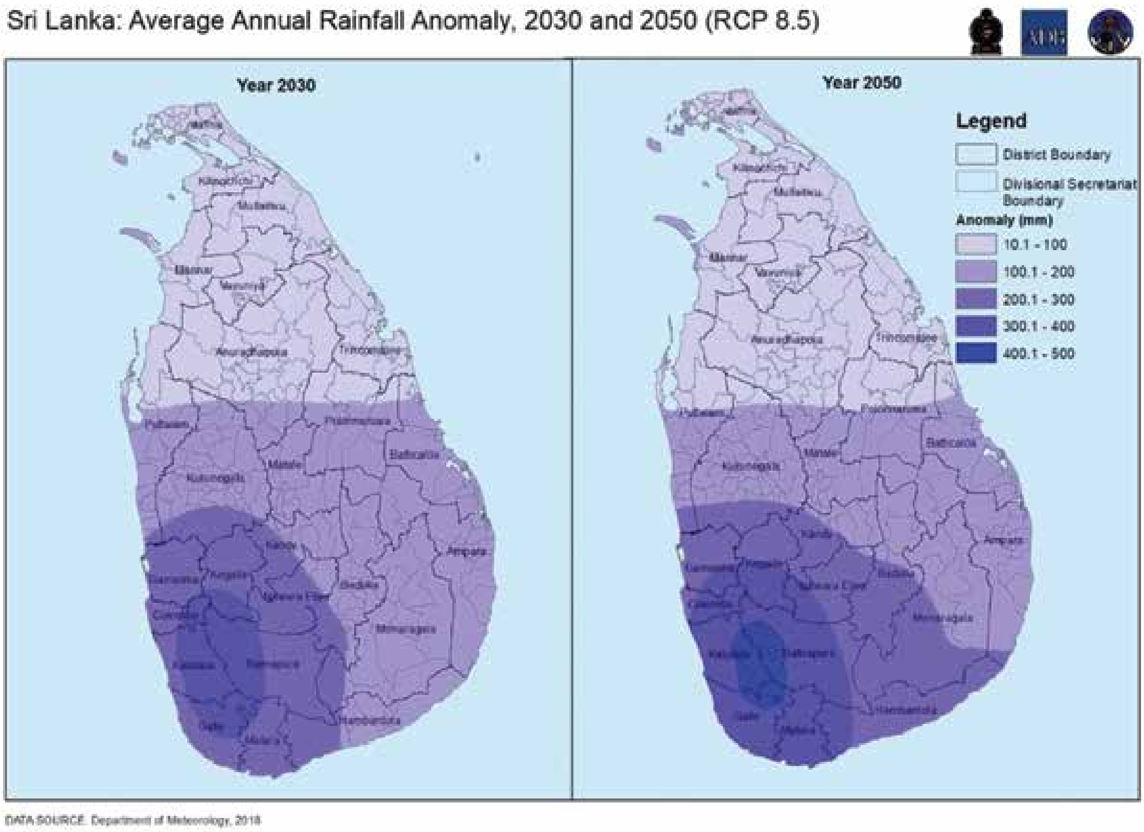
Source: Climate Risk Assessment 2018, ADB (TA-8572 REG)

Figure 3.2 Average annual rainfall anomalies by monsoons, 2030 (RCP 8.5)



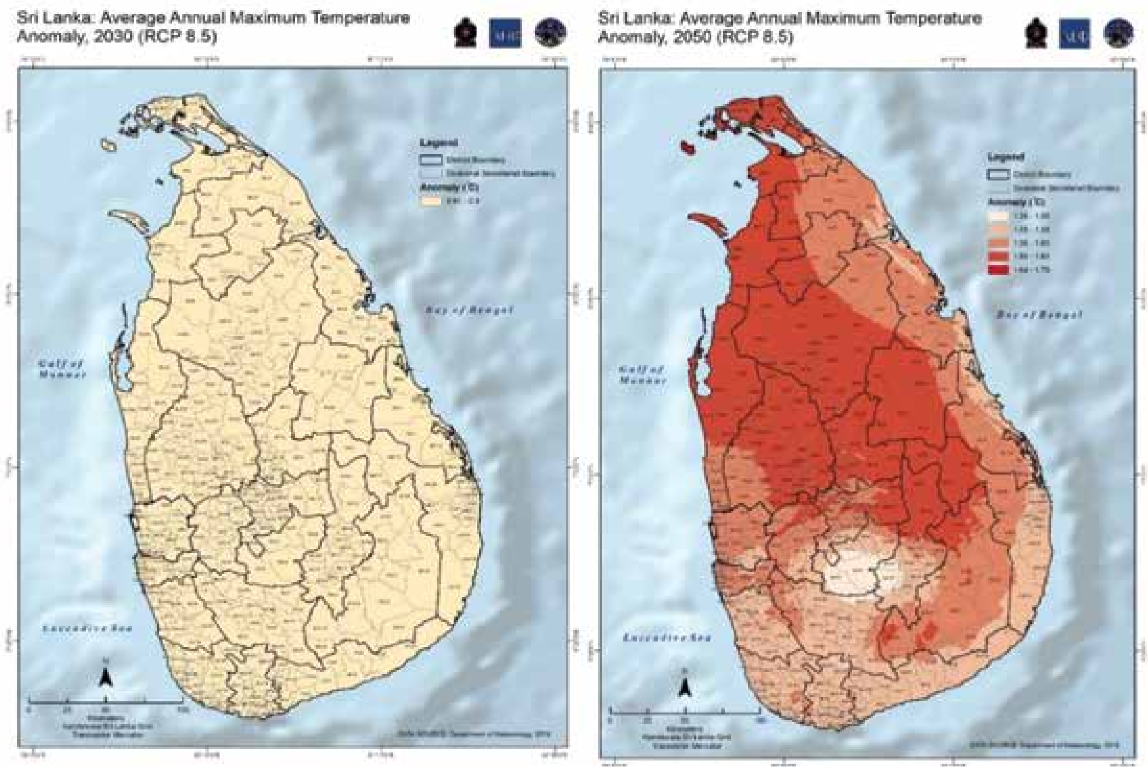
Source: Climate Risk Assessment 2018, ADB (TA-8572 REG)

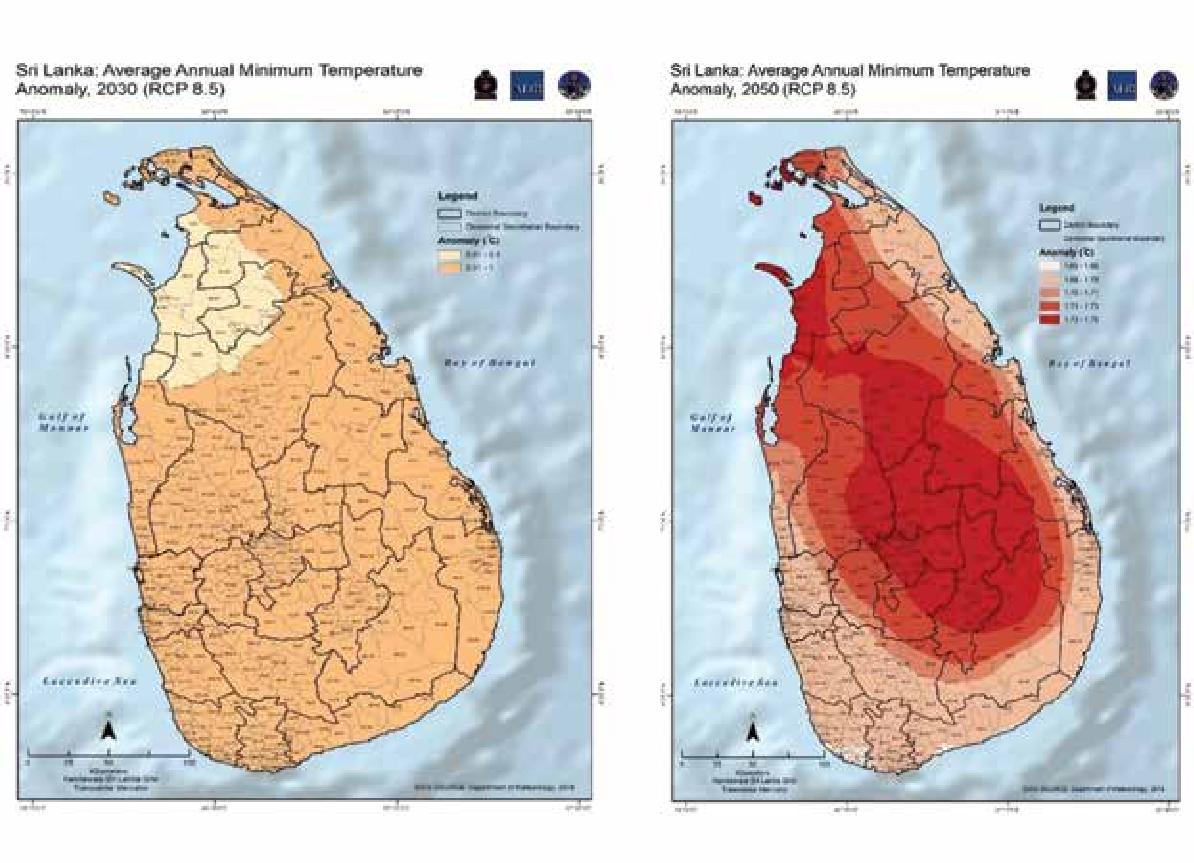
Figure 3.3 Average annual rainfall anomalies by monsoons, 2050 (RCP 8.5)



Source: Climate Risk Assessment 2018, ADB (TA-8572 REG)

Figure 3.4 Average annual rainfall anomalies for 2030 and 2050





Source: Climate Risk Assessment 2018, ADB (TA-8572 REG)

Figure 3.5 Average annual maximum temperature anomaly (up); and average annual minimum temperature anomaly (bottom); 2030 and 2050

3.3 Climate change trends in Sri Lanka

3.3.1 Observed local trends (temperature and precipitation, 1980-2015)

Standardized and homogeneous daily rainfall and maximum and minimum temperature records were obtained from 19 weather stations of DoM for the time period of 1980-2015. These were used for analyses of trends in annual extreme indices of temperature and precipitation in Sri Lanka (Jayawardena et al., 2018). Ten extreme precipitation indices and nine extreme temperature indices were computed for all stations using the RClimDex software developed by the World Meteorological Organization Expert Team on Climate Change Detection and Indices (WMO-ETCCDI) (Easterling et al., 2003; Alexander et al., 2006).

The results of this analysis reveal that warm nights are increasing and cold nights have significantly decreased (Figure 3.6). It is evident that annual average minimum temperatures are increasing significantly across the country. The diurnal temperature range difference between maximum and minimum temperatures is decreasing (Easterling et al., 1997; Jayawardena et al., 2018), indicating that the minimum temperature is increasing faster than the maximum temperature (Figure 3.7). Moreover, significantly decreasing trends were observed for "*Maha*" season than "*Yala*" season.

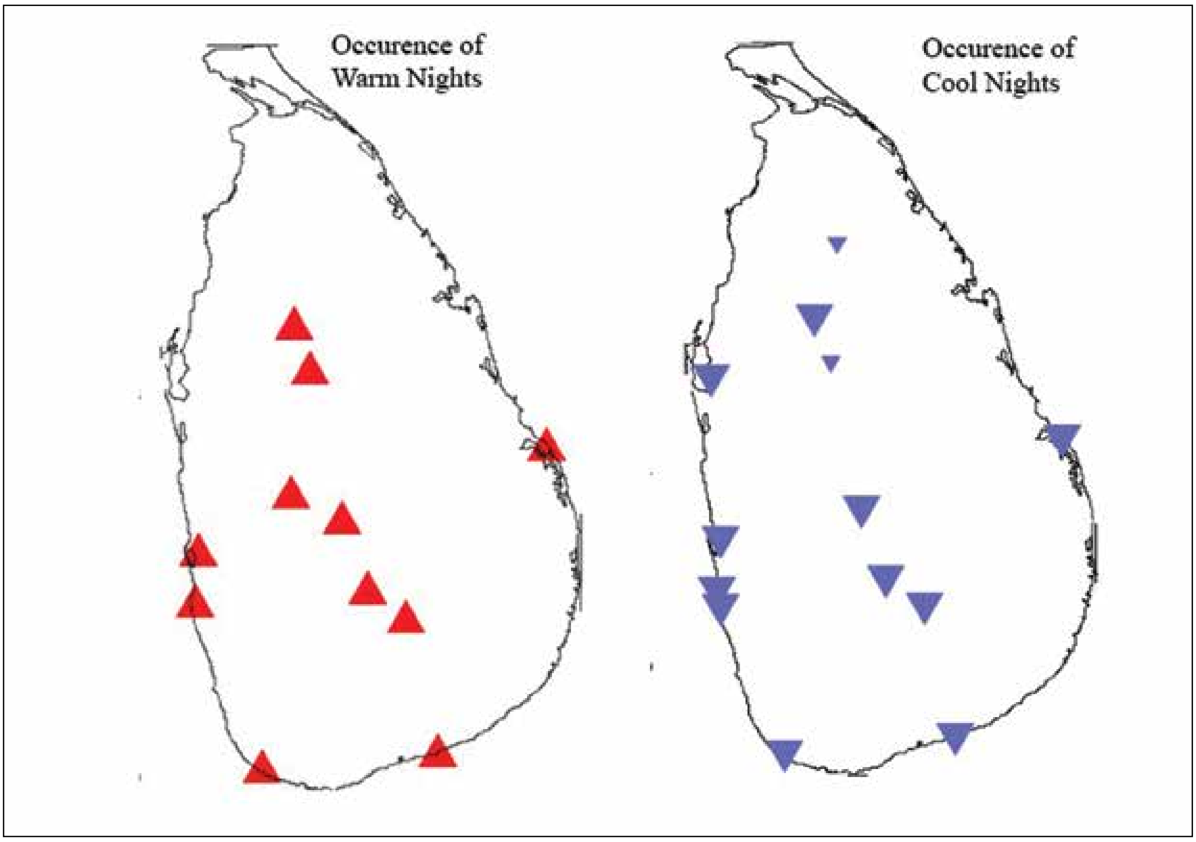


Figure 3.6 Spatial distribution maps of trends in occurrence of warm nights (left) and occurrence of cold nights (right) (see Note 01 for explanation of triangles)

Note 01: Red triangles show an increasing trend; blue triangles indicate a decreasing trend; significant changes at the 5% level are indicated by large triangles and 10% levels are indicated by small triangles (Adopted from Jayawardena et al., 2018).

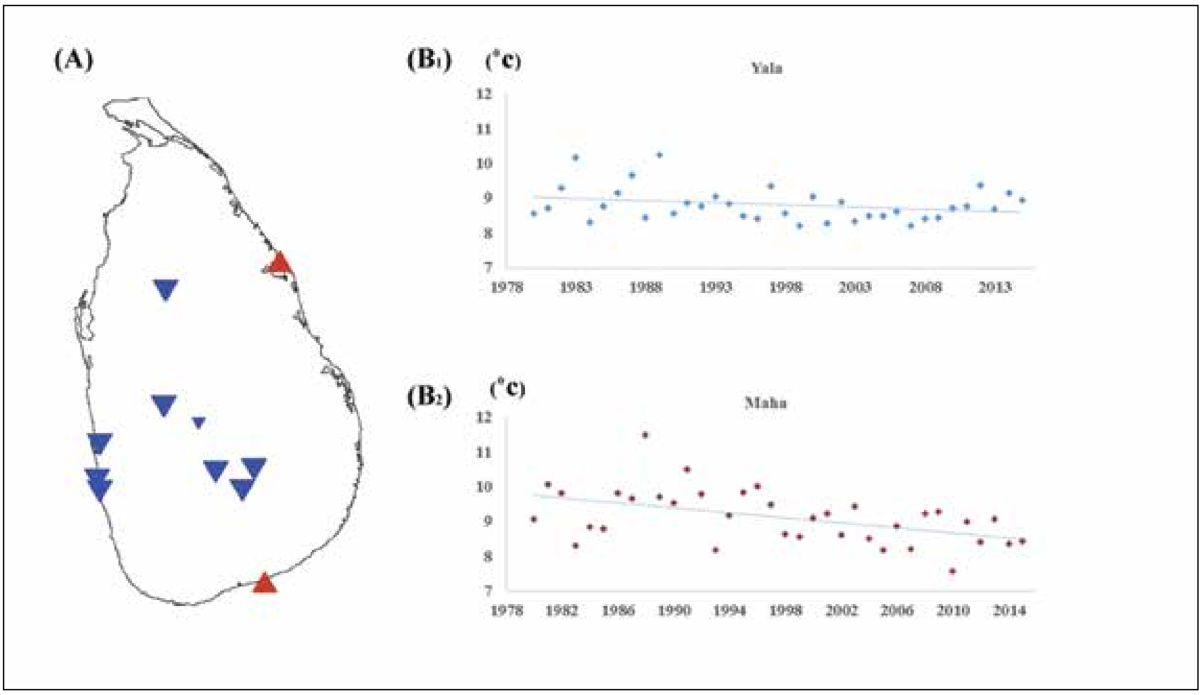
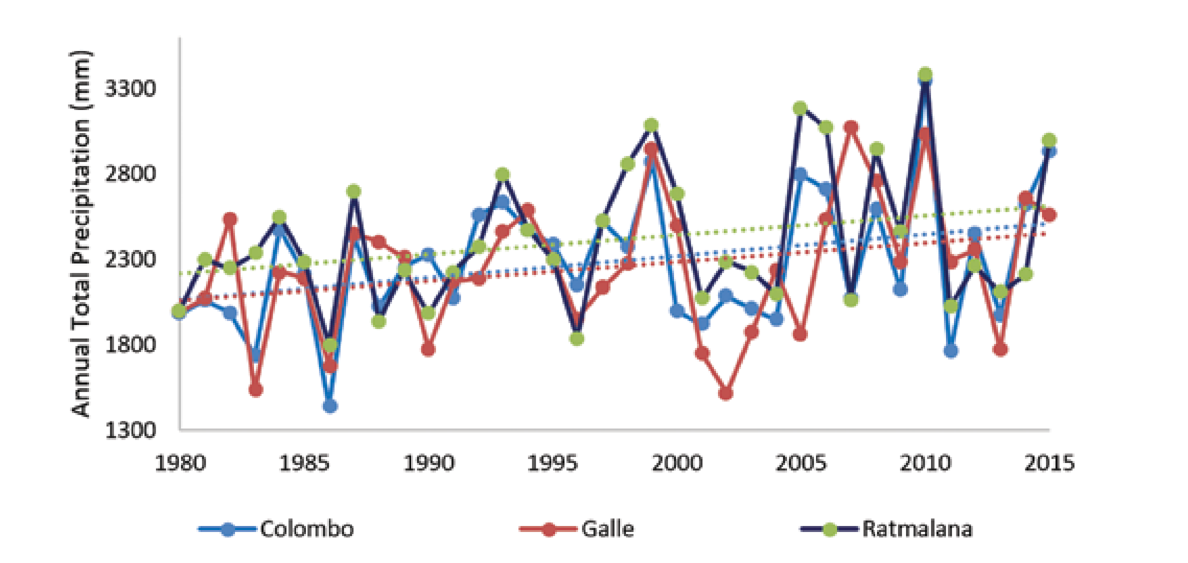


Figure 3.7 Spatial distribution maps of trends in diurnal temperature range and time series for diurnal temperature range for Yala (B1) and Maha (B2) seasons at Anuradhapura (Note 01)

Rainfall: An increasing trend was observed for total annual rainfall in Sri Lanka for the period of 1980-2015 (Figure 3.8). Statistics revealed that 65% of stations have shown significantly increasing trends for annual precipitation at 5% or 10% level (Jayawardena et al., 2018) (Figure 3.9). The maximal one-day and five-day precipitations from 2010-2015 in main three climatic zones when compared with decadal changes, revealed; 60% and 50% increase in maximal one-day and five-day precipitation in Anuradhapura, 110% and 60% increase in Batticaloa (compared to the 30 years average) in Table 3.1. Additionally, 90% of the stations showed non-significant increasing trends in total precipitation on extreme rainfall days. However, 20-25% of the station trends are significant at the 5%-10% levels in Figure 3.9 (Jayawardena et al., 2018).



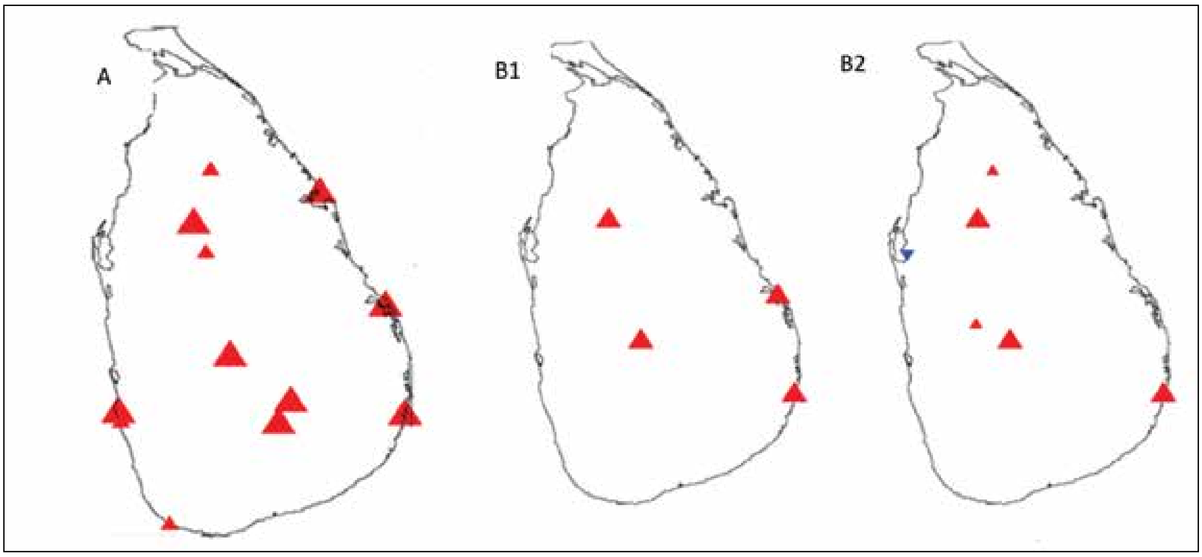
Source : Jayawardena al., 2018

Figure 3.8 Time series for annual total precipitation at few stations located in Colombo, Galle and Ratmalana

Table 3.1 Decadal changes in five-day maximum rainfall and one-day maximum rainfall in selected stations representing the three climatic zones

Period	Dry zone			Intermediate zone			Wet zone		
	Anuradhapura	Puttatum	Batticoloa	Kurunegala	Badulla	Bandarawela	Katunayake	Katugastota	Nuwara Eliya
	Maximum Five-Day Rainfall								
Average 30	175	193	251	221	192	159	142	93	85
Decade 80	166	213	238	229	237	177	123	95	91
Decade 90	176	189	225	214	168	144	162	94	94
Decade 2000	184	180	286	219	171	160	133	90	70
2010-2015	**281**	**159**	**528**	**301**	**257**	**192**	**146**	**127**	**95**
	Maximum One-Day Rainfall								
Average 30	89	113	126	123	95	76	257	177	188
Decade 80	73	133	130	123	110	78	243	178	217
Decade 90	99	114	113	115	94	75	265	179	197
Decade 2000	94	95	135	131	81	75	252	173	150
2010-2015	**135**	**79**	**200**	**172**	**124**	**91**	**263**	**249**	**198**

Source: Jayawardena et al., 2018

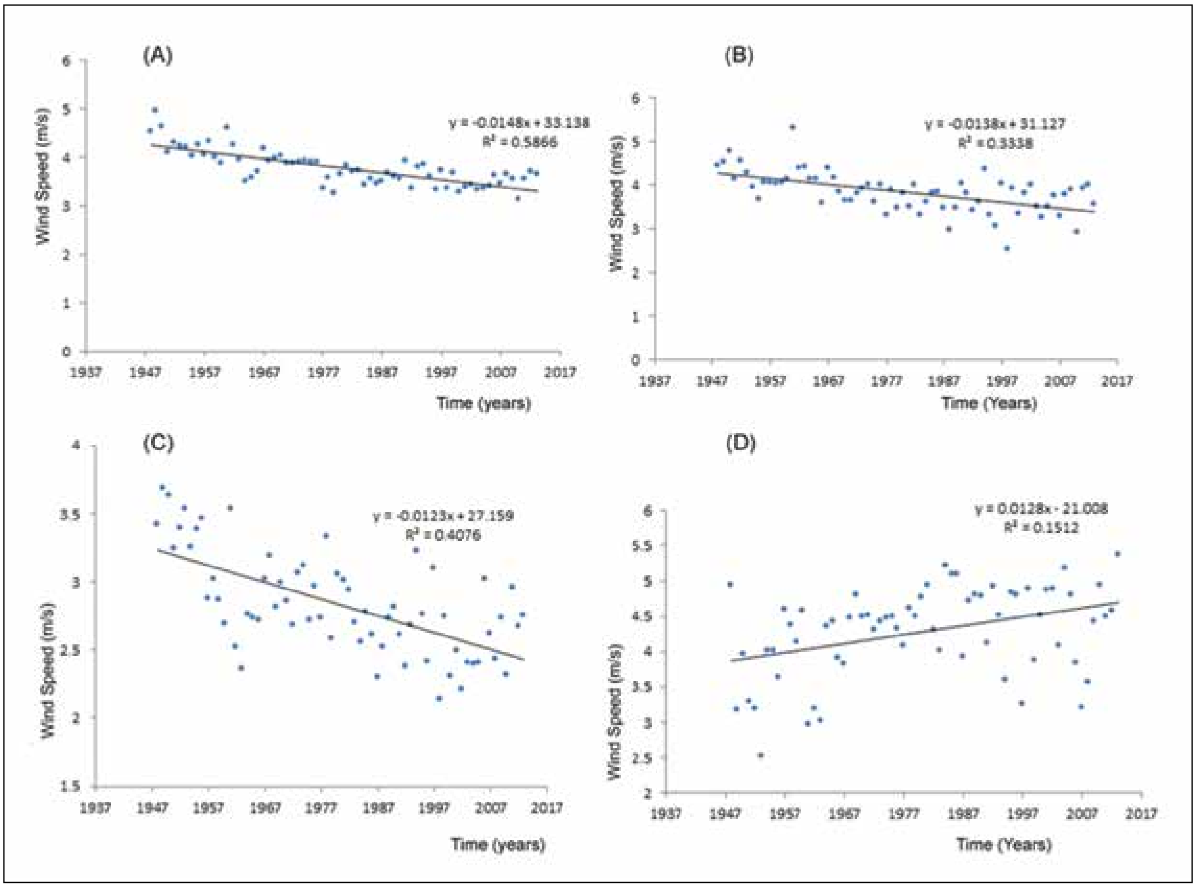


Source: Jayawardena et al., 2018

Figure 3.9 Spatial distribution map of trends for annual total precipitation (A), spatial distribution maps of trends for very wet (B1) and extremely wet (B2) days (Note 01)

Consecutive wet days (CWD) and Consecutive dry days (CDD) have shown mixed trends for all 19 meteorological stations for period of 1980-2015. The station in Katugasthota station showed increasing trends while Nuwara Eliya and Ratnapura stations resulting a decreasing trend in CWD. Meteorological stations such as Colombo, Katunayake, Ratmalana and Puttalam that are located in the west coast showed lesser number of CDD. Increasing trend of high precipitation indicate that occurrence of extreme rainfall events will influence the total annual precipitation in Sri Lanka in Figure 3.9. Therefore, the increases in total rainfall observed in many locations may be due to extreme rainfall events.

Wind: Sri Lanka has two distinct monsoonal wind patterns; southwest and northeast monsoons. The Department of Meteorology has commenced a study to understand the changes in southwest monsoon wind pattern using two major study areas located on Bay of Bengal and the Arabian Sea. The wind speeds in both these locations showed decreasing trends while meridional component showed increasing trends. The meridional wind component will dominate over the Arabian Sea causing a stronger southwest monsoon in Sri Lanka (Figure 3.10).



Source: Premalal, 2018

Figure 3.10 Time series for area average wind speed (ms-1) of zonal wind (A) and meridional wind (B) at Arabian Ocean and zonal wind (C) and meridional wind (D) at Bay of Bengal zone during onset of southwest monsoon from 1937-2017

3.3.2 Climate change projections (Scenarios)

Statistically downscaled (25 km^2 grid resolution) NASA Earth Exchange Global Daily projection data sets were used to analyze through CanESM2, CNRM-CM5, CSIRO-MK3-6-0, GFDL-CM3, MRI-CGCM3 and NCAR-CCSM4 under Coupled Model Inter-comparison Project 5 (CMIP5). The research also investigated future changes of precipitation and temperature for three time periods as 2030s, 2050s and 2080s. The study refers 2020-2040 as a short term, 2040-2060 as medium term and 2070-2090 as long term for the two emission scenarios of RCP 4.5 (moderate emission) and RCP 8.5 (high emission) against climatological means during the historical run period from 1975-2005. Spatial patterns of precipitation for all three futures have been discussed for seasonal and annual patterns in this section.

Temperature: In the ensemble multi model prediction, results increase in minimum and maximum temperatures for all three-time horizons for both RCP 4.5 and RCP 8.5. Further, results of multi model ensemble prediction revealed that minimum and maximum temperature of RCP 4.5 is expected to be increased by 0.7-1.2°C in short term, by 1.0-1.6°C in medium term and 1.5-2.3°C by long term with respect to climate projections. According to the RCP 8.5, temperature increased under the projections in short, medium and long term will be 1.1-1.5°C, 1.6-2.5°C, and 2.4-3.5°C for maximum temperature and 1.0-1.5°C, 1.4.-2.3°C and 2.2-3.2°C for minimum temperature in Figure 3.11.

Rainfall: *South West Monsoon (SWM):* In the short-, medium- and long-term projections, the positive anomaly of rainfall is predicted over most parts of the island by multi-model ensemble prediction under RCP 4.5 and RCP 8.5 scenarios including the wet zone that could result in more intense rainfall with greater aerial extension in the future in Figure 3.12.

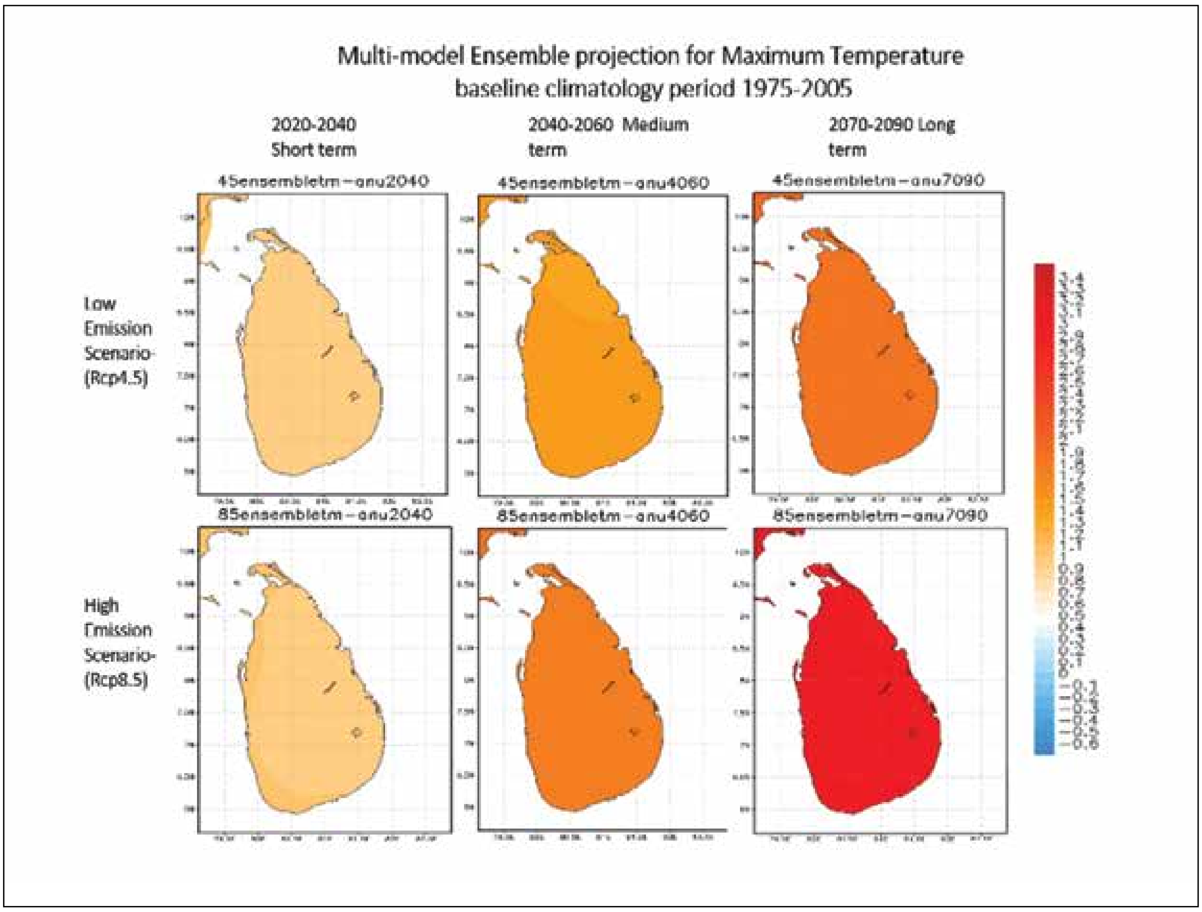
North East Monsoon (NEM): Northeast monsoon rainfall anomaly is negative for short-, medium- and long-term projections with a slightly positive anomaly over most parts of the island under RCP 8.5 for short term projection. During the medium term, projections indicate a negative rainfall anomaly over most parts of Sri

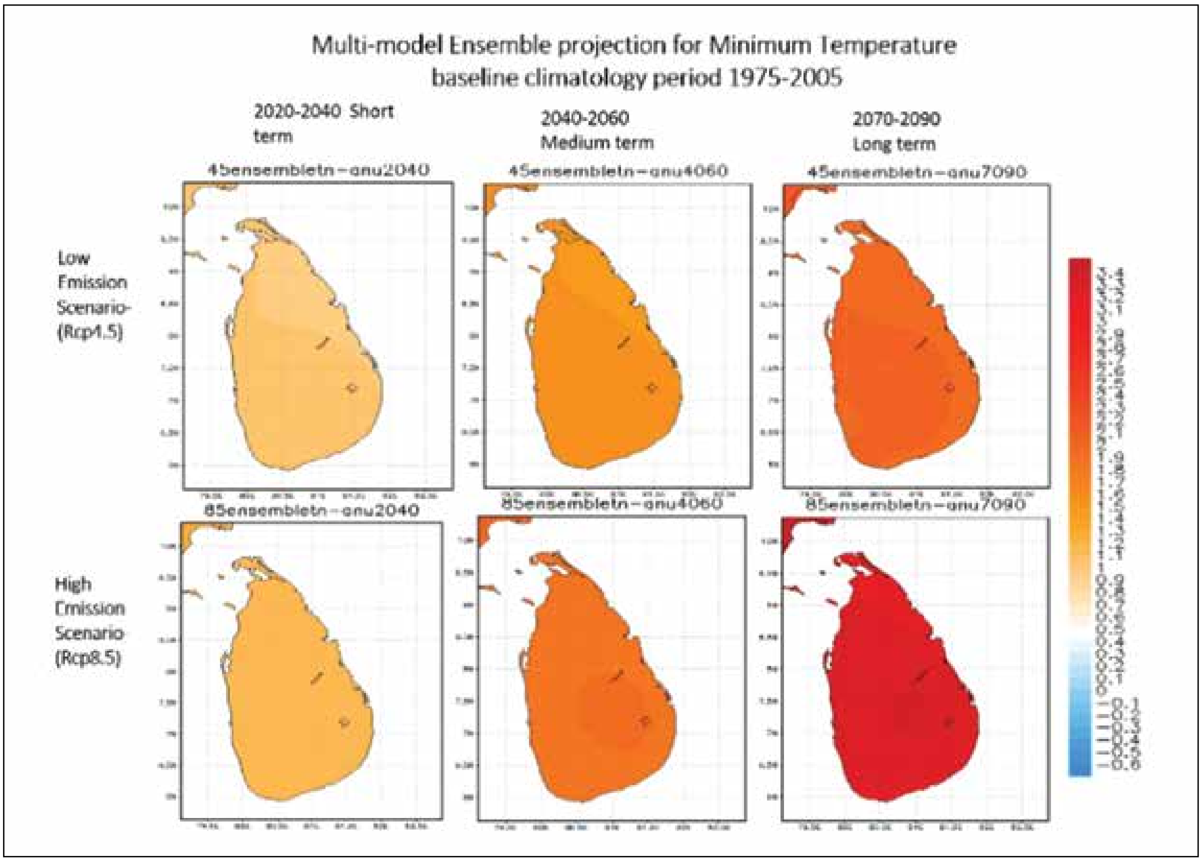
Lanka for both RCP 4.5 and RCP 8.5 scenarios. Negative anomalies of rainfall are predicted in the long term for both emission scenarios with lesser number of rainfalls in the dry zone (Figure 3.13).

First Inter Monsoon (FIM): A negative rainfall anomaly is evident for the short term, slightly negative for the medium term and a positive anomaly for the long term according to the RCP 4.5 scenario. However, RCP 8.5 resulted in negative anomalies for the rainfall for short-, medium- and long-term periods.

Second Inter Monsoon (SIM): The multi-model ensemble predicted a negative anomaly over the north-eastern parts and positive anomalies in the remainder of the country for RCP 4.5 in the short term, while RCP 8.5 projected positive anomalies for the rainfall over most parts of the island in the medium term. The long term scenario for RCP 4.5 and 8.5 indicates a positive rainfall anomaly for entire country.

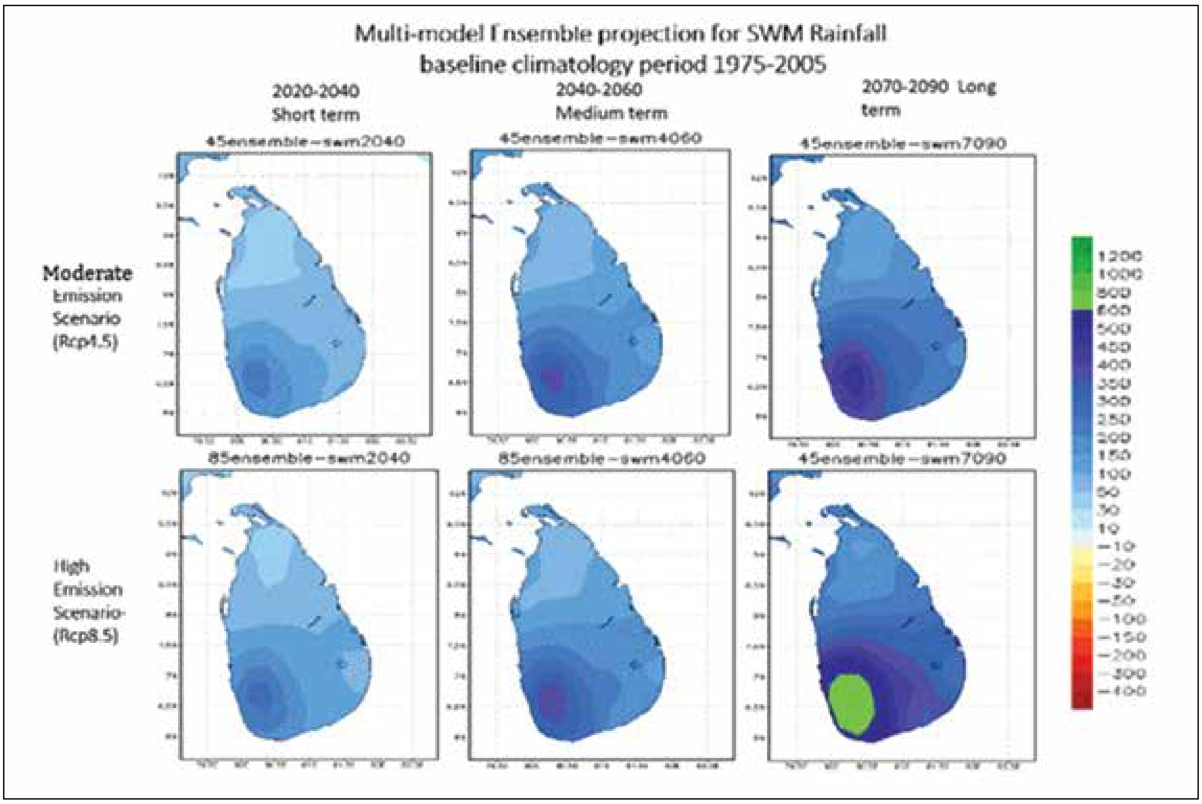
Annual Rainfall: The study using multi-model ensemble projections indicated that the annual rainfall anomaly to be negative in the dry zone, especially in the north-eastern parts, however, positive in southwestern parts in the short term, while the anomaly is positive and increasing under the RCP 4.5 thereafter. The annual rainfall anomaly is positive and increasing under RCP 8.5, where this increment would be significant in the wet zone.





Source: Jayawardena et al., 2018

Figure 3.11 Multi-model ensemble of change in maximum temperature (up) and minimum temperature (bottom), relative to 1975-2005 for moderate emission scenario (top; RCP 4.5) and high emission scenario (bottom; RCP 8.5) for time periods; short (2020-2040), medium (2040-2060), long (2070-2090)

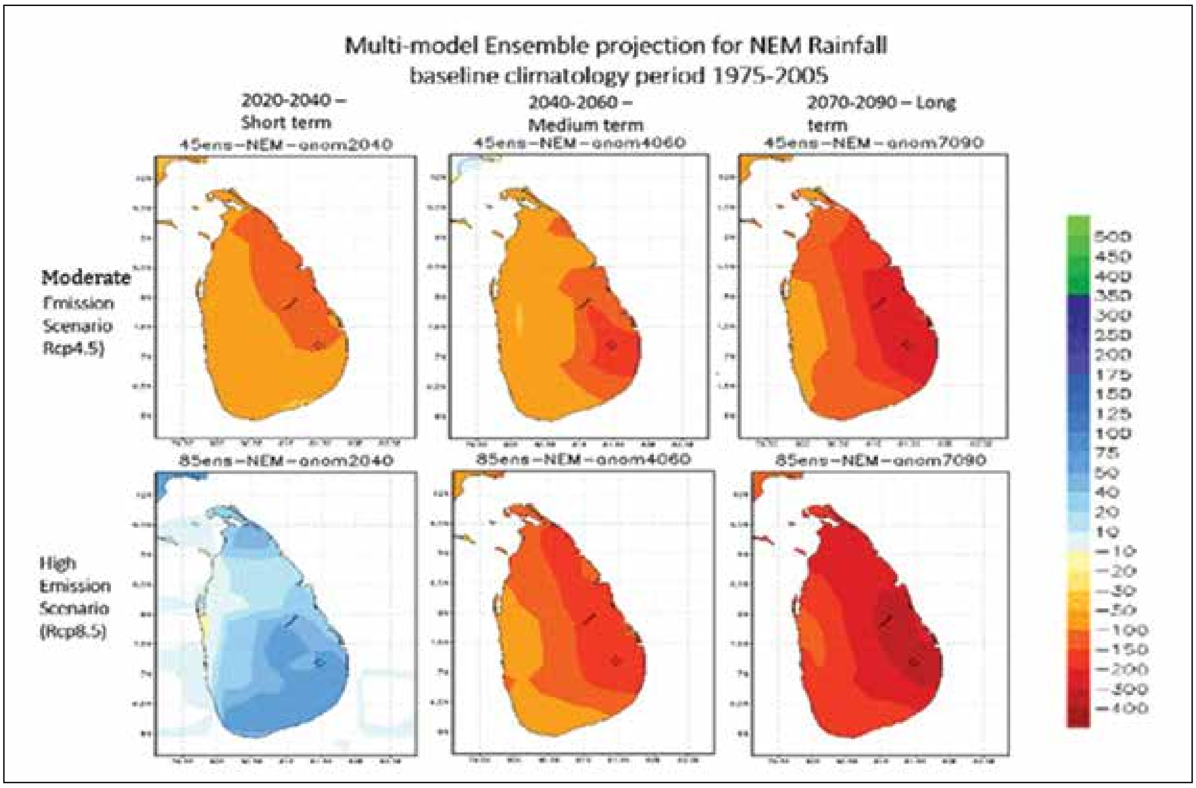


Source: Jayawardena et al., 2018

Figure 3.12 Multi model ensemble of change in Southwest Monsoon (SWM) rainfall, relative to 1975-2005 for RCP 4.5 (up) and RCP 8.5 for time periods (left; 2020-2040), (middle; 2040-2060), (right; 2070-2090)

3.4 Predicated climate change impacts in Sri Lanka

Changes in NEM rainfall compared to the baseline climatology clearly indicate a negative rainfall anomaly, especially in the dry zone under RCP 4.5 and RCP 8.5 scenarios. More frequent droughts are expected in the dry and intermediate zones. Rainfall reduction in the NEM will increase vulnerability of agriculture sector to prolong droughts, as nearly 70% of rice cultivation takes place during the *Maha* season in the dry zone in Sri Lanka. Increases in air temperature observed in the recent past and expected to continue in future projections are likely to have huge impacts on evaporation and evapotranspiration. Projected changes in precipitation patterns, changes in extreme weather events and increasing evaporation could result in reduced water availability and thereby agricultural productivity decreases in the dry zone.



Source: Jayawardena et al., 2018

Figure. 3.13 Multi model ensemble of change in North East Monsoon (NEM) rainfall, relative to 1975-2005 for RCP 4.5 (up) and RCP 8.5 for time periods (left; 2020-2040), (middle; 2040-2060), (right; 2070-2090)

An increase in the frequency and severity of extreme rainfall events has been observed during the recent past. Climate projections indicate notable increases of extreme rainfall events that will influence annual/total precipitation in parts of the country. This pattern would increase climate variability, resulting in more floods, landslides and droughts. Changes in annual as well as southwest monsoon rainfall compared to the baseline climatology indicate a positive rainfall anomaly in the wet zone that could rise over time under RCP 4.5 and RCP 8.5 emission scenarios. This could make the western slopes of the central hills more prone to natural disasters such as landslides, land degradation and soil erosion (Darshika et al., 2018).

3.4.1 Uncertainties in predicted climate change impacts for Sri Lanka

Climate modelling provides the basis for forecasting future climate change. Making decisions based on projections requires a thorough understanding of the sources, their impacts and uncertainty for future planning. Uncertainties are associated with GHG emissions scenarios, unexpected climate induced disasters, demographics, changes in land use, economic development programmes and other variables. Further, uncertainties in climate modelling arise from uncertainties in initial conditions, boundary conditions (e.g. a radiative forcing scenario), observational uncertainties, uncertainties in model parameters, and structural uncertainties resulting from the fact that some processes in the climate system are not fully understood or are impossible to resolve due to computational constraints.

3.5 Governance framework for building resilience in Sri Lanka

This section mainly focuses on how Sri Lanka has been able to integrate climate change adaptation and resilience-building into spheres of life, governance and development using mainstreaming approaches and supportive policies. The CCS established under the Ministry of Environment in 2008, the operational focal point to the UNFCCC, advocates a comprehensive approach to deal with climate change related issues in the country. The Secretariat is supported National Climate Change Policy of Sri Lanka and other sectoral policies and legislations. Further, there are a number of strategies, plans, projects and programmes to strengthen adaptation measures. However, CCS would require legal provisions mandated by a separate Parliamentary Act to build better resilience in coordination with line ministries and institutions that are responsible for climate resilience building.

Sri Lanka, through an Act of Parliament, has established National Sustainable Development Council to steer the Global Agenda for 2030. The CCS is responsible for monitoring and coordinating the Goal 13 "Climate Action". The Disaster Management Act and National Policy on Disaster Management are implemented by the DMC which provides directives for a more resilient and safer country against disaster risks induced by climate change. These policy instruments help to prepare for pre and post disaster damages and relief with substantial support to minimize loss and damages brought by climate risks. Implementation of climate actions proposed in the NAP, NDCs and SDGs should build resilience in an integrated, mainstreamed and synergistic manner to face the adverse effects of climate change in Sri Lanka.

3.6 Sectoral risk assessments and adaptation measures

3.6.1 Agriculture sector and climate change impacts

Sri Lanka is predominantly rural and agriculture-based country. It boasts a world renown hydraulic civilization spanning over two millennia. Approximately 2.6 million ha, equivalent to 42% of the country's total terrain, is in crop production. Much of this land is owned by 1,650,000 smallholder farmers. The agriculture sector, although it employs over 30% of the rural labour force, generates less than 10% of GDP and the contribution has declined annually in recent years to 7.7% in 2015, 7.1% in 2016 and 6.8% in 2017 (CBSL, 2018). Sri Lanka encompasses three major agricultural production systems as food, plantation and minor export crops. The most important food production systems in Sri Lanka are rice (paddy), maize, pulses and vegetables. The main plantation crops in Sri Lanka are tea, rubber and coconut. The minor export crops of Sri Lanka consist of cloves, cinnamon, cardamom, nutmeg, mace and pepper. This sector is governed by several ministries and supported by several departments and institutions.

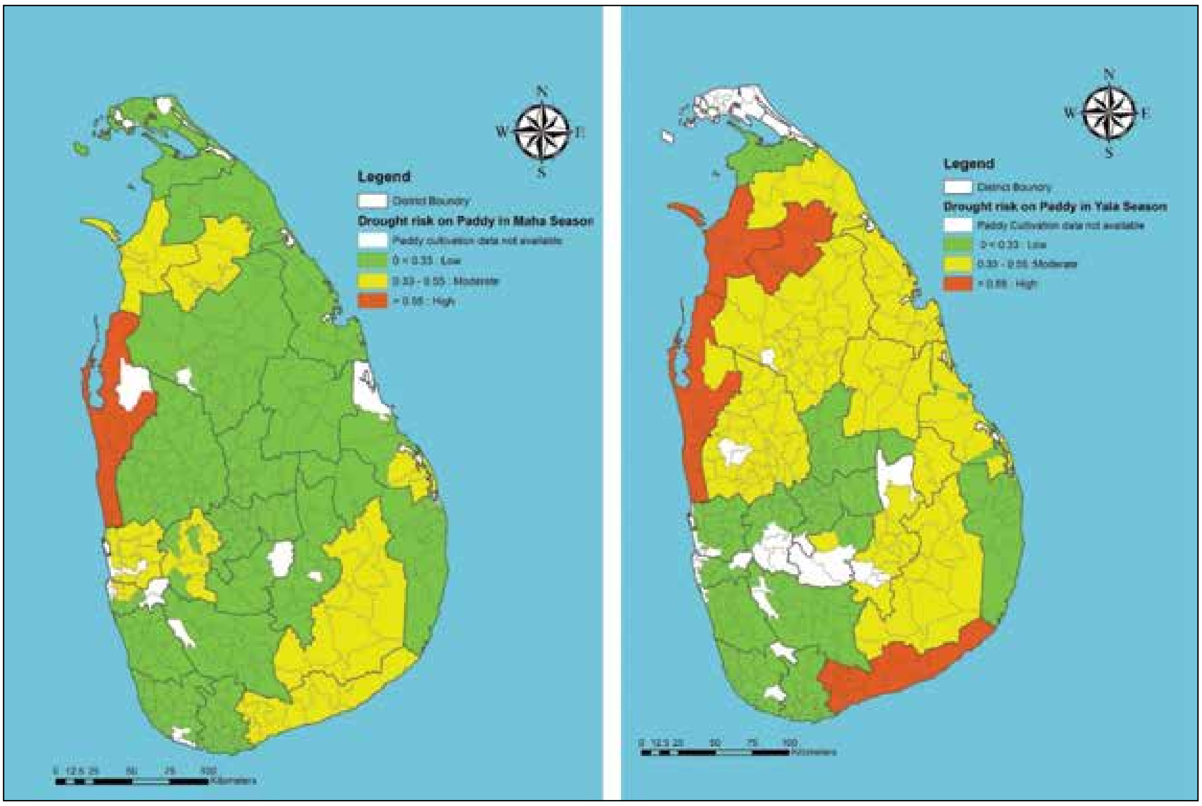
At present, climate change impacts are threatening the entire life cycle of food production and food security in Sri Lanka. A study done by Eriyagama et al., (2010) found that the farming districts of Nuwara Eliya, Badulla, Moneragala, Ratnapura, and Anuradhapura are more sensitive to climate change. Jayatillaka and Droogers (2004) revealed that major climatic parameters such as temperature, CO_2 and precipitation are the most influencing factors for crop growth. A controlled experiment conducted by Vidanage and Abeygunawardane (1994) concluded that an increase in temperature from 0.1°C to 0.5°C could reduce rice yield by approximately 1%-5%. Further, the study revealed that ambient temperature exceeding 35°C even for just 60–90 minutes at the flowering stage of paddy can cause sterile grains, in the Yala season in dry and intermediate zones in Sri Lanka. Moreover, Sri Lankan farming communities have faced frequent and severe droughts since 1974. Statistics show that 283 dry spells have been reported over a period of 30 years since 1974 (Berundharshani and Munasinghe, 2015) and this has negatively impacted on agriculture, livelihoods and the socio-economic condition of farmers. Furthermore, increased temperatures and decreased daytime and night time temperature differences have negatively affected high value crops, especially vegetable and potato cultivation (De Zoysa and Inoue, 2014).

Agriculture in Sri Lanka is considered to be the sector that is the most vulnerable to the adverse impacts of climate change. Moreover, Sri Lanka may experience a severe food insecurity situation in the country with a number of associated issues. In this assessment, the impacts of droughts, floods and landslides were evaluated for six major agricultural crops (paddy, tea, rubber, coconut, minor export crops and sugarcane) at the Divisional Secretariat level.

3.6.1.1 Paddy cultivation

Rice is the staple food in Sri Lanka and is mainly cultivated as a wetland crop. The country has two predominant cultivational seasons linked with the bi-modal monsoon patterns. The primary cropping season for paddy is *Maha* with cultivation of about 6,067 km^2 (606,702 ha) in 2019. Around half of that of area is cultivated in the *Yala* season. Nearly 879,000 farmer families are engaged in paddy cultivation providing livelihoods for up to 32% of the population. Rice cultivation is highly vulnerable to climate shocks such as droughts, dry spells, floods and sea-level rise. Rainfed paddy farmers are highly exposed and sensitive to drought. Consecutive failure of five years' of *Maha* season (2013-2017) in the dry zone reduced resilience of farmers, crops and livelihoods to climate change impacts. As a result of this, the government had to mobilize SLR 9.1 billion in crop insurance to compensate their losses from 2014 to 2018 in the both *Yala* and *Maha* seasons as per a communication of Agriculture and Agrarian Insurance Board in 2019.

Drought risk in *Maha* season: Puttalam district, which depends entirely on NEM rain for *Maha* cultivation is at high risk, while Hambantota, Monaragala, Mannar, Vavuniya and parts of Gampaha, Kegalle and Batticoloa districts face a moderate risk (Figure 3.14-A). According to the RCP 8.5 for 2030, the maximum temperature and rainfall anomalies are increasing (Figure 3.2, 3.4 and 3.5). This can further increase the risk to paddy cultivation in some of areas in the dry zone. The situation will further aggravate in 2050 with higher temperature intensity and lesser rainfall, thus expanding the risk to additional areas in the dry zone in Figure 3.3, 3.4 and 3.5.



Drought risk on paddy-*Maha* season (A)   Drought risk on paddy-*Yala* season (B)

Figure 3.14 Drought risk of paddy in *Maha* and *Yala* seasons

Adaptation measures: Implementation of larger-scale irrigation projects and crop diversification for vulnerable districts are major adaptation measures that have been recommended. Further, rehabilitation of the ancient irrigation system (cascading village reservoirs) is one important adaptation measure for droughts in the dry zone. Research and development of drought-resistant paddy varieties are to be done as an important adaptation measure. Additional adaptation measures could include awareness raising on climate shocks, use of cropping calendars by paddy farmers, enhancement of the infiltration rate, adopting post harvesting techniques, timely transmission of early warning and seasonal forecasts and establishment of two-way climate information dissemination with the DoM.

Drought risk in *Yala* season: Puttalam, Mannar, Vavuniya and Hambantota districts are at high risk for droughts during *Yala* seasons whereas Moneragala, Kurunegala and rest of the dry zone confront a moderate risk (Figure 3.14-B). The Ampara district reveals a low risk due to access to major irrigation schemes. Rainfall and temperature anomaly maps show increasing trends for temperature and reduced trends for rainfall during *Yala* season in the dry zone. This might increase dry spells and create a shortage of water for paddy cultivation by further increasing the risk in the dry zone. Conversely, the wet zone could experience more intense flooding from the southwest monsoon. According to 2050 anomaly maps for temperature and rainfall, the situation in the dry zone will be further aggravated with more dry spells and less rainfall, increasing the risk as per the RCP 8.5 scenario (Figure 3.3, 3.4 and 3.5).

Adaptation measures needed: Implementation of larger-scale irrigation projects and crop diversification for vulnerable districts are major adaptation measures that have been recommended. Research and development of drought resistant varieties and short term paddy varieties are major adaptation measures. Rehabilitation of abandoned cascade tanks/reservoirs (and associated infrastructure) as well as building of new reservoirs would be an attractive and effective adaptation measures. Maintenance of the reservoir system and, collection and conservation of water for irrigation would enhance resilience. Promotion of alternative short-term crops in the fields during low rainfall seasons to ensure sustainable livelihoods is another important adaptation measure.

Additional adaptation measures could include awareness raising on climate shocks, use of cropping calendars by paddy farmers, enhancement of infiltration rate in catchments and watersheds, adopting post harvesting techniques, timely transmission of early warnings and seasonal forecasts and establishment of effective climate information dissemination systems.

Flood risk in *Maha* season: During the *Maha* season, the western and southern coastal areas receive less rainfall while some parts of Jaffna, Eastern and North-Central Provinces are subject to moderate flood risks for paddy cultivation. The rainfall anomaly maps for NEM for 2030 predicts less rain in the dry zone and this further lowers the risk from floods and inundations (Figure 3.2). However, localized flash floods stemming from high intensity rainfall can harm paddy fields unless drainage infrastructure can cope. The risk for wet zone paddy cultivation will remain low in 2030 and 2050 as per the RCP 8.5 scenario (Figure 3.2, 3.3 and 3.4).

Flood risk in the *Yala* season: According to this assessment, Ratnapura, Kalutara, Galle, Matara, Colombo and Gampaha districts possess considerable risk to floods during southwest monsoon. The western, southern and most parts of the Sabaragamuwa provinces and Puttalam district face a moderate risk for flood related damages. During the *Yala* season when southwest monsoon is active, the flood risk is low for paddy cultivation in the dry and intermediate zones. The wet zone will receive more rains with moderate to higher flood risk by 2030 and it will be worsen by 2050. However, the flood risk in the dry zone and the intermediate zone will be reduced in 2030 and 2050 according to the rainfall and temperature anomaly of RCP 8.5 scenario (Figure 3.2, 3.3 and 3.4).

Adaptation measures needed: Research and development of flood resistant and short-term paddy varieties are potential adaptation measures for wet zone paddy farming. Enhancement of river catchment and upper catchment infiltration is important while water capacity of reservoirs is enhanced to prevent flood.

Another major adaptation measure would be the development of management systems and infrastructure to quickly drain excess water out of the flood zones to storage reservoirs or to the sea. Construction of rainwater storage in the flood prone areas and diversion of excess water in the wet zone could be so useful during drought spells in the dry zone. Enhancement of ground water recharge systems is another potential adaptation measure.

3.6.1.2 Tea cultivation

Tea is grown as a rain fed crop in the country. Tea is one of the main sources of foreign exchange for Sri Lanka and contributing over LKR 233.3 billion to the economy as per the Annual Report of Sri Lanka Tea Board in 2017. The majority of tea plantations in Sri Lanka, except those at high elevations (>1200m), are likely to be adversely affected by higher temperatures and drier weather conditions. The reduction of monthly rainfall by 100 mm, reduces the productivity by 30-80 kg of 'made' tea per hectare. However, the increase in ambient

CO_2 concentration from present level (around 370 ppm) to 600 ppm increases tea yield by about 33-37% (Wijeratne et al., 2007).

Landslides risk for Tea cultivation: According to landslide maps, most tea growing areas have a landslide risk. Also, some DSDs in Badulla, Kegalle, Ratnapura, Kandy, Nuwara Eliya, Matara and Galle districts experience a high risk of landslides while associated with floods could be shallow or starting from bedrock. According to the rainfall anomaly maps for 2030 and 2050, higher rainfall is expected in most of the tea growing areas which could further increase landslide risk for the most of tea plantations under RCP 8.5 scenario (Figure 3.2, 3.3 and 3.4).

Drought risk for Tea cultivation: Risk and hazard maps indicate that due to prolonged droughts and increased ambient temperature, low country tea would be affected. Tea plantations in Galle, Matara and Kalutara districts will be heavily affected by drought conditions. Increasing temperatures will significantly impact the yield. Ratnapura and Kegalle districts will face a moderate impact due to drought conditions and occasionally upcountry tea plantations could face severe dry spells.

Adaptation measures needed: Implementation of proper regulations to limit the growing of tea below 3,000 feet, use of soil conservation techniques on landslide prone steep slopes and conservation, catchments and fragile areas are key adaptation measures to ensure safety from landslides. In addition, landslide risk maps prepared by the NBRO should be used as a land use planning basis and for building approvals. Further, use of organic fertilizers for tea estates is recommended to maintain the physical structure of soil. Avoiding extreme slopes for tea cultivation and using recommended drainage facilities are also considered to be effective adaptation measures.

Since most of the low country tea grown by smallholders, proper adaptation measures can save the livelihood of these families. Efficient irrigation when there are prolonged dry spells (especially using solar powered micro pumping systems), development of drought resistant varieties, implementation of community driven irrigation facilities, proper drainage facilities to improve ground water recharge, implementation of micro scale sprinklers, and research on multi cropping of tea plantations to provide an alternative income to smallholder families are key recommended adaptation measures.

3.6.1.3 Coconut Cultivation

The coconut sector of Sri Lanka accounts for 0.7% of the country's GDP (CBSL, 2019) and significantly contributes to foreign exchange earnings. The total land area under cultivation covers more than 440,000 ha, annually producing about 2.5-3.0 billion nuts.

Coconut palms that were frequently exposed to warm/drought seasons have significant failures in fruit formation as reproductive organs of a mature coconut palm (from flowers to mature nut) are more sensitive to water stress and high temperature than the vegetative organs. Coconut palm produces one inflorescence every month and the crown of a healthy palm generally bears 14-16 coconut bunches of different development stages. These stages of inflorescence development such as pollen formation followed by button nut formation will be sensitive to prevailing climatic conditions. Continuous exposure to heat or water stress can prevent the accumulation of starch and sucrose in the developing anthers, which are the main source of energy for pollen germination, resulting in poor pollen quality. Further, high temperatures, low relative humidity and a high vapor pressure deficit at the stage of pollination may cause pollen drying which results in reduced formation of the nut.

In Sri Lanka, floods and landslides are the other conditions that damage coconut farming. Over 14,000 acres of coconut lands are highly vulnerable and another 49,000 acres are moderately vulnerable to flood exposure (MoE, 2011). Occasional flooding does not harm coconut palms, but poorly-drained soils persisting for an extended period may eventually damage the palms.

Drought risk for coconut cultivation: The risk map shows that Puttalam and Mannar districts experience higher drought related risk for coconut plantations while Hambantota and Kurunegala districts and the most of areas in the dry zone reveals a medium risk of drought. During the past few years, coconut cultivations in Puttalam, Mannar and Hambantota districts were severely affected by droughts. The temperature and rainfall anomaly maps for 2050 predict further enhancement of dryness in terms of reduction of rainfall and increase of temperature in the dry and intermediate zones, further intensifying the drought risk (Figure 3.3, 3.4 and 3.5). This will further aggravate the situation in Puttalam, Mannar and Hambantota districts. The wet zone will not have serious impacts but could be affected by seasonal dry spells/longer dry spells.

Adaptation measures needed: Use of varieties with heat and drought tolerant characteristics is one of the major adaptation measures to effects of climate change. The degree of sensitivity to high temperature can vary with the variety, depending on their tolerance to stress. Climate resilient tree-based agroforestry systems have been identified as an adaptation measure for climate change impacts. For instance, coconut based mixed cropping systems or coconut-based agroforestry systems can improve the microclimatic condition by influencing air temperature, soil temperature, vapor pressure deficit, and soil moisture content of plantations.

Additional measures include providing irrigation, introduction of new watering technologies such as underground drip feeding, greater use of organic fertilizers for soil moisture retention, groundwater recharging facilities, introduction of inter cropping in coconut estates, and promotion of micro rainwater ponds/irrigation facilities. Development of heat and drought tolerant seed material in the seed gardens would need to be increased.

3.6.1.4 Rubber cultivation

Rubber is a plantation crop that is totally dependent on rainfall. The accepted norm for rubber growing is warm climatic conditions with around 2,000 mm rainfall evenly spread across the entire year. Rubber plantations resist drought conditions more than any other plantation crop grown in Sri Lanka. Similarly, they are flood-resistant for several days. Although commonly grown in rainy districts such as Kalutara and Ratnapura, the best weather for rubber is in the intermediate zone. Recurrent rainfall and floods lead to lower yields due to frequent interruptions in rubber tapping which impose costs on planters, their labours and smallholders. A short dry spell is advantageous for rubber to avoid leaf diseases caused by fungi during the period of new flush of young leaves (mid-Feb to mid-March). However, rain and drought affect tapping days and disrupts harvesting. Furthermore, climate change may cause new diseases which are detrimental to trees. The existing clones that have tolerance to climate change are limited (Yogaratnam, 2011).

Irregular rainfall and flood risk for rubber cultivation: The hazard and risk maps show that in some areas in Kalutara and Kegalle districts, there is significant risk to rubber. Except in coastal areas in Galle and Matara districts, the other areas in the wet zone indicate a moderate risk of floods. New rubber growing areas such as Moneragala demonstrates a low risk of floods. The RCP 8.5 rainfall anomalies for 2030 and 2050 indicate that most of the rubber growing areas are going to experience higher precipitation, thus posing an increased flood risk (Figure 3.2, 3.3 and 3.4).

Landslide risk for rubber cultivation: According to the risk assessment results, Kegalle and Kalutara districts have a significant risk of landslides. Medagama and Moneragala DSDs indicate a medium risk for landslides. However, rubber is a tree which conserves soil and prevents shallow landslides (Keith and Broadhead, 2011), on the other hand, large rubber trees can add to the weight and increase the intensity of landslides due to bedrock collapse. Galle and Matara districts show a low risk for landslides. The new areas of rubber growing in Moneragala illustrate a medium risk. According to the projections of the rainfall anomaly maps for 2030 and 2050, high rainfalls can be expected in Kegalle and Kalutara districts as well as all other rubber growing areas in the wet zone where a greater risk of landslides would be expected (Figure 3.4).

Adaptation measures needed: An effective rain guard, developed through research conducted by the Rubber Research Institute (RRI), can reduce interruptions to tapping during rainy season. Eventually, moving rubber plantations to other areas where rainfall is 2,000 mm but also has a more even distribution and more sunshine hours per day will reduce the risk to rubber due to climate change impacts. Growing rubber in a mixed plantation with other crops and inter-cropping are other adaptation measures that allow growers to diversify and have alternative incomes when rubber tapping is not possible during rainy seasons.

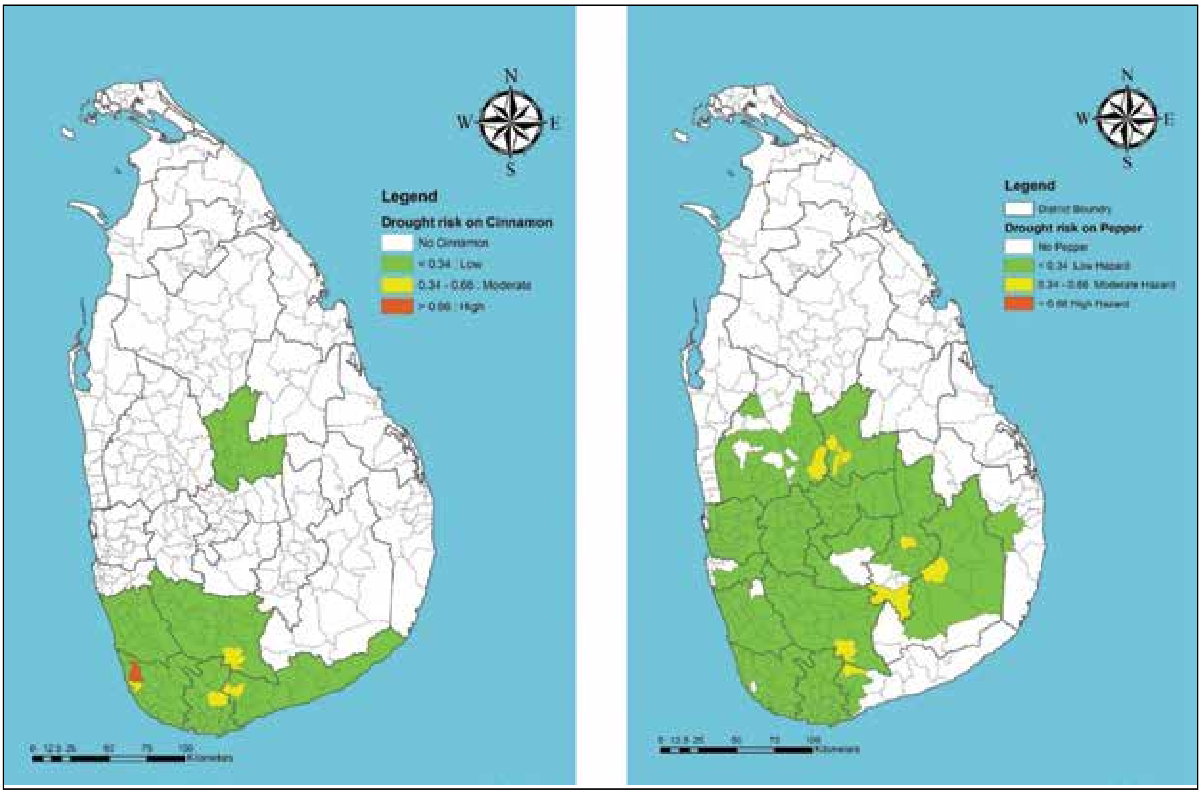
The risk of landslides can be reduced by shifting rubber plantations to intermediate zone where moderate rainfall occurred, protection of higher elevation areas through soil stabilization techniques and development of proper storm water drainage systems are also required.

3.6.1.5 Minor export crops

In Sri Lanka, nearly a quarter of gross export earnings are derived from minor export crops. Minor export crops including clove, cinnamon, cardamom, nutmeg, mace, pepper etc., contributed by 14.5% of export earnings in 2013. Sri Lanka is the world's largest producer and exporter of cinnamon which accounts for approximately 77% of the world exports. The country produces 2% of the world supply of pepper with an export value per year of over 7 US$ billion (Sachitra and Chong, 2015).

A. Cinnamon cultivation: Cinnamon originated in the central hills where seven wild species are found in Kandy, Matale, Belihul Oya, Haputale, Horton Plains, and the Sinharaja forest ranges. Presently, cultivation is concentrated along the coastal belt from Negombo to Matara, and has made inroads in Kalutara and Ratnapura. According to the Department of Export Agriculture, cinnamon can withstand high temperatures up to 32°C if rainfall is over 1,750 mm and tolerate high humidity. Sri Lanka's cinnamon has high concentrations of essential oils and is a highly sought after commodity and, the sector is dominated by smallholder farmers.

Drought risk for cinnamon cultivation: The overall risk of drought is comparatively low as cinnamon grows in the wet zone and a few areas in the intermediate zone. The map indicates a few growing areas such as Karandeniya, Kollonna, Walasmulla and Mulatiyana with moderate risk, while Ambalangoda shows high risk (Figure 3.15-A). According to temperature and rainfall anomaly maps of 2030 and 2050, the wet zone will not see diminished rainfall but variability will increase and the temperature could exceed safe thresholds, thereby elevating the risk from low to moderate levels as per RCP 8.5 scenario (Figure 3.2, 3.3, 3.4 and 3.5).



Drought risk on cinnamon (A) Drought risk on pepper (B)

Figure 3.15 Drought risk maps for cinnamon and pepper

Adaptation measures needed: Conducting further research on growth parameters for cinnamon can be recommended. Field trials to propagate cinnamon to other areas such as Moneragala and Kandy, while developing new varieties to suit to different regions, could help the industry stand for climate change risks and impacts. In addition to that, promotion of alternative livelihood options, promotion of mix culture, implementation of micro watering systems, promotion of community driven irrigation mechanisms are potential adaptation measures that could be applied.

B. Pepper cultivation: Pepper is a rain-fed crop that requires over 2,000 mm of annual rainfall and temperatures higher than 12°C up to a maximum of 35°C. Areas with prolonged drought or dry periods should be avoided for pepper cultivation unless there is supplementary irrigation. A clear dry spell and sufficient rainfall for flower induction and pollination are vital for the production while strong winds are harmful. Growth and yield performances are better in the humid tropics.

Drought risk for pepper cultivation: According to the map, cultivation in the wet and intermediate zones have low risk due to high rainfall expected in the models. Within the pepper growing areas, a few DSDs shows a moderate risk to drought. Rideegama DSD in the Kurunegala district shows a moderate risk of drought. Similarly, Pallepola, Matale and Ambanganga Korale DSDs in the Matale district, Haldummulla and Soranatota DSDs in Badulla district, Walasmulla DSD in Hambantota district and Kollonne DSD in Ratnapura district show moderate drought risk (Figure 3.15B). However, in 2030 and beyond, pepper growing in the intermediate zone could be seriously affected due to less rainfall and increasing temperatures (Figure 3.2, 3.4 and 3.5).

Adaptation measures needed: Development of new pepper varieties resistant to drought will have long term benefits. However, introduction of efficient irrigation schemes, especially community driven water management, would be useful in the short term coupled with improved maintenance of pepper plants to obtain increased yields.

C. Sugarcane cultivation: Sugarcane is a semi-perennial, commercial crop grown in the intermediate and dry zones of Sri Lanka. At present, nearly 15,000 farmer families are directly involved in sugarcane production for vacuum-pan sugar mills, while large number of farmer families produce jaggery and syrup as cottage products (Wijayawardhana and Kumarasinghe, 2011). There is a potential of producing an average yield of 56-112 MT/ha from local sugarcane plantations. Scarcity of water and prolonged drought periods severely affect the sugarcane crop, while unseasonal rainfall and shifts in monsoonal weather patterns are considered more critical climatic factors.

The effects of drought in early and mid-growth stages mainly reduces cane yield and thereby sucrose yield. A shift in temperature will affect diseases, insects and weeds in sugarcane production. The prolific dry weather exacerbates the symptoms of ratoon stunting disease. On the other hand, water logging is a widespread phenomenon that drastically reduces the growth and survival of sugarcane causing 18-64% reduction in cane yield depending on the duration, plant growth stage and cultivars (Zhao and Li., 2015).

Adaptation measures needed: Adaptation for such adverse climatic variations are limited in the present context. Two available adaptation options are to change of the planting and harvesting schedules of sugarcane to minimize the impact of drought conditions and supplementary irrigation. The establishment of small ponds within plantation areas to maintain the ground water level is also a possibility. Farming communities are used to the current cropping cycles and adjusting practices to respond to climate risks could need a government led top-down approach. Promotion of climate smart agriculture techniques and weather-based insurance schemes could also be useful.

3.6.2 Livestock sector and climate change impacts

Livestock is closely integrated with agriculture and a high national priority for meeting protein requirements and ensuring food security in the country. The sector grew by 4% in 2019 (Livestock Statistical Bulletin, 2020) and continues to do so. The sector covers farming of cattle, poultry, buffalos, goats, sheep and swine. The majority of cattle farms are distributed in the dry zone while only about 12% of the total cattle population is found in the wet zone. Swine farming provides employment for over 5,000 families in the coastal belt of the western and north-western provinces. Around 90% of the goat population is found in the dry and intermediate zones.

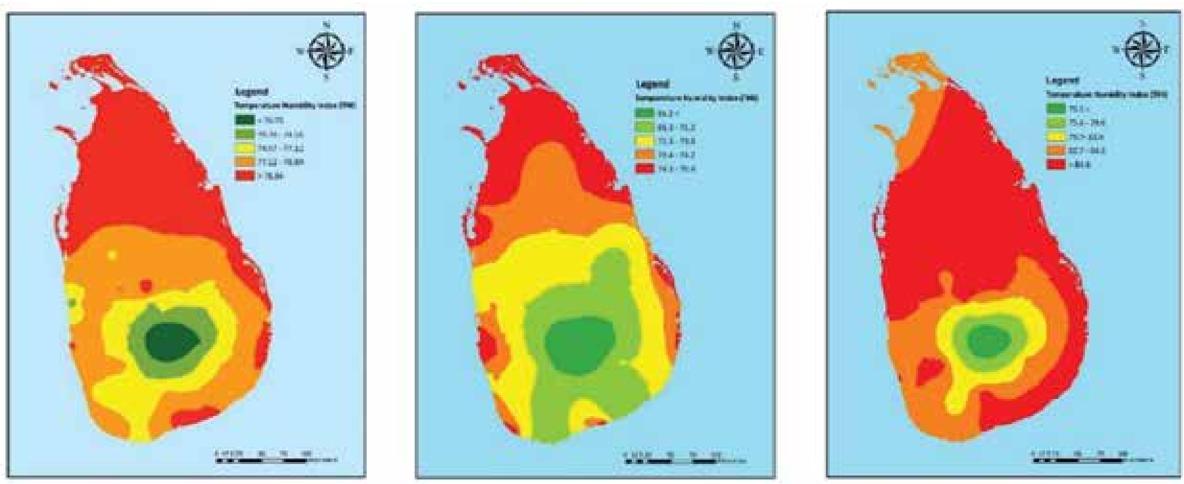
Climate change poses formidable challenges to the livestock sector and its future development. The predicted temperature increased from 2.3°C - 4.8°C and increased precipitation by 2050 will aggravate the stress on dairy animals by adversely affecting productivity and reproductive capacity on high yielding dairy cattle. Given Sri Lanka's vulnerability to extreme weather conditions, the impact of such events on the livestock sector will result in a loss of income for rural households and will indirectly affect livestock production by aggravating feed, fodder and water shortages. The recent droughts during 2016-2017 provided clear evidence for such adverse conditions for livestock sector.

3.6.2.1 Dairy farming and cattle rearing

The Thermal Comfort Zone (TCZ) for temperate dairy breeds is in the range of 5°C - 25°C. Intensification of dairy systems in dry regions using temperate breeds could lead to greater vulnerability to temperature and humidity increases. Temperature Humidity Index (THI) greater than 72 units generates heat stress for dairy cattle.

Temperature anomalies in 2030 and 2050 indicate part of the intermediate and dry zones are at high risk of increasing temperature (Figure 3.13). According to the Temperature Humidity Index (THI) maps in Figure 3.16, the upcountry wet zone is the most suitable area for exotic breed since a favourable climate prevails throughout the year. However, further expansion of the dairy industry in this area is hindered due to restriction of resources such as land and fodder. The THI values in the intermediate and dry zones vary with the day and night time temperature changes. The majority of dairy animals are distributed in the intermediate and dry zones (88%) where land is available however, these zones will face greater challenges from temperature increase, droughts and diseases.

Adaptation measures needed: During prolonged drought periods, it is important to apply better management practices such as shade grazing, and introduce animals (cattle) that having moderate productivity to these areas. Conservation of animal genetic resources through proper breeding strategies to retain economically important characters that resist extreme weather changes would be vital. Development of new feed varieties, promotion of integrated farming techniques with agriculture and fisheries, and introduction of micro cooler areas are other effective adaptation measures to overcome stress level.



(A) Variation of the THI on average temperature and relative humidity

(B) Variation of the THI on maximum temperature and relative humidity

(C) Variation of the THI on maximum temperature and relative humidity

Figure 3.16 Variations of the Temperature Humidity Index (THI)

Drought risk for cattle: As demonstrated in the rainfall anomaly maps above Figure 3.2, 3.3 and 3.4 risk to drought will range from moderate to high in the intermediate and dry zones. This has a negative impact on dairy production due to the unavailability of grazing lands, especially in the intermediate and dry zones. Furthermore, grazing and mixed rain-fed pastures and farm crop residues used as fodder will be affected by prolong drought situation. Water scarcity will be a major problem for dairy animals since their water requirement is extremely high compared to other livestock. The combined effect of water and feed scarcity during droughts adversely affects productivity of the cattle farming and reproductive capacity (Figure 3.17).

Adaptation measures needed: To enhance adaptation, there is a need to increase farmers' awareness and knowledge related to climate change and crop stock mixed farming systems. Climate change related research and development (R&D) and encourage public private partnerships for specific crop stock farming systems. Strengthening adjacent watershed capacities and management of grazing lands to improve resilience coupled with location specific low cost techniques to increase water use efficiency for livestock would be pivotal.

3.6.2.2 Poultry farming

High temperatures, rainfall and relative humidity can have profound impacts on poultry production, especially with regard to meat and egg production, outbreak of diseases, feed intake and immune systems (Adesiji and Baba, 2013).

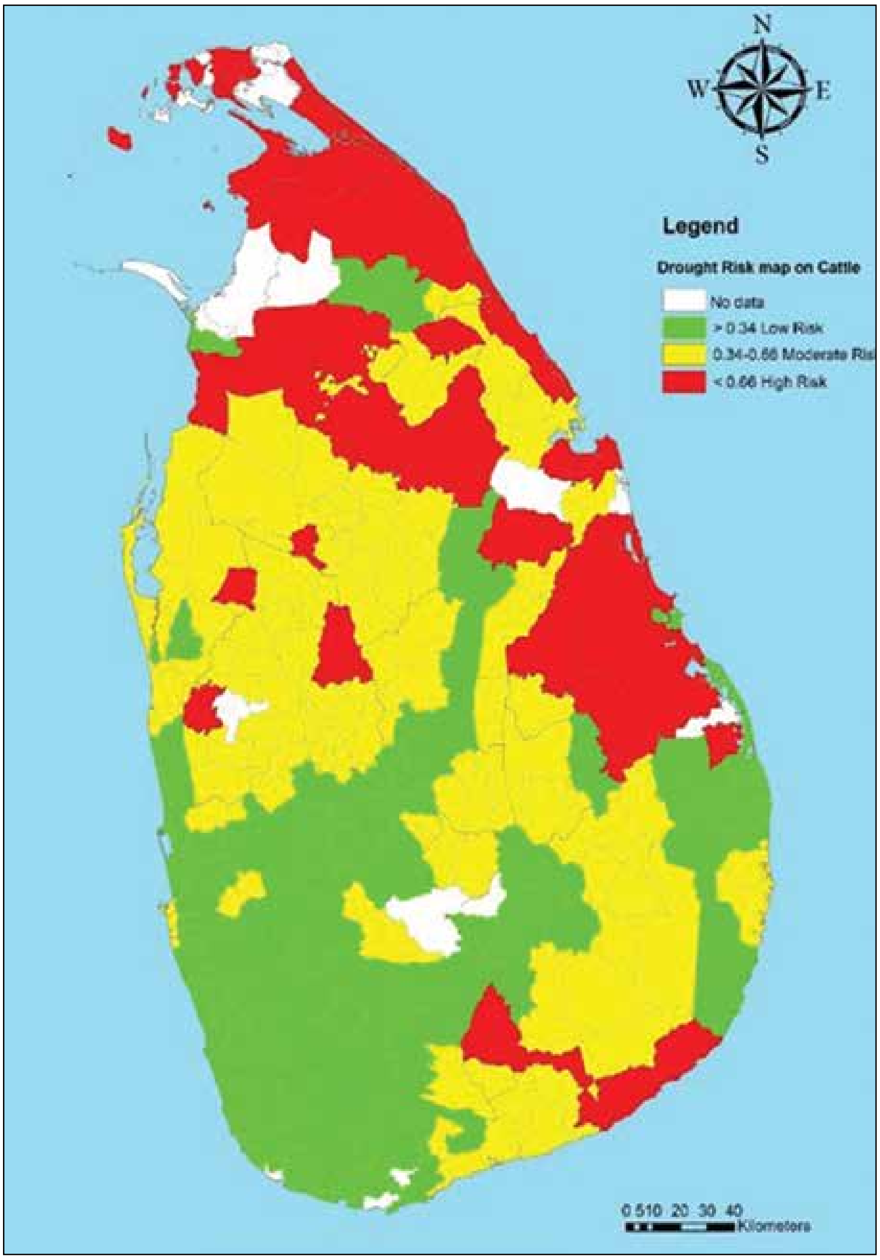


Figure 3.17 Drought risk map for cattle

Most large farms with over 100,000 population are managed under closed house systems where climate within the house environment is completely controlled. These farms are not affected by the outside environment or temperature and such farms account for around 22% of the total poultry population. The small and medium scale farmers mostly manage their poultry in open house systems and they are the most vulnerable to the adverse impacts of climate change.

However, a large number of medium scale farmers use the open house deep litter system to manage their poultry. Such farms are not economically sound and are highly vulnerable to climate change since they are unable to control adverse climatic conditions such as high temperature and humidity. Changing climate conditions directly affect feed intake and productivity. Further, extreme heat and humidity may lead to high mortality. Broilers in final stages of their life are usually more susceptible to high temperatures than the layers (Manisha et al., 2019). Poultry is a self-sustaining industry and government involvement is limited on policy interventions to monitor and control the poultry industry.

Extreme temperature risk for poultry farming: Moderate to high risks exist in the intermediate and dry zones for poultry farming. The maximum temperature anomaly for 2030 shows an increase of temperature uniformly across the country and 2050 shows a very high risk in most parts of the dry and intermediate zones (Figure 3.5). According to the risk maps of extreme temperature, a moderate risk prevails in Kurunegala, Gampaha, some parts of the Puttalam and Rathnapura districts (Figure 3.18). Prolonged drought may have an impact on feed industry, but it will not have a significant influence on poultry industry since feed ingredients are mostly imported. Therefore, risk and hazard on poultry industry due to drought are not discussed.

Adaptation measures needed: Adapting to climate change anomalies, poultry farming should be managed to effectively cope with extreme conditions with enhanced resilience, coupled with good management and modernization of farms. Further, implementation of micro water schemes, use of insulation for poultry farms and the introduction of shady areas to combat heat effect around the poultry farms are other adaptation measures that can be recommended.

3.6.2.3 Swine farming

Swine farming is another important industry to supply animal proteins to local consumers. This industry was popular in the coastal belt of Kalutara to Negombo in the past. However, in recent times, it has spread to the interior where urban markets are being established. About 60% of swine farms are small scale, while 25% are medium sized and the remaining 15% are large scale.

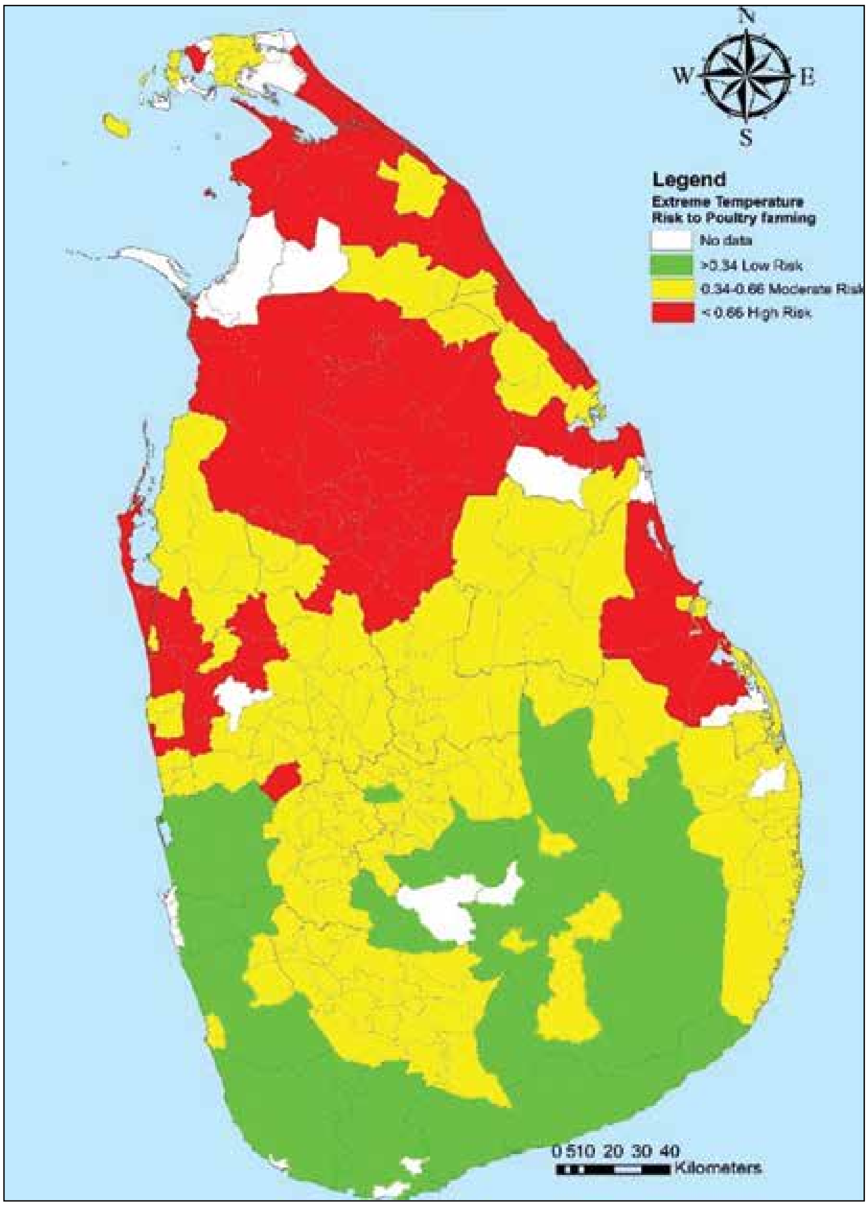


Figure 3.18 Extreme temperature risk to poultry farming

Medium and large scale farms are intensively managed in housing and fed with concentrates throughout their entire production period. Animals in small farms are managed using extensive or semi intensive systems. The swine industry is mainly dependent on exotic breeds such as Landrace and Large White which are highly vulnerable to stress conditions caused by high temperature and humidity. In addition to the exotic breeds, a substantial number of farmers in coastal areas are rearing indigenous pigs which have valuable traits such as adaptability to poor feed quality, resistance to diseases and the ability to survive under a wide range of environments (Silva et.al., 2016). The industry has been stagnating due to various constraints including religious taboos. The total swine population in the country is approximately 75,000-80,000 (DAPH, 2015). However, the industry is very profitable due to the low cost management systems adopted by the farmers.

Extreme temperature risk for swine farming: Swine are highly vulnerable to temperatures above 28°C. The maximum temperature anomaly for 2030 shows an increase of temperature uniformly across the country while 2050 shows a very high risk in the most parts of the dry and intermediate zones, and even in the wet zone (Figure 3.5). Extreme temperature makes the dry and intermediate zones and, occasionally, the wet zone to be unfavourable for swine farming (Figure 3.19).

Adaptation measures needed: To adapt to climate change anomalies, the swine industry can introduce improvements for farm houses to effectively cope with anticipated climate and weather extreme. Improved access to water sources will be an important adaptation measure. Enhancement of shading areas, insulation for swine farms and use of micro water schemes are also a proposed adaptation measures for swine farming resilience.

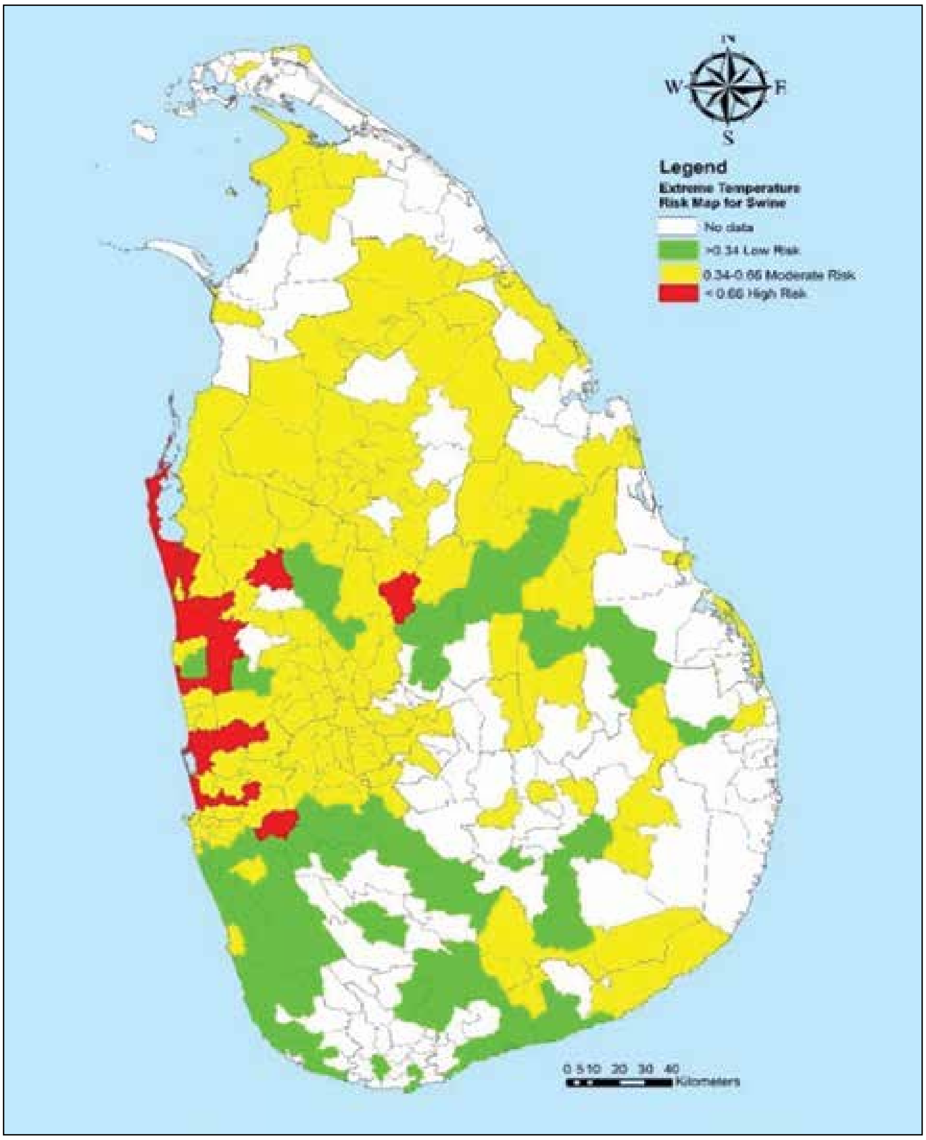


Figure 3.19 Extreme temperature risk map for swine

3.6.3 Fisheries sector and climate change impacts

The fisheries sector of Sri Lanka consists of three main sub sectors namely; offshore, deep sea, and inland and aquaculture. These sub sectors employ around 250,000 active fishers and another 100,000 in support services, where 560,000 people have found direct and indirect employment.

The fishery sector constitutes the major economic activity in the coastal region which is home to 25% of the population in the country. The sector provides about 70% of the animal protein requirement in the country and contributed 1.3% to the GDP in 2016 (NARA, 2016).

The country possesses an Exclusive Economic Zone of 517,000 km^2 as a marine resource. There are 45 major brackish water lagoons and estuaries covering 1,580 km^2 along the coastal belt. An extent of 5,200 km2 of freshwater bodies including irrigation reservoirs, perennial tanks and seasonal tanks, constitute inland fisheries. The total fish production is 530,920 tons in 2016 of which 456,990 tons of fish came from the ocean while the remaining 73,930 tons were harvested from inland and aquaculture sources (NARA, 2016).

There are 59,116 fishing vessels, 24,028 outboard engine fiberglass reinforced boats, 17,813 non-motorized traditional craft and 4,218 inboard multi-day vessels. Along the coast, there are 700 landing sites for minor fish harvesting by traditional crafts and outboard motorboats. The multiday and someday boats use 12 fishery harbours and the country possesses 19 locations for anchorages. The inland fisheries subsector includes capture fisheries in inland waters (perennial reservoirs) and culture-based fisheries (minor perennial reservoirs and seasonal reservoirs). The inland fisheries subsector produced 68,500 tons from capture fisheries and 8,740 tons from culture-based fisheries in 2017 (MFARD, 2018).

Climate change issues for the fisheries sector have received relatively little attention. However, the sea level rise at the rate of 1.5 mm/year to 3 mm/year over the past 100 years (Arulananthan, 2016) and warming of the sea has recently been identified as the most two crucial factors in the fisheries sector. The effects of climate change on aquatic ecosystems can be seen through the sea surface temperature (SST) rise and associated changes in the phenology of the organisms, or indirect through ocean acidification. The increasing frequency and intensity of storms could also increase the sector's vulnerability to climate change (Figure 3.20).

Due to climate change, fisheries sector experience differences in species distribution. Changes in freshwater levels in estuaries would alter the composition of brackish water species. A changing climate would impact seagrass bed ecosystems which in turn, would affect marine production and income of fishery based livelihoods. The property and physical infrastructure of small scale fishers and their communities would also be threatened with rising sea levels. Changes of the SST according to climate change impacts on the distribution, growth and reproduction of fish stocks will lead to significant shifting of potential fishing grounds, causing impact on offshore deep sea fisheries.

Sea level rise will result in loss or change of coastal habitats and species distribution with profound impacts on fisheries. Landward migration of coastal wetlands would result in the loss of established freshwater and brackish water habitats (such as mangroves, salt mashers, coral reefs and seagrass) that are important breeding grounds for coastal and marine fisheries. Loss of wetlands in coastal areas and changes in salinity of lagoons and estuaries affect fish and shellfish. Increasing storm surges and disaster events will damage reefs, leading to reduction in fish breeding and feeding grounds. Also, damage to coral reefs will increase coastal erosion and salinity of inland soil and freshwater sources. Ocean acidification would make it more difficult for shellfish, crabs, lobsters and corals to build calcium carbonate shells, causing stocks to diminish.

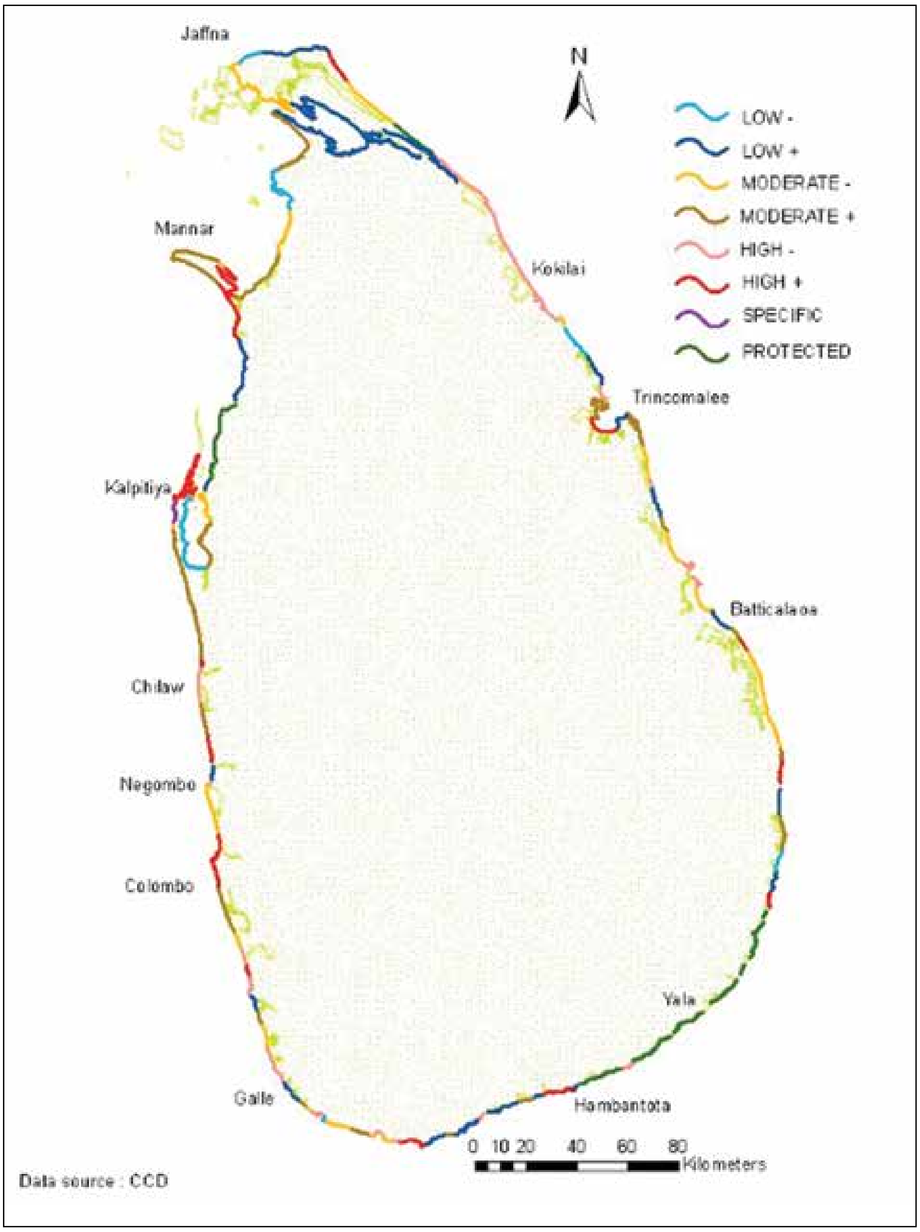


Figure 3.20 Vulnerability levels of fisheries sector (Arulananthan, 2016)

Threats to aquaculture due to climate change are more manageable. However, shrimp farming in the north-western coast found to be particularly vulnerable to climate change. There is insufficient scientific information available on the climate change impacts of inland fisheries. The freshwater ecosystems are threatened by changes in temperature, drought, precipitation, run off and floods. These impacts create a high risk environment for fish stocks. Recent studies illustrate that inland fisheries in northern, north-western, north-central and eastern provinces are subject to high risks from climate change impacts.

In marine fisheries sector, Kalpitiya in Puttalam district emerges as highly vulnerable to sea level rise. Kalpitiya area has 43 fishery landing sites providing livelihoods to approximately 6,000 people and they are highly vulnerable due to sea level rise. The inland and brackish water fisheries in the dry and intermediate zones have been identified to be vulnerable to droughts (MERE, 2011).

Coastal fishery infrastructure development should be in line with possible coastal inundation due to sea level rise. Implementation of sand nourishment and structures to overcome sand erosion will be required. Other potential adaptation measures are climate proof infrastructure development and alternative livelihoods for fishing communities. Enrichment of catchment areas to maintain sufficient water flow in the inland irrigation systems and development of new varieties which could adapt to climate shocks.

Figure 3.21(A) Sea-level rise impacts on coastal fisher population in coastal districts in 2030

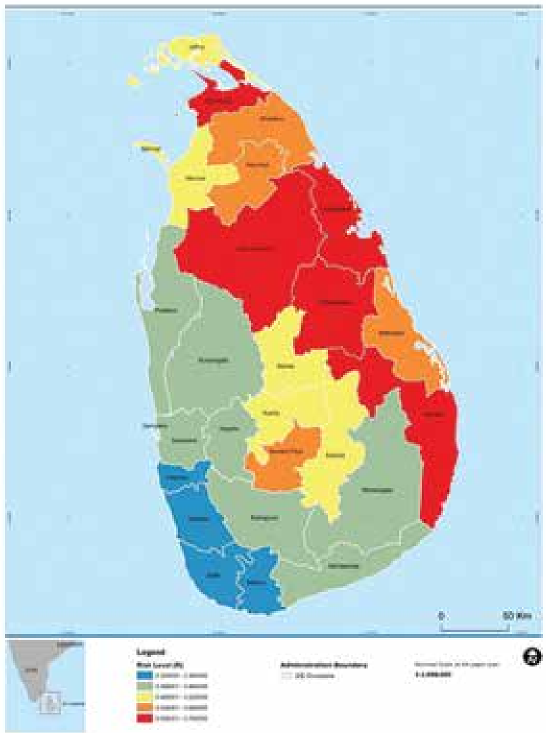


Figure 3.21(B) Inland fishery sector risk to climate change impacts

According to the risk map in Figure 3.21 (A), the districts with high risks for coastal fishing populations from sea level rise are located in the northern and eastern provinces. Further, low lying coastal fishing settlements of these districts are prone to multiple natural hazards based on climate change impacts in addition to sea level rise.

In Figure 3.21(B), illustrates high risk areas for inland fisheries sector from climate change and indicates the vulnerability of districts in the northern, northcentral and eastern provinces. The risk for inland fisheries would be further aggravated due to the rainfall anomaly of the northeast monsoon in 2030 and 2050, and temperature anomaly as per RCP 8.5 scenario (Figure 3.2, 3.3, 3.4 and 3.5).

Adaptation measures needed: Establishment of an efficient climate information management and communication system, including satellite-based vessel monitoring system to provide early warnings is one of the adaptation measures needed. Adaptive management and co-management approaches that recognize the threats and counter the impacts of climate change could be included in policies related to fisheries. Research and development should be conducted to assess climate impacts on fisheries sector.

3.6.4 Climate change impacts on human health

Climate variability has multiple influences on human health with direct impacts which include the effects of rising temperatures and more intense heat waves and floods. Increasing temperatures could encourage spread of vector borne diseases such as dengue. Sri Lanka has recently experienced outbreaks of diseases those are closely connected with extreme weather events.

Polluted surface water, secondary to floods increases the risk of vector borne, rodent borne and water borne diseases. Extreme weather conditions which are aggravated due to impacts of climate change could further lead to disasters which cause injuries and fatalities (MoE, 2010). Changes in rainfall patterns, intensities, increasing temperatures and prolonged droughts could impact on food security, affecting nutritional status and lead for psychiatric illnesses, predominantly among the rural poor (WHO, 2015).

In identifying vulnerability of health sector, this section focuses on vector borne diseases (dengue, malaria, filariasis, leishmaniasis), zoonotic diseases (leptospirosis), nutritional status, food and water borne diseases, extreme climate related health concerns, heat induced health issues and diseases associated with air pollution. Further, this section describes predictions targeting the year 2030 with vulnerability to climatic changes and repercussions on human health in Sri Lanka.

A. Vector borne diseases: Vector borne diseases transmit through a bite or sting of mainly insects such as mosquitoes and ticks though it could be transmitted by other animals as well. Spread of vector borne diseases in to new areas with changing patterns of local climate is a potential health hazard that needs close attention. Increasing temperatures have a positive correlation with disease occurrences. Climate change may increase the risk of some infectious diseases especially those in warmer areas spread by mosquitoes and other insects where the climatic conditions will be favourable for the growth of the vector organism. Rainfall is one of the principal climatic factors influencing mosquito population, because it increases the extent of mosquito vector breeding sites. The rainfall also modifies the temperature and relative humidity which influence for higher longevity and vector survival. Normally higher temperatures increase the number of blood meals taken and number of times the eggs are being laid. This will also induce for parasite multiplication. Therefore, increasing temperature may have a positive correlation for disease occurrences.

B. Dengue: Dengue has become the main vector borne disease of the country. It is invading newer areas with outbreaks occurring more frequently and explosively. A Sri Lankan study conducted in the western province provides evidence for a strong correlation between dengue outbreaks and rainfall. The distribution patterns of dengue vector mosquitoes overlap with monsoon rains.

The Colombo Municipal Council area has shown the highest risk for dengue under the prevailing climate conditions. The districts of Colombo, Gampaha, Kalutara, Kandy, Ratnapura, Kurunegala, Galle, Jaffna and Matara exhibit higher risk for dengue especially in urban setups. However, the risk of dengue remains at a moderate to high risk level throughout the country. According to temperature and rainfall anomaly maps of 2030 and 2050, rainfall will increase in southwest monsoon in the wet zone and positive anomaly for temperature for entire country poses (Figure 3.2, 3.3, 3.4 and 3.5). As a result of, a notable increment of dengue outbreaks is shown in Figure 3.22(A).

C. Malaria: Malaria is transmitted though mosquitoes of the genus Anopheles. Sri Lanka achieved "malaria free" certificate from the WHO in September 2016 for maintaining zero indigenous malaria cases during 2012-2016 (Simac et al., 2017). However, the country remains vulnerable to its re-introduction and transmission due to the continuous influx of migratory malaria cases through travellers to the country. Some studies conducted in previous malaria endemic areas in Sri Lanka highlight that the climatic factors; especially temperature, rainfall, relative humidity are favourable for malaria epidemics (Gunathilaka et al., 2016).

Climate change risk on malaria: According to the risk assessment, all the districts in Sri Lanka indicate a moderate risk for Malaria, except Colombo and Galle districts denoting low risk level. The expected increments in rainfall and temperature anomaly for 2030 and 2050 as per the RCP 8.5 scenarios (Figure 3.2, 3.3, 3.4 and 3.5) would influence the breeding and distribution of Anopheline vectors, thereby further increasing the risk [Figure 3.22(B)].

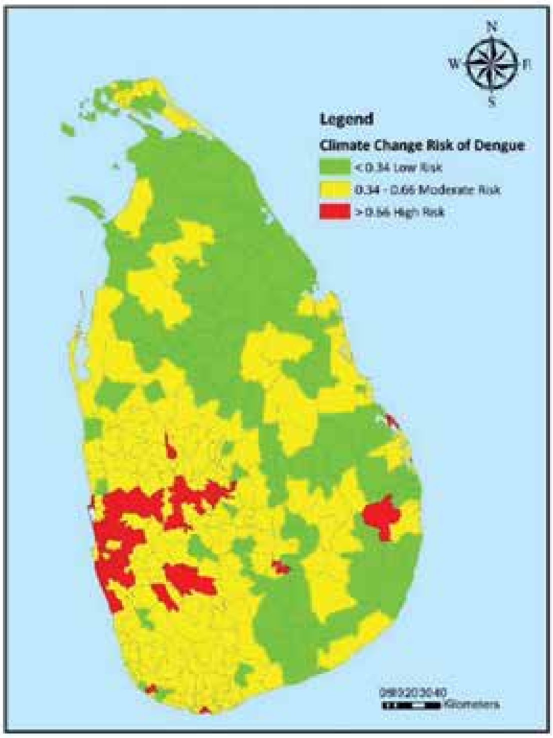


Figure 3.22(A) Climate change risk on dengue

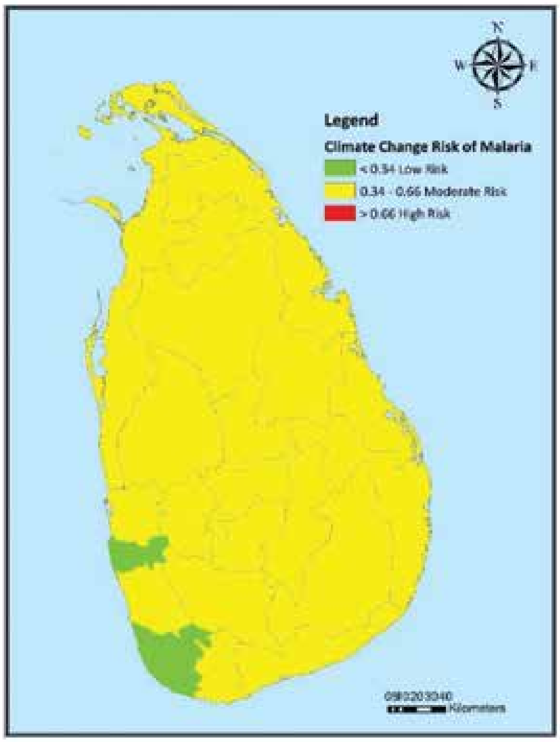


Figure 3.22(B) Climate change risk on malaria

D. Leishmaniasis: Leishmaniasis is newly established in Sri Lanka with the first reported case in 1990's. Previous studies reported that the occurrence of leishmaniasis is seasonal (Adegboye et al., 2017). The main method of transmission of this disease is through the bite of the female sand flies of subfamily Phlebotominae (Diptera: Psychodidae). Climatic changes in rainfall, humidity and atmospheric temperature influence behavioural activities and life cycle of the vectors and reservoir hosts. According to the records from 2009 to 2016, it indicates a seasonal trend in the northcentral part of the country during July to September and in the southern region during October to December. It is further noted that the maximum temperature humidity and wind speed are significantly associated with climatic variables with the occurrence of disease incident in endemic areas.

A moderate risk level is shown by majority of districts in Sri Lanka for leishmaniasis, except for the MOH areas without previous incidents. However, the districts of Anuradhapura, Hambantota, Polonnaruwa, Kurunegala and Matara had relatively higher risk levels for leishmaniasis than the rest. The predicted increments in rainfall and temperature would directly influence the behavioural activities and life cycle of vectors and reservoir hosts, thereby elevating the overall risk for leishmaniasis within the country in 2030 and 2050 according to the RCP 8.5 temperature and rainfall scenario (Figure 3.2, 3.3, 3.4 and 3.5).

E. Filariasis: Filariasis is a mosquito borne protozoan disease mostly transmitted by mosquitoes in genus Culex and Mansonia. In Sri Lanka, Wuchereria banacrofti and Brugia malayi are the causative parasites for lympatic filariasis. However, majority of microfilaria positive cases were due to Wuchereria bancrofti. The disease is endemic in eight districts; Colombo, Gampaha, Kalutara, Kurunegala, Puttalam, Galle, Matara and Hambantota belonging to western, southern and north western provinces. Colombo district denotes the highest microfilaria rate. Changes in temperature, rainfall and relative humidity is also important in the transmission, as mosquitoes can survive longer and disperse further in areas with suitable relative humidity. Further, unplanned urban development may lead to create suitable breeding habitats for disease transmitting vectors.

Adaptation measures needed: Dengue spreads through prolific breeding of the Aedes vectors in unattended water pockets after rains. Often when the public health outbreak occurs the breeding is well on its way. Open dumping contributes to water collection and vector breeding and hence the most micro level waste management is required. Real time risk mapping and dengue risk modelling, utilization of additional vector indices such as pupal indices and motivation of entomologists/ MOH/ PHI (Public Health Inspectors) at the regional and local level are important in dengue management. Meanwhile, proper motivation and training of vector controlling officers, community participation and better multi institutional coordination for vector control are required urgently to contain outbreaks and implement early control actions. Implementation of integrated vector control methods based on climate risks and rainfall forecasts issues by the DoM are vital. Further, exploring feasibility of using novel vector control strategies such as Sterile Insect Technique, Incompatible Insect Technique, Genetically Modified strategies or gene drive mechanisms could be recommended after complying risk assessment and biosafety procedures under a proper monitoring system. In patient management, development of molecular based rapid diagnostics tools would be beneficial.

Improvement of current surveillance system and establishment of a rapid response system for patient management, continuous monitoring of vector densities and strengthening of research studies on potential vectors and their vectoral capacity remain as the key adaptation measure to control malaria. In addition, promoting public awareness on potential malaria risk and sustaining further funding for maintaining the malaria free status in Sri Lanka are also important. Assessing the vectoral capacity of available vectors by vector incrimination and molecular based studies could be recommended to identify the entomological risk for disease transmission. Finally, in order to prevent reestablishment of malaria, continued financial support (local and international), sustained surveillance for vector species present in Sri Lanka and effective control of imported cases through rapid detection and early diagnosis are all required.

Strengthening the current vector surveillance system by using GIS based risk prediction methods, establishment of an early warning system linked to rainfall/temperature forecasts and further study of vector biology are key adaptation measures to control climate-induced spread of leishmaniasis in the country. In addition, development of disease forecasting models locally would be a useful tool in disease control and management. Meanwhile, raising awareness of medical staff, vector control officers and the public on vector management, disease symptoms and effective patient treatment methods could also play a major role in epidemic management. Given the importance of Leishmaniasis vectors, investigations of the biology, behaviour, distribution and population dynamics of these insects should be integrated into routine of public health services, especially in areas where the disease is endemic and climate vulnerability persists. Therefore, it is high time for health authorities to assess the need of establishing a Leishmaniasis Control Unit to conduct such activities in a systematized manner.

Strengthening the current vector surveillance system, incorporation of risk prediction/ early warning approaches, further study of vector ecology and improvement of diagnostic facilities can be identified as the major adaption measures for Filariasis. Raising awareness on Filariasis and encouraging community based vector control approaches are also important for management of Filariasis. Preparation of guidelines for screening of tourist and foreign workers influx from disease endemic countries could be better adaptive measure in order to minimize the transmission and re-establishment of the disease to a public health importance in the country.

F. Zoonotic diseases: Leptospirosis is prevalent in the western province. Outbreaks have been reported from new areas except Jaffna since 2008. Although the disease is reported throughout the year, peaks usually correspond to the two main monsoons with some variations during epidemic years. Some studies have indicated that in the wet zone, reported cases of leptospirosis have increased significantly with land preparation and harvesting seasons of agriculture. Outbreaks of leptospirosis have been associated with regional and seasonal conditions such as high mean ambient temperature, increased rainfall and alkaline soil pH (Levett, 2003).

The leptospirosis risk remains moderately high in the districts of Colombo, Kalutara, Gampaha, Ratnapura, Galle, Matara, Kegalle, Matale and Kurunegala while other areas denote a lower risk level. The predicted temperature rise and rainfall increase in the wet zone by 2030 and 2050 as per the RCP 8.5 scenario (Figure 3.2, 3.3, 3.4 and 3.5) further trigger the risk for leptospirosis in the urban and suburban MOH areas.

Adaptation measures needed: Strengthening the current vector surveillance system by using GIS based risk prediction methods, establishment of an early warning system and further study of vector biology can be recommended as the key adaptation measures to control a leptospirosis in the country. Meanwhile, raising awareness of farming community on disease prevention and controlling outbreaks, vector controlling officers, the public community and effective patient treatment methods could also play a major role in epidemic management.

G. Nutritional status: Nutrition is an essential factor in the human health and it depends on the availability of food and access to sufficient nutritional food. According to the available literature under-nutrition (severe, moderate and mild), micronutrient malnutrition (anaemia, iron deficiency, vitamin A deficiency and Iodine deficiency), overweight and obesity are the major nutritional associated issues in Sri Lanka. All these complications may directly or indirectly associate with climate change and will obstruct the overall development in the country (MRI, 2009). Climate change will affect food production, especially cereal crops due to changes in temperature, rainfall patterns, soil moisture and fertility. Situations of food insecurity as a result of climate change would lead to widespread malnutrition and hunger affecting mainly children and pregnant mothers (MRI, 2009).

Adaptation measures needed: Strengthening policies and programmes on nutrition and nutrition related education on evidence based approaches, continuous monitoring of nutrition deficiencies and potential risk factors and facilitation of nutrition clinics can be recommended to the reduce risk. Establishment of a comprehensive national nutrition surveillance system, multisectoral coordination, promotion of nutrition enhancement, assurance of food security at the household level and conducting further research can also be recommended.

H. Heat-related illnesses: Heat-related illness, also called hyperthermia is a result of exposure to extreme heat where a rapid rise in body temperature observed (CDC, 2017). According to the available information, there is no reported evidence on heat-waves in Sri Lanka. This may be due to lack of research and proper investigations. Adverse health effects related to extreme hot environments include chronic dehydration, heat exhaustion and heat stroke, kidney disease (Kjellstrom et al., 2009).

According to the World Health Organization, the kidney disease is the seventh most common cause of death in Sri Lanka (WHO, 2012). The aetiology of the disease is unclear, but researchers have proposed that "heat stress nephropathy may represent one of the reasons for chronic kidney disease (CKDu) in Sri Lanka (Jayasekara et al., 2019). Some studies have emphasized that the occupational heat stress is more common in the north central province, since majority of the population is engaged in farming, where temperature and other environmental factors are thermally stressful (Siriwardhana et al., 2015).

Further, exposure to hotter temperatures increases vulnerability to heat-related illnesses and death mainly in elderly, children and those with existing cardiovascular and respiratory diseases (Martinez-Austria and Bandala, 2018). Mostly agricultural and other outdoor workers, school children and outdoor sportspersons exposed to direct sunlight are subject to heat related illnesses.

Adaptation measures needed: Provision of occupational health services, strengthening the existing patient identification systems and identification of potential risk communities play a major role in strengthened adaptation measures. Promotion of climate smart cities, climate resilient villages and schools; tree planting and shading in urban areas; well-ventilated and insulated recreational facilities and public places will increase resilience. This can be supported with continuous public awareness campaigns during high risk periods/days, research studies, heat early warning system and adopting action plans for Heat Health.

I. Respiratory related illnesses: Climate changes depress air quality through different pathways. In addition, emission of greenhouse gases has contributed to air pollution and ultimately causing adverse impacts on human health. Some of air pollutants can directly cause respiratory complications or aggravate existing conditions in susceptible population, especially among children and elderly populations, while influencing the occurrence of lung cancers, cardio vascular diseases and stroke. Some of the impacts that climate can have in the respiratory system include chest pain, coughing, throat irritation, pneumonia and lung inflammations leading to Chronic Obstructive Pulmonary Disease (COPD) and lung cancers.

Adaptation measures needed: Improvement of current air quality monitoring facilities to cover the entire country, strengthening diagnostic facilities of related diseases and raising awareness of air quality and risks can be identified as major adaptation measures. In addition, development of policies and regulations for air pollution control, conducting research studies on the climate change impacts on air pollution, novel methods for air pollution control and introduction of training programs for environmental and occupational health and safety are also important for risk reduction. Proper monitoring system of vehicles emissions and testing services should be strengthened. In addition, monitoring and certification system for industrial emissions should be established. Creating green zones in city areas with forest cover and encourage home gardening could also be recommended. Establishment of a national multi-stakeholder platform for formulation and coordination of all air quality improvement and management programs, ensure source identification, quantification, monitoring & reduction of harmful air pollutants, formulate, strengthen and implement an appropriate regulatory framework for ensuring effective air quality management and capacity building programs for Air Quality Management could also be recommended.

3.6.5 Climate change impacts on drinking water sources

Sri Lanka, in comparison to many other countries, possesses abundant water resources in terms of total aggregate water availability. However, spatial and temporal fluctuations in rainfall lead to variations in both surface and ground water availability. Historically, the monsoon rainfall patterns created a need for planned water conservation and good water governance practices. Historical practice of water governance in the dry zone ensures water for all living beings in varied ecosystems. However, much of the historical water governance systems are no longer functional.

During the past few decades, a number of warning signals have pointed out for the need of sustainable management of water resources in Sri Lanka. Competition for water, and seasonal water shortages are drastically increasing. Watersheds are also drying due to prolonged droughts. Recent and more frequent extreme weather events are causing profound and long term impacts on the spatial and temporal water availability.

Risk assessment shows that 44 DSDs represented as high water risk to drought and 125 DSDs denoted as a moderate risk, in addition, 159 DSDs in Sri Lanka exhibit specific low for drinking water (Figure 3.23). With temperature and rainfall anomalies projected for 2030 and 2050 as per the RCP 8.5 scenario, the situation would be further aggravated in the dry and intermediate zones via evapotranspiration (Figure 3.2, 3.3, 3.4 and 3.5).

Colombo and Gamapaha districts lying in the Kelani river basin, Matara in Nilwala river basin and Hambanthota district have a high degree of flood-associated risks for drinking water quality (turbidity, micro-organisms and colour). The risk will be greater when rainfall anomaly projections for 2030 and 2050 as per the RCP 8.5 scenario (Figure 3.2, 3.3 and 3.4), especially in the wet zone.

Adaptation measures needed: Increasing green cover for catchment preservation and de-siltation of village reservoir cascades could improve ground water recharge and water availability in downstream dug wells, especially for communities in the dry zone. Moreover, protection of upper watersheds, increased groundwater recharging facilitates, introduction of community-owned and managed water supply schemes, implementation of storage capacities, strengthening government water supply schemes to respond to drought warnings, demineralization plants, and use of solar powered desalination plants to supply drinking water in coastal districts are some of practical adaptation measures.

One of the best adaptation measures to address drinking water issue in a prolong drought situation for the community living in the dry zone, where there is no access to safe drinking water, is the establishment of rainwater harvesting tanks. In addition to that, construction of salinity barriers, replenishing upper watersheds by fog interception through cloud canopy improvement, introduction of separate pipelines to convey reclaimed water to use of non-potable water are additional adaptation measure for drought risk on drinking water. Other measures are; analysis of water demand increasing and taking actions to meet the increased demand; introduction of an integrated water resources management policy; construction of small weirs/dams; new dedicated storage reservoirs for drinking water.

Designing new water facilities that incorporate flood modelling and implementing new purification technologies are key adaptation measures. Others include green roofs and infiltration surfaces, storm water drain maintenance, flood retention basins and storm water tunnels in urban areas. Establishment of water quality monitoring stations, preservation of wetlands and creating of natural wetlands, monitoring and maintains of periodical cleaning of storm water drains, introduction of infiltration trenches along roads, construction of large scale storm water tunnels in populated areas, converting intakes pumps to submersible wet well type or converting intake structures to suit vertical turbine pumps and fuel storage located above high flood levels to avoid oil contamination are suggested additional adaptation measures to improve the resilience against to flood.

The risk of drought for sanitation services could be addressed by improving water availability, improving sanitation infrastructure and ensuring adequate coping and adaptive capacities during a drought. Moreover, introduction of better water treatment facilities, especially membrane filters and enrichment of catchment areas to improve the partial water retention capacity are considered as practical adaptation measures. Other measures include better human settlement management and improved downstream drainage.

3.6.6 Climate change impacts on irrigation

Sri Lanka has a historical irrigation-based cultivation system dates back over two millennia and inherited an advanced hydraulic infrastructure and knowhow. Sharp variations of water availability for agriculture over space and time led to the development of an intricate irrigation and water supply system giving rise to one of the world most advanced hydraulic engineering accomplishments.

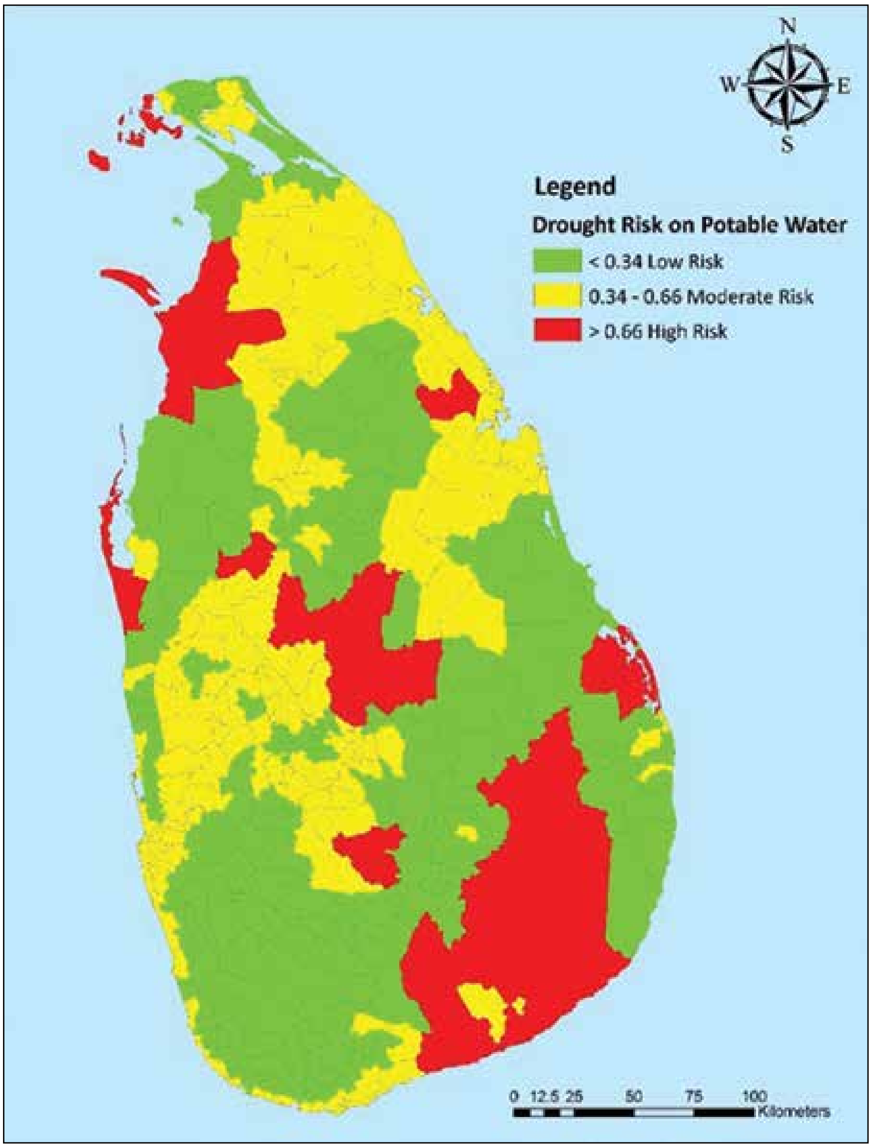


Figure 3.23 Drought risk on drinking water

Irrigation systems in the country are categorized in accordance with the size of the command area. Major irrigation schemes that have command area or flood mitigation above 6.1km^2 while medium schemes are between 0.8-6.1km^2. Small tanks or minor irrigation schemes are those having an irrigated command area of 0.8 km^2 or less.

Climate risks for irrigation: Agricultural activities during the two main cropping seasons; *Yala* and *Maha* - use rainwater stored in irrigation systems. The north western and north central provinces have a large number of minor and major irrigation schemes to collect rainwater for agriculture. The increasing trend of longer droughts and altered rainfall patterns threaten water storage in irrigation networks. The increasing intensity of ambient temperatures and evapotranspiration from these water bodies further reduce water availability. Siltation due to soil erosion in uplands reduces the depth of reservoirs, aggravating water loss via evaporation.

The projected climate scenarios for 2030 and 2050 as per the RCP 8.5 shows an increase in maximum ambient temperature and negative rainfall anomalies in the dry zone during northeast monsoon (Figure 3.2, 3.3 and 3.4) and as a result, drought risk for irrigation will be further aggravated in the dry zone. The study reveals that districts of Anuradhapura, Polonnaruwa and parts of Ampara are highly risk to the current climate change context.

Adaptation measures needed: The village irrigation system built with a cascade of small and large tanks having with numerous environmental safeguards and climate resilience over two millennia. This system is at present being rehabilitated as one of the most vital adaptation measures to address the water scarcity due to adverse impacts of climate change in the dry and intermediate zones. The rehabilitation of climate resilient features in this ancient tanks cascade system such as hydro-catchment deserves and the tree girdle around water bodies and irrigation canals could help minimize water loss from evapotranspiration and dry winds. Water use efficiency for agriculture can be improved by introducing technologies such as drip irrigation, smart agricultural practices, crop diversification and vertical gardening. To enhance climate resilience, research and development in breeding and farming practices, and water usage would be vital. Further, adaptation measures could be implemented to control water loss through evaporation by establishing floating solar panels and shade balls without harming to the biodiversity of reservoirs. Education, communications and awareness should be increased among the farmer communities to improve irrigation water use efficiency.

3.6.7 Climate change impacts on coastal resources

Sri Lanka is richly endowed with varied coastal and marine ecosystems that include estuaries and lagoons (214,522 ha), mangroves (11,656 ha), seagrass beds (37,137 ha) salt marshes (27,520 ha), coral reefs and large extents of beaches including barrier beaches, spits (5,731 ha), sand dunes, mangroves and associate waterbodies (10,363 ha). Each of these coastal habitats possess a significant amount of species and provides an array of ecosystem services vital to human. In addition to the environmental services, these habitats support livelihoods of the coastal communities in significant manner to enhance their economic status and maintain social integrity. Many coastal and nearshore resources associated with the coastal habitats support a developing export industry based on export of prawns, lobsters, crabs, beach de mer (sea cucumber), chanks and shells and other fishery products which earned over LKR 24,716 million in 2015 (SLCZCRMP, 2018).

Coastal ecosystems are among the most popular destination for outdoor recreation and tourism. The coastal region in the country supports a range of nationally important economic activities including fisheries, tourism and ports/harbours. In Sri Lanka, around 25% of people live in the coastal region.

Over the last century, mean sea level has risen by 15 cm. Generally, coastal ecosystems are affected with varying degrees by inundation, coastal erosion and change in ecological systems/processes due to sea level rise. Coastal flooding will be accompanied by coastal erosion and salinization of coastal soils and ground water. Since most coastal towns and cities are densely populated, communities and people in coastal areas face the risk for loss of properties and livelihoods due to climate change.

The risk assessment focuses on identifying the degree of future risks and vulnerable areas induced by climate change and sea level rise. Likely impacts of climate change on coastal areas include sea level rise and associated saline water intrusion further inland. This results in increased salinity making the existing primary production activities untenable. The above impacts could be further exacerbated by reduced river flows, causing a reduction of fresh water flushing in their annual cycles of change, thereby salinity around estuaries and lagoons are increased. Increased flooding of the lower coastal areas and changes in monsoonal weather patterns could aggravate all of the above impacts. All or some of the above impacts, acting alone or in combination, are likely to bring about many changes in different ecosystems in the coastal belt, threatening availability of spawning and nursery grounds for important food/commercial fishery which is main livelihood in the coastal belt.

Marine habitats are threatened from climate change induced sea level rise and ocean acidification. Frequent storm surges and coastal flooding are occurred. Loss or changes in coastal habitats and species distribution, landward migration of coastal wetlands, resulting loss of freshwater and brackish water habitats that are important for fisheries and coastal aquaculture. Changes in salinity of lagoons and estuaries may affect fish and crustaceans. Salinity also affects near shore habitats and associated fishery resources and near-shore reefs. Storm surges can particularly affect reefs which could lead to more serious coastal erosion and high levels of saline intrusion. Damage to coastal habitats such as coral reefs, mangroves and sea grass beds due to climate change associated disasters will affect availability of fish stocks for the marine fishery as they serve as feeding and breeding grounds for fish.

The coastline within a 2 km band is located between 'flooded' and 'run-up' areas while most places including the areas closer to water bodies are susceptible to the impacts of ocean surges (Figure 3.24).

Higher sea surface temperatures increase the risk of coral bleaching and lead to coral death with subsequent loss of critical habitats for other species and the tourism industry. During the El Nino in 1998, the sea surface temperatures in the Indian Ocean were elevated to 3-5°C above normal, and wiped out almost all coral reefs at the Bar Reef Marine Sanctuary, more than 90% in Hikkaduwa Marine Sanctuary, 60% at Weligama and 80% at Rumassala (Rajasuriya, 2010).

With increasing sea levels, inter-tidal zones could shift to towards land and potentially affect the total extent of mangroves, corals and seagrasses. However, increased surface temperatures combined with atmospheric CO_2 are expected to affect mangroves and other coastal ecosystems by not only changing species composition and the phonological patterns, but also changing metabolic activities (UNEP, 1994). Thus, a changing climate will threaten the resilience of mangrove ecosystems that typically occupy intertidal zones. Seagrass areas along the coastline that are already affected by human activities (causing e.g. sedimentation, nutrient enrichment, eutrophication and other environmental destruction) are most vulnerable to climate change impacts such as physical damages, light intensity, changes in sea surface temperature and changes in ocean current and atmospheric CO_2.

Based on the mapping done for this assessment, Jaffna, Mullaitivu and Kilinochchi districts exhibit a high risk of inundation of sensitive coastal habitats (coral reef, seagrass, salt mashers, sand dunes and mangroves) due to sea level rise by 2030 (Figure 3.25). As per the risk assessment, low-lying coastal wetlands of these districts are at a high risk from climate change impacts. Further, Kilinochchi and Batticaloa districts show the highest risk on coastal populations due to sea level rise. Low-lying coastal settlements of these districts are vulnerable to multiple natural hazards related to climate change.

Adaptation measures needed: Physical structures in coastal areas (manmade and natural) are prone to damage or even complete removal by the force of ocean surges due to sea level rise and storms. Integrating coastal vegetation such as mangroves, seagrass beds and sand dunes could enhance protective buffering. Port and harbour infrastructures such as breakwaters along the coast provide greater protection against ocean surges. Better infrastructure and settlement planning along the coast can also reduce vulnerability to sea level rise.

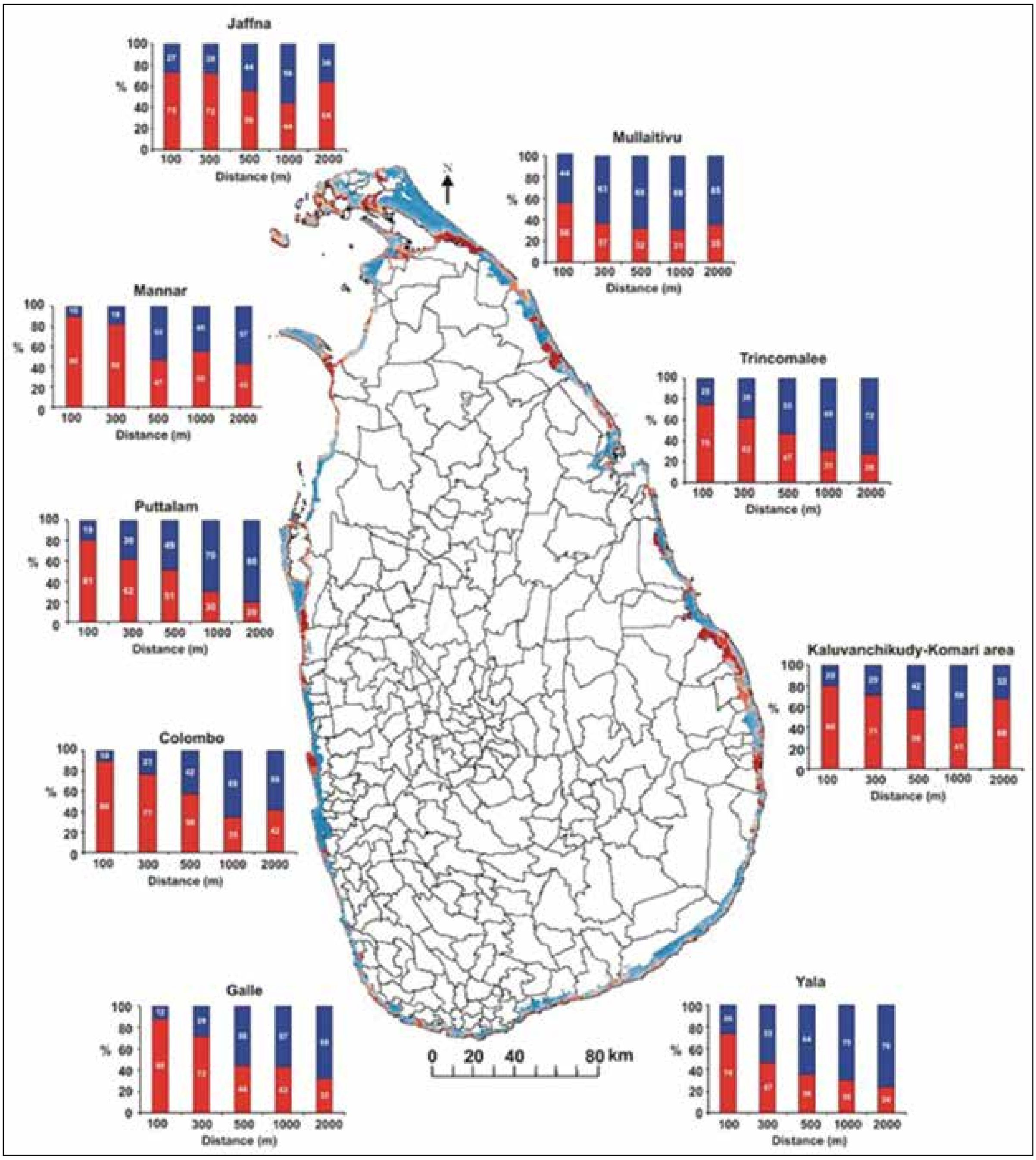


Figure 3.24 Climate vulnerability index of vulnerable (red) and less vulnerable (blue) areas along the coast

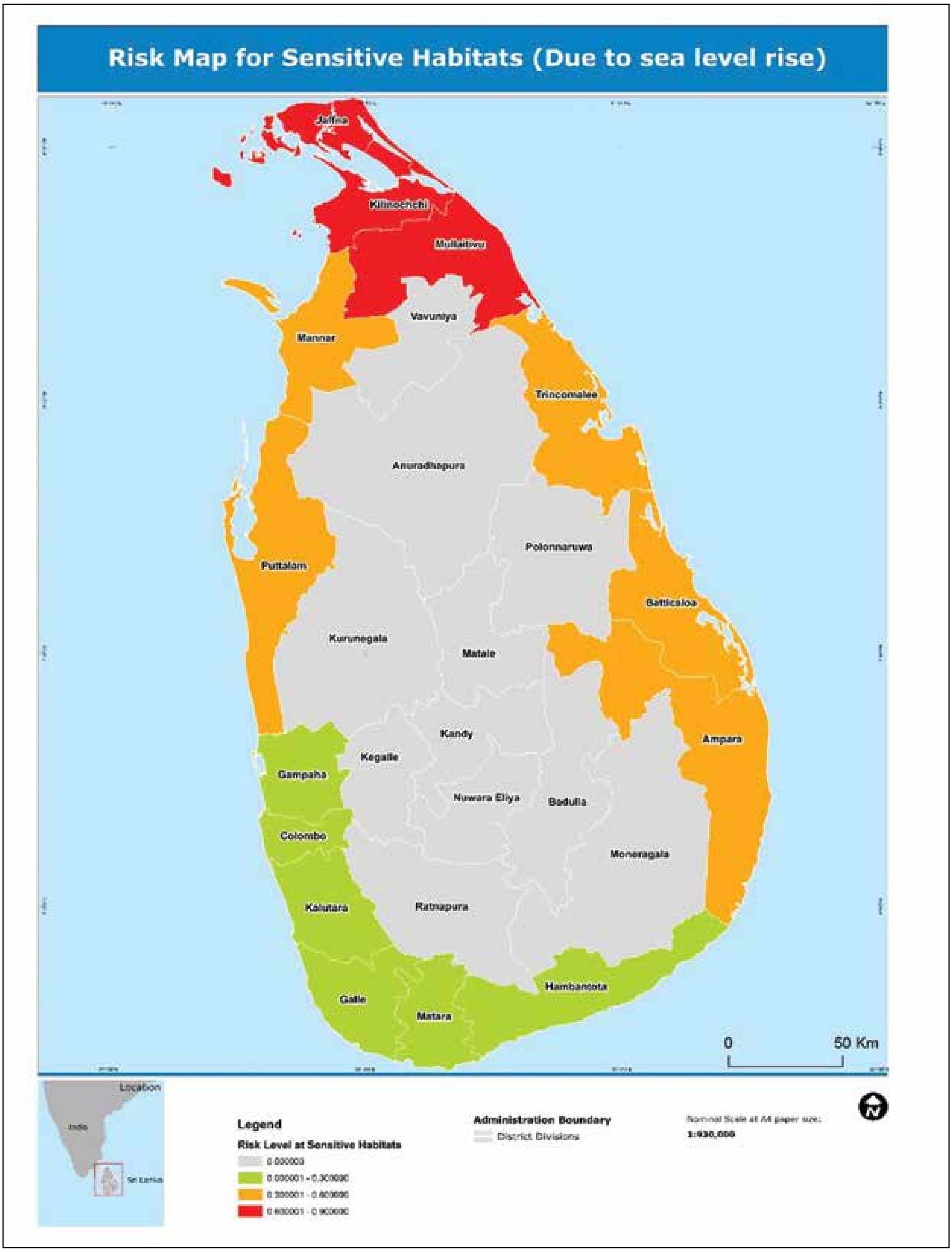


Figure 3.25 Coastal sector risk to sea level rise based on inundation of sensitive coastal habitats in coastal district by 2030

Onshore and offshore measurements of meteorological indices, sea level rise, wave measurements and sediment transport will be useful for the implementation and monitoring of adaptation measures efficiently and effectively. The establishment of a network of monitoring stations is recommended to support development of a Digital Elevation Model (DEM) for the entire coastal zone using GIS and remote sensing. A coastal resources database could enhance coastal adaptation measures and resilience. Re-establishment of the mean sea level around the country could lead to baseline maps including inundation maps of coastal habitats that are needed to monitor long term changes. Identification of patterns of connectivity between coastal ecosystems to improve the design of marine protected area networks and allow for ecological linkages and shifts in species distribution would help to address climate change adverse impacts occurred in the coastal belt.

Enhanced public participation through raising awareness of the value and threats of coastal habitats could further strengthen resilient efforts. Promotion of in-situ and ex-situ conservation, elimination of invasive alien species and temporary migration/translocation of species to suitable habitats based on scientific analysis are additional adaptation measures.

Coastal erosion accelerated by sea level rise and storm surges needs to be managed and minimized to safeguard human settlements and infrastructures in the coastal belt. Introduction of physical barriers could help protection of coastal resources. Vegetation growing on high salinity conditions can be introduced as salinity barriers near estuaries and low-lying coastal areas.

3.6.8 Climate change impacts on biodiversity and ecosystems

Sri Lanka (along with India's Western Ghats) is one of the world's 36 biodiversity hotspots of the world. Though its relatively small size, Sri Lanka has a diverse array of ecosystems with a very rich species composition of fauna and flora. The diversity of ecosystem distribution in Sri Lanka is based on spatial variation of rainfall, temperature, topography and soil. This diversity is highest in the southwestern part of the country which is the wet zone. The few remaining rainforests here are home to nearly all of the country's woody endemic plants and about 75% of its endemic animals. The diversity and high endemism significantly contribute to the country's species richness. Based on the patterns of distribution of the angiosperm flora and their endemicity, 15 different floristic regions have been recognized in the island (Gunatilleke et al., 2017). According to the National Red List 2012, there are 349 flora and 5,717 fauna of which 27% and 17% respectively are endemic to Sri Lanka and also has a rich biodiversity in lower plants and invertebrates.

Sri Lanka has a multitude of terrestrial (19,334 km^2), coastal (2,352 km^2) and marine (517,000 km^2), and aquatic ecosystems (2,024 km^2). The terrestrial ecosystem hosts a dense forest cover of 14,382.75 km^2 (29.7%), grasslands across 680 km^2 and dry monsoon 11,213 km^2. There are six wetlands recognized by the Ramsar Convention covering a total area of 1,982 km^2. Montane forest ecosystems located at the central highland complex rise up to 2,500m and have been declared as a World Heritage Site by UNESCO in 2010 consisting of the Peak Wilderness Protected Area, Horton Plains National Park and Knuckles Conservation Forest which is considered a super biodiversity hotspot. According to UNESCO's Man and the Biosphere Programme, the country has four biosphere reserves: Hurulu, Sinharaja, Kanneliya-Dediyagala-Nakiyadeniya and Bundala. The coastal landform in Sri Lanka is approximately 1,700km in length and is comprised of estuaries, lagoons, beaches, rocky shores, sand dunes, salt marshes and mangroves. The Gulf of Mannar has the most extensive shallow coral reefs and seagrass beds in Sri Lanka while fringing coral reefs are common in the northern, eastern and southern coastal waters.

Deforestation and forest fragmentation are the predominant threat to Sri Lanka's biodiversity, while invasive alien species are increasingly dominating the landscape aided by climate changes. Very few studies have been conducted on the impacts of changing rainfall patterns and temperature increases on forest species and ecosystems. Habitat sensitive species such as freshwater fish, pteridophytes (ferns), orchids and other aquatic plants are sensitive to water availability. In 2010, severe bleaching of the coral reefs in the Pigeon Island National Park and Dutch Bay in Trincomalee damaged the coral ecosystems (Rajasuriya, 2010). Similar coral bleaching has been recently observed (2019), especially for reefs in the east and north coasts.

Habitat suitability assessment: To understand the survival of and threats to endemic and indigenous species and eco-systems in the climate change context, a study was carried out for threatened categories (MoE, 2012). To represent the entire fauna and flora in Sri Lanka, two species of endangered higher plants (*Strobilanthes habracanthoides* and *Strobilanthes helicoides*), one species of butterfly (*Parantica taprobana*) and a reptile (*Ceratophora stoddartii*) were selected to study the correlation between species distinction and climatic variables among the initially selected 27 threatened species.

According to the study, *Strobilanthes habracanthoides* favors montane to mid-elevation southwestern regions. It faces the threat of losing its existing range (around 4% of habitats) owing to montane habitat loss by 2050 (Figure 3.26). The *Strobilanthes helicoides* demonstrates a similar contraction of suitable habitat from 2% to 1% in 2050 (Figure 3.27). The reptile species studied- *Ceratophora stoddartii* could lose its already isolated habitats and could result in fragmentation and isolation in to small unviable populations by 2050 (Figure 3.28). The species *Parantica taprobana* showed loss of suitable habitats from 3% to 2% in 2050 with the increase of less suitable habitats by 4% to 5% (Figure 3.29).

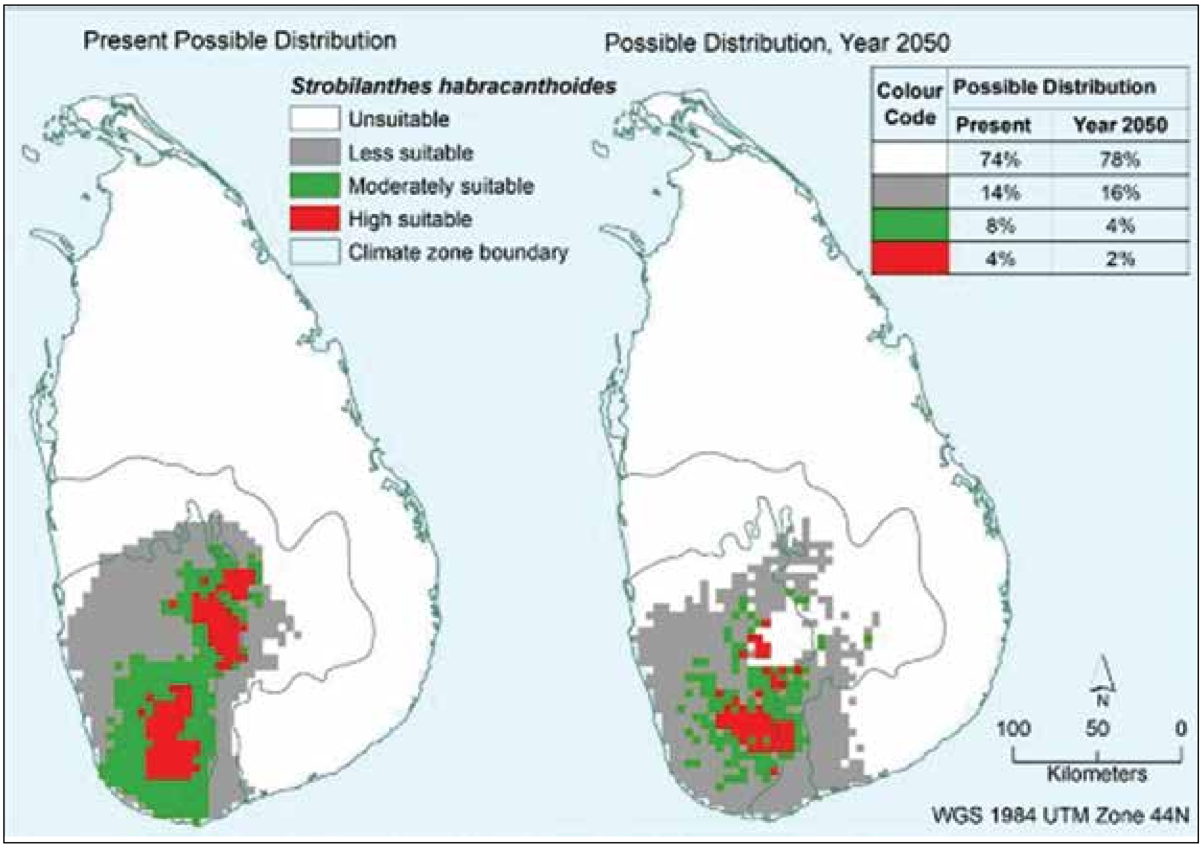


Figure 3.26 Present and future possible distribution of Strobilanthes habracanthoides

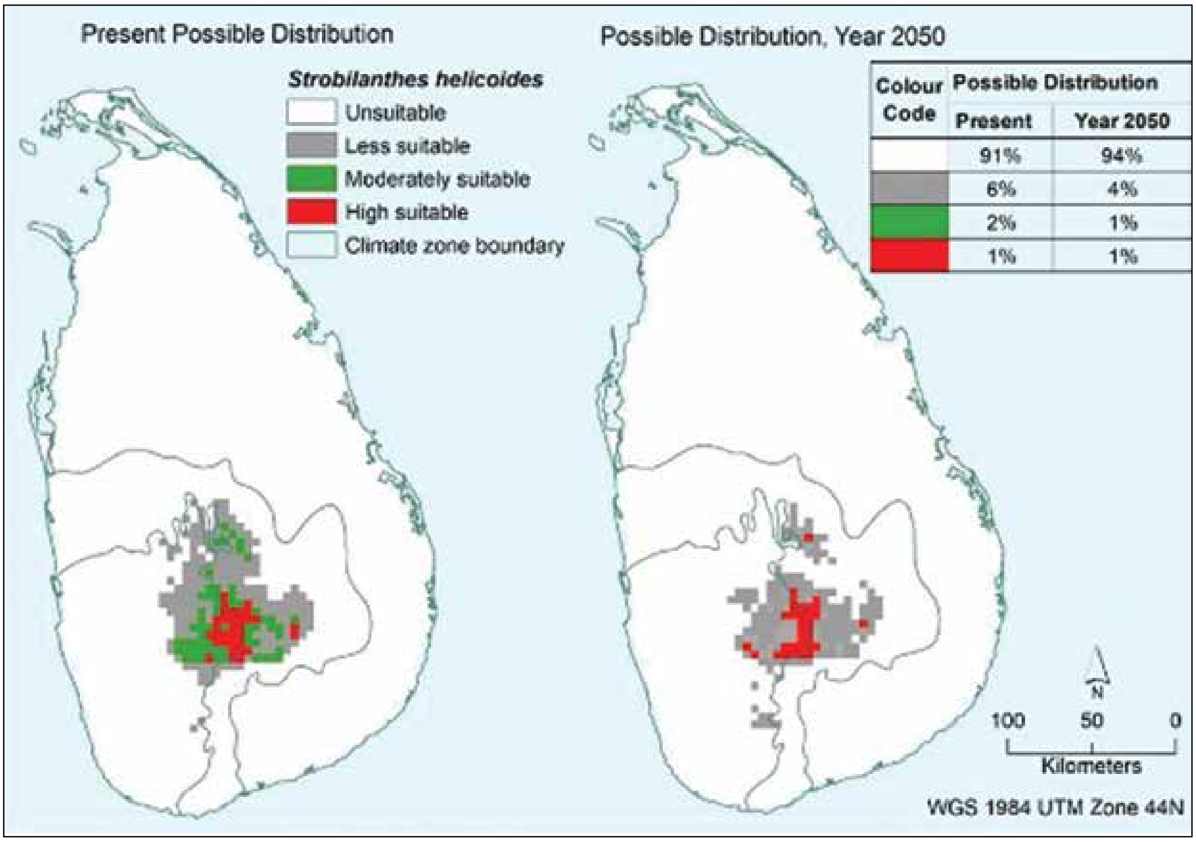


Figure 3.27 Present and future possible distribution of Strobilanthes helicoides

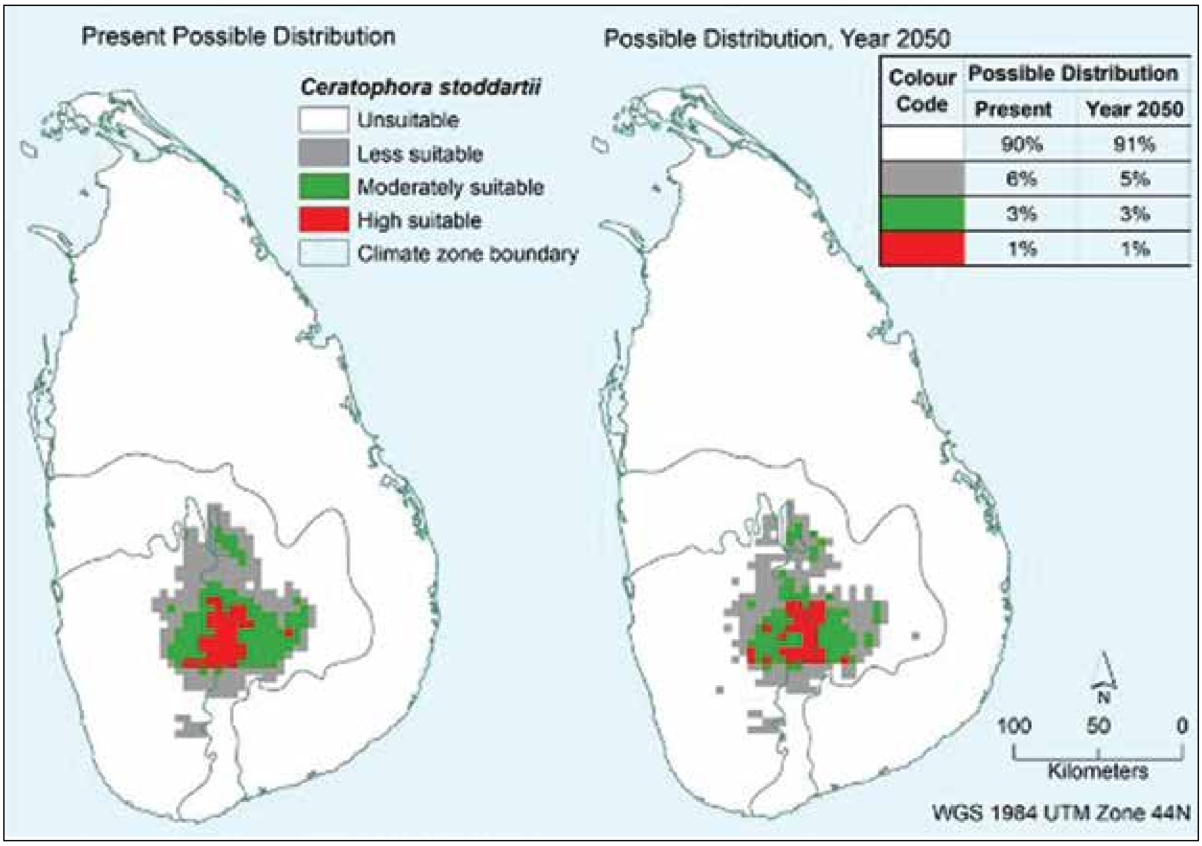


Figure 3.28 Present and future possible distribution of Cerotophora stroddarti

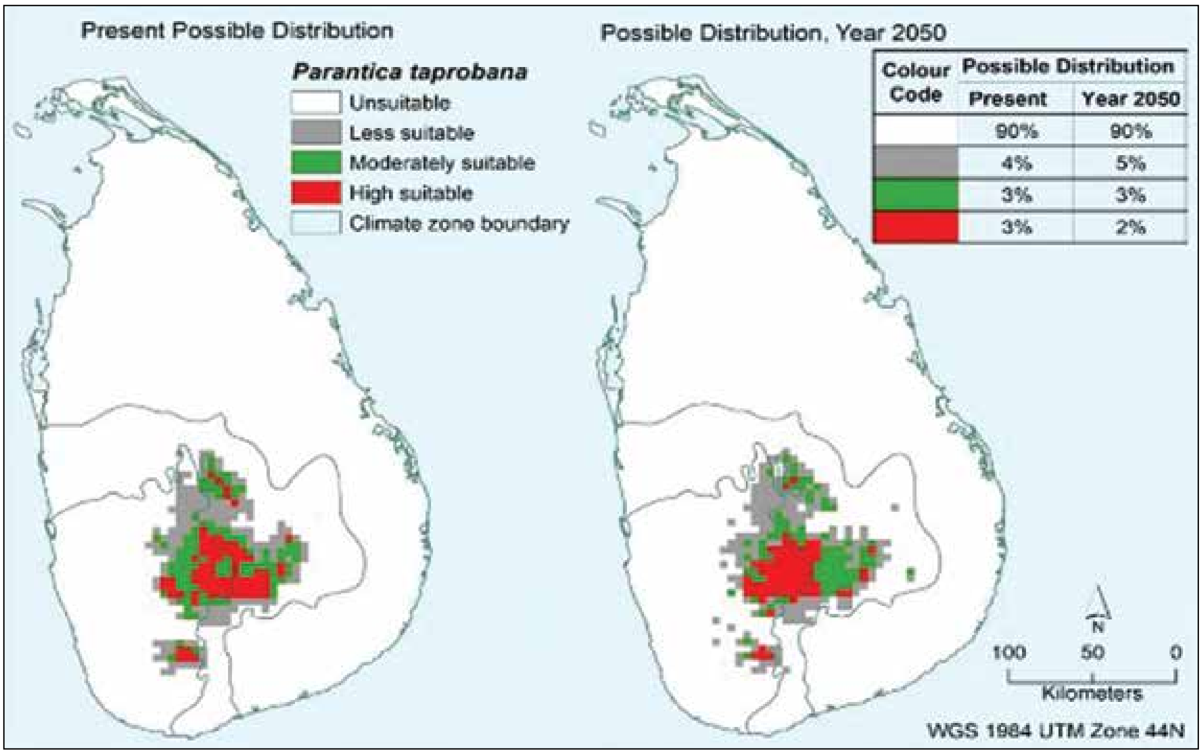


Figure 3.29 Present and future possible distribution of Parantica taprobana

Climate change impacts on mangrove habitats: The study carried out on impacts of 1m sea level rise to mangrove forest distribution published by the Department of Forests Conservation in 2010 revealed that vegetation along the coastal belt is subject to inundation by sea water, changing species diversity, composition and their interactions (Figure 3.31). The Figure 3.30 clearly shows that a 1m inundation due to sea-level rise along 911.5 km^2 of land is going to inundate the area from Puttlam to Jaffna including islands located in north western side of Sri Lanka (Kalpitiya and Jaffna Islands; Wedithalathiwu), which represent a higher mangrove species diversity. This will result in a shift in species composition, abundance and ecological services provided by mangrove habitats.

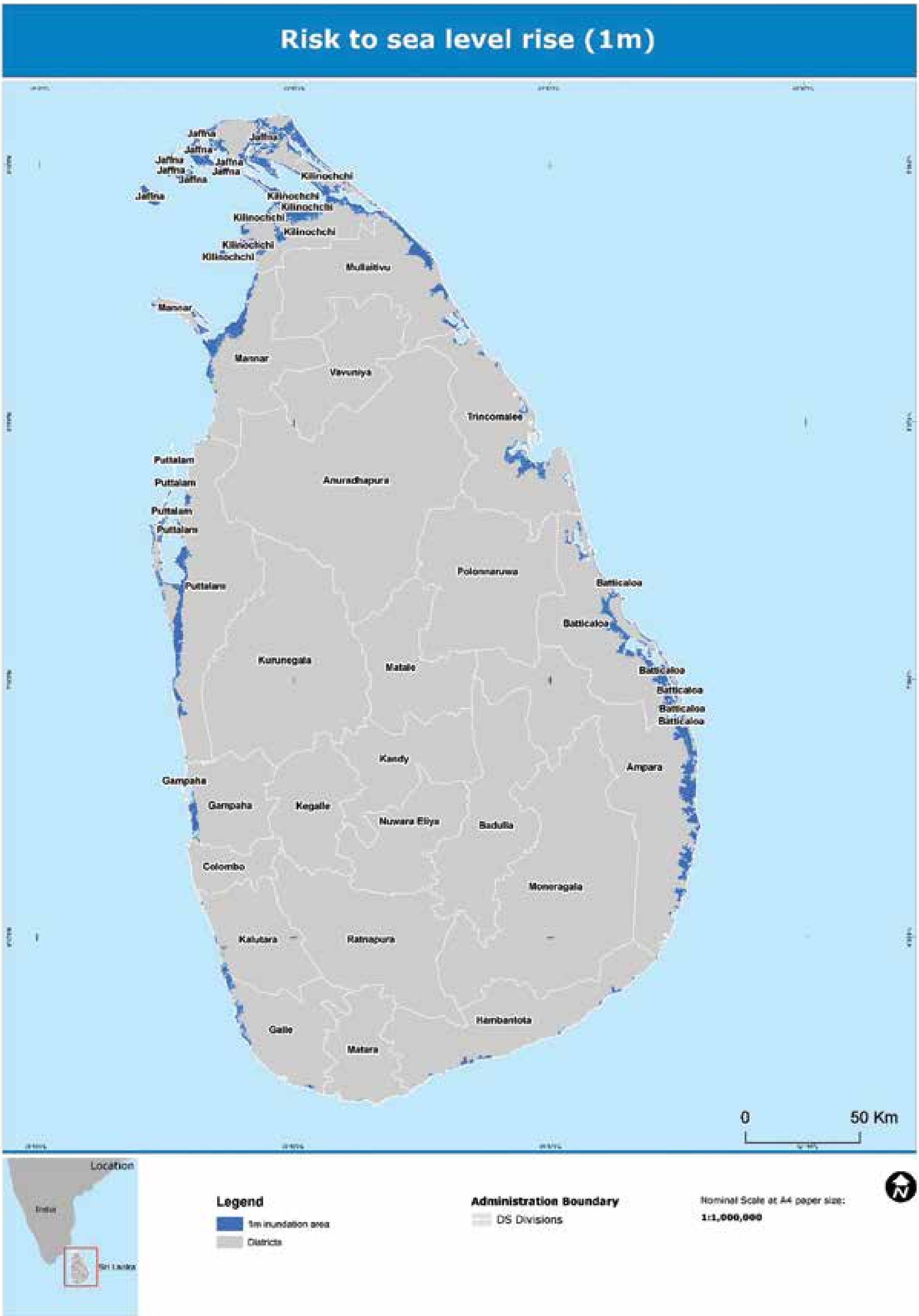


Figure 3.30 One-meter inundation map in 2010

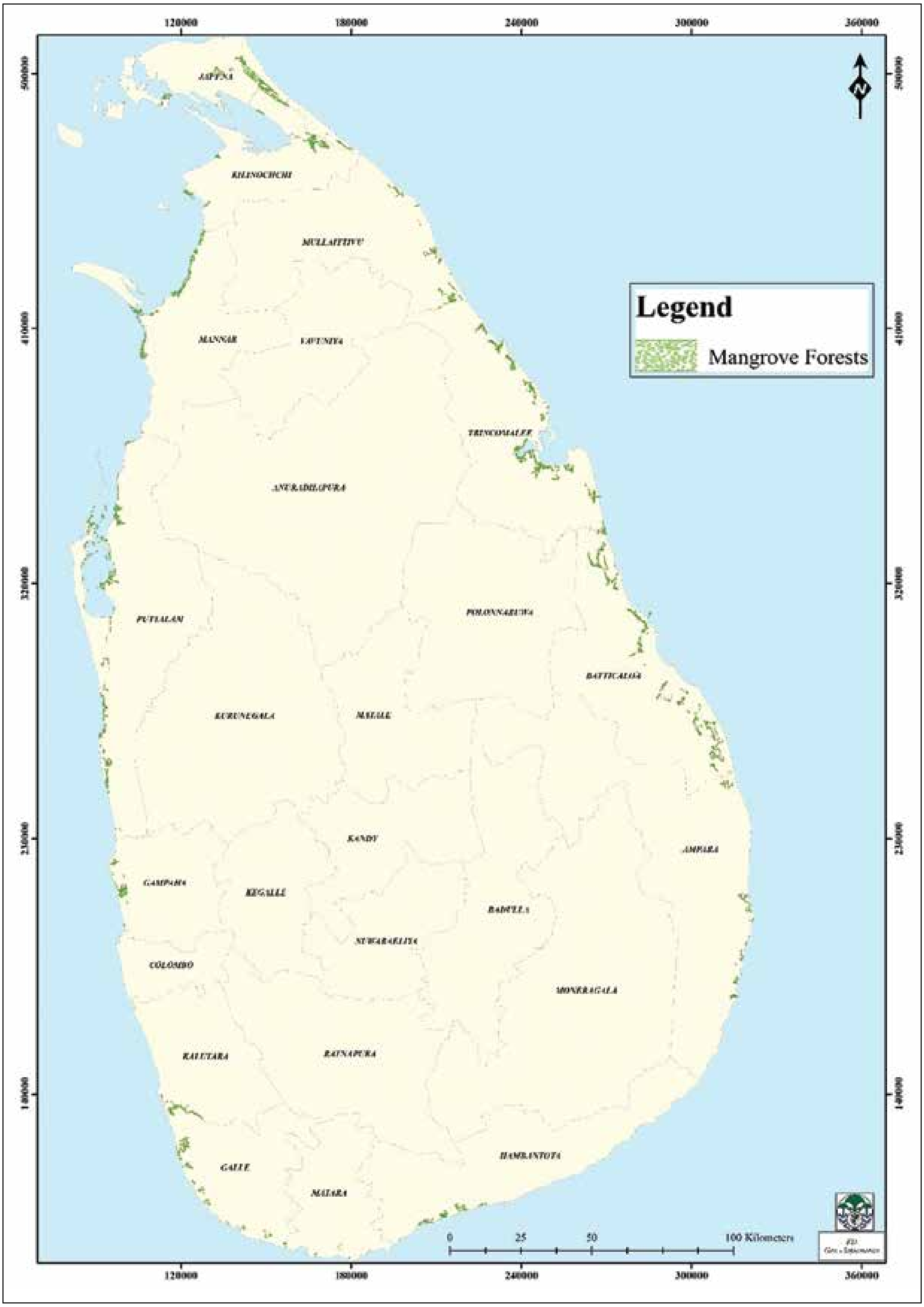


Figure 3.31 Mangrove distribution

Adaptation measures needed: Species diversity and distribution depend on climatic and micro-climatic conditions that moderate habitat suitability. Change in macro environmental parameters, especially precipitation, humidity, temperature and pH, trigger considerable threats to favourable micro climates sought by already threatened/rare/endemic species. Climate induced threats can undermine connectivity of ecosystems resulting in forest fragmentation, species isolation and inability to maintain viable populations or the requisite gene pool to foster physiological adaptations to these changes. Adaptation measures for conservation could start with preserving existing high-conservation value forests which provide much needed micro climates for many rare and endemic species and protect forest corridors which could preserve connectivity. Establishment of micro climatic monitoring plots, declaration of Environment Sensitive Areas and enhancement of protected areas with effective monitoring could enhance resilience of outside protected areas. Further, identification of new biodiversity hotpots, while strengthening conservation of existing ones, will enhance the sector's resilience. Promotion of in-situ and ex-situ conservation, identification and elimination of invasive alien species, preparation of the list of species recovered from extinction and temporary migration/translocation of species to suitable habitats based on scientific analysis are additional adaptation measures. Implementation of community driven conservation projects and programmes and promotion of traditional methods of biodiversity conservation can further increase resilience.

3.6.9 Climate change impacts on human settlements

Human settlements in Sri Lanka comprise of urban, rural and estate sectors. The rural population is 77.4% of the total population, while urban and estate populations constitute 18.2% and 4.4% in 2014. However, while defined as rural, many people are crowding in to peripheries of regional cities and district capitals and creating sprawling suburbs. As forecast in the Urban Development, Human Settlements and Infrastructure report of 2010, 70% of Sri Lanka's population is expected to reside in urban settlements by 2030.

Human settlements are highly vulnerable to the adverse impacts of climate change including higher temperatures, longer periods of drought and disasters caused by erratic rainfall patterns, floods, landslides and sea level rise. Urban and rural settlements are susceptible to flood risk while settlements in slopes over 450 area are highly threatened to landslides. 25% of the country's population living within two kilometers of the sea, and the generation of 45% of GDP earned through coastal economic activities. Thus, climate change impacts on settlements in the coastal region through sea level rise are a key socioeconomic threat faced by the nation.

Risk for urban settlements from floods: Major urban areas and cities in specific districts are at high risk to floods (Colombo, Ratnapura, Kalutara, Galle, Matara and Puttalam) while some areas in Jaffna and Mannar districts show moderate risk of flood. The RCP 8.5 rainfall anomaly maps for 2030 and 2050 (Figure 3.2, 3.3 and 3.4) indicate that the southwest monsoon and the two inter monsoons yield more rain that will generate more frequent and intense flood events in the wet zone in future.

Risk for urban settlements from drought and temperature increase: According to the map on drought risk to urban settlements, a few areas in Nuwara Eliya, Trincomalee and Vauniya districts and some urban settlements in other DSDs are currently experiencing moderate risk of drought. Though many urban settlements have better infrastructure facilities than rural settlements, a continued drought might increase the limits of resilience in these areas. More people and/or higher population densities could also impact on coping capacities for drought. According to the prediction for 2030 and 2050 for RCP 8.5 (Figure 3.5), the positive temperature anomaly will create more drought conditions in the dry zone areas.

Adaptation measures needed: Given the existing and future risk in urban settlements to floods, careful planning is required and recommended to improve adaptation. Urban councils and local authorities should plan and construct infrastructure to prevent or mitigate damages to humans, properties and ecosystems. Conserving existing flood retention areas, especially wetlands, and demarcation and development of new open spaces or reservoirs for flood capture and storage are some recommended adaptation measures. In response to flooding, actions should be taken during post disaster situations to further support affected communities to build back better. Further, in preparedness, systems should be designed with scenarios developed through intelligent flood modelling to minimize the damage.

Zonal planning with guidelines for buildings and other infrastructure could be the starting point towards climate smart urban settlements. Planning is needed to avoid the extreme conditions brought by climate change such as urban heat islands and saline intrusion into drinking water which are made worse by drought. Encouraging spatial planning and green buildings using natural wind flows and green spaces to create more liveable conditions are sound adaptation measures. Preserving and enhancing green cover including urban forests, urban wetlands and water bodies can minimize heat impacts.

Risk for Rural settlements from floods: The most rural areas in eastern, western, southern and Sabaragamuwa provinces and the parts of northern province are vulnerable to frequent floods. However, past records show that Puttalam district in north-western province has also faced frequent floods in the last few years. The RCP 8.5 rainfall anomaly maps for 2030 and 2050 (Figure 3.2, 3.3 and 3.4) indicate that the southwest monsoon and the second inter-monsoon will generate a higher positive rainfall anomaly which could result in frequent flood events especially in the rural and urban areas in the wet zone.

Risk for rural settlements from drought: The risk assessment findings shows that the rural districts and DSDs in north-western, northern and eastern provinces will face a moderate risk from drought exposure. Resilience of rural settlement to drought can be identified as moderate due to the large number of manmade village reservoirs providing multi-uses of water nonetheless with reduced functionality due to rapid siltation and catchment degradation. This will be aggravated by the reduction of rainfall, especially the weakening of NEM and first Inter-monsoon and rising ambient temperatures. According to the RCP 8.5 climate scenario for 2030 and 2050 for Sri Lanka, the negative rainfall anomaly and positive temperature anomaly for dry zone will be expected to increase the vulnerability to rural settlement for the dry zone (Figure 3.2, 3.3 and 3.4).

Adaptation measures needed: Both urban and rural locations in the wet zone are prone to floods, especially in western, southern and Sabaragamuwa provinces. These areas are predominantly low-lying and need special adaptation measures and interventions such as in flood retention areas and capture and storage facilities for flood. At risk for climate induced disasters, rural infrastructure needs to be rebuilt. Emergency plans and improvement of flood management capacities in cities and rural areas are of utmost importance to enhance coping ability.

The existing cascading reservoirs and related rural infrastructures are resilient enough to adapt to moderate risk to droughts in rural settlements. However, the future climate risk would challenge the resilience of rural settlements. Therefore, improving infrastructure by upgrading existing village reservoir networks with additional climate resilient features such as enrichment of catchment, addition of ponds, enhancement of perennial green cover, introduction of eco-friendly housing solutions, and eventually climate smart villages and settlements could make rural settlement more resilient to climate change.

Risk for rural settlements from landslides: Hazard maps show that landslide risk is higher in rural settlements in DSDs in Kegalle, Nuwara Eliya, Badulla, Ratnapura and Kandy districts. The risk maps demonstrate a moderate risk in Rattota, Matale DSDs in Matale district and Agalawatta in Kalutara district. In 2030, the rainfall anomalies show intensified rains in the wet zone. This situation will be aggravated by 2050 according to projected rainfalls as shown in the rainfall anomaly maps. Therefore, the risk for landslides in these areas can further intensify and advanced adaptive measures should be implemented. However, the rainfall anomalies show a lesser rainfall in Badulla district in 2030 than in 2050 (Figure 3.2, 3.3 and 3.4). This may reduce the landslide risk in Badulla; however, intense rainfall events may still trigger landslides even though overall annual rainfall may see a decline.

Adaptation measures needed: The landslide risk is intensified in the western slopes of central highlands during the southwest monsoon. Most of these rural areas are on high elevations and steep slopes and hence need to consider identification of safe human settlements and infrastructure development solutions. Introduction of early warning systems, soil stabilization and scientifically developed vegetation cover without planting heavy trees in those areas and implementation of the zonal demarcations as per the guidelines developed by the NBRO could further help to climate change adaptation and resilient building.

Risk for estate settlements from floods: The estate settlements refer to the communities living in tea plantations. The study shows the most estate settlements in Nuwara Eliya, Ratnapura, Kegalle, Kalutara, Galle and Matara districts possess moderate risk from floods. In the 2030 and 2050 of RCP 8.5 climate scenario (Figure 3.2, 3.3 and 3.4), the positive rainfall anomaly expected from southwest monsoon could cause floods, especially in the rubber and coconut plantations in the wet zone.

Risk for estate communities from Landslide: The landslide risk for the estate communities is very high and incrementally increasing, especially during the southwest monsoon in the areas of Kegalle, Kandy, Nuwara Eliya, Matale, Rathnapura, Kalutara and Matara districts. A low literacy rate coupled with poverty in the estate sector further reduces coping capacity and makes them more vulnerable to increased risk of climate change.

The projected climate scenarios for 2030 and 2050 as per the RCP 8.5 indicate positive rainfall anomalies in the wet zone during south western monsoon (Figure 3.2, 3.3 and 3.4) and, as a result, the risk from landslides will be further aggravated, especially in areas already identified as high risk.

Adaptation measures needed: Much of the labour force in the plantation sector lives in housing provided by the estates where they work. These houses are risks associated with floods where there are floods occurred frequently. Improvement in sanitation facilities and effective drainage networks could minimize flood related epidemics and improve their living standards. The estate labour force consists of day wage earners and hence, during floods, they would require social security to rely on daily income and meet immediate cash needs. The early warning systems and flood retention housing should introduce for estate settlements where frequently flood occurred.

Similar to adaptation measures for the rural sector, the estate communities could be resettled to safer areas, preferably in the same plantation or an adjacent one as their livelihood is tied to the plantation work. Settlement planning coupled with early warning systems, soil stabilization and plantation of scientific vegetation cover are other adaptation measures.

3.6.10 Climate change impacts on tourism

Sri Lanka is a popular tourist destination and has been described as one of the best island countries to visit for its contrasting geophysical and climatic zones that can be accessed within hours of each other. The country is identified as one of the top ten countries showing the strongest growth potential via improved governance of tourism sector, prioritization of tourism and investment incentives (WTTC, 2017).

Tourism Development Plan of 2011-2016 and 2017-2020 have embedded strategies to enhance the tourism industry and boost arrivals to 2.2 million in 2016 and 4.5 million by 2020. The tourism sector contributed 11.5% to GDP in 2016, making it the third highest earner of foreign exchange for the national economy (Central Bank of Sri Lanka, 2018). The current strategy sought earnings of 7 US$ billion by 2020 while it is targeted to 10 US$ billion by 2025. The sector employs 360,000 people directly and indirectly (SLTDA, 2017).

The tourism sector is highly vulnerable to the adverse effects of climate change such as temperature rise, heat waves, sea level rise and extreme weather events (storm surges, prolong drought, flash flood and landslides). The majority of tourism facilities are located in the coastal areas (60%) where elevation is less than 2m which further exposes the sector to risks from sea level rise and storm surges (Nayanananda, 2007). In addition, climate change would exacerbate loss of beaches and marine biodiversity (eg. coral bleaching), spread of infectious diseases, warmer temperatures and heat stress for tourists and lack of water in certain areas. Moreover, prolonged droughts could undermine sightseeing in wildlife parks and reserves, mainly located in the dry zone.

Risk to tourism from floods: The risk assessment indicates that Colombo (the tourism hub of the country) has a high risk from floods along with Kalutara, Ratnapura, Kegalle, Batticaloa and Ampara districts. The rainfall anomaly maps for 2030 and 2050 showed a positive anomaly for the wet zone and a negative anomaly for the dry zone as per the RCP 8.5 scenarios (Figure 3.2, 3.3 and 3.4). As such, both flood and landslide risks could increase in the wet zone, threatening infrastructure for tourism.

Risk to tourism from drought: The risk assessment shows a high risk of drought in Trincomalee district which is one of famous tourist destinations in the country. The entire dry zone has significant tourism facilities centered around the ancient capitals and wildlife parks and has a medium risk from drought. The sector would need to adapt to the situation with more options for cooling and air conditioning, designing better buildings and other tourism infrastructure to modulate the heat, as well as implementing more water conservation strategies. Rainwater harvesting and revival of village irrigation schemes could be useful for tourism practices in the dry zone.

Adaptation measures needed: Better networking among hotels, local authorities and district disaster management committees is needed to develop contingency planning, flood early warning systems and early evacuation of tourists out of flooded areas, all of which could further enhance resilience. Planning of tourists to the country based on the climate change scenarios and develop tourism packages accordingly is one of the best adaptation measures that can be applied.

Effective adaptation measures include implementing policies that make rainwater harvesting compulsory for all new hotels and registered homestays and providing technical facilitation for rainwater harvesting. Moreover, use of potable water for mundane uses such as toilet flushing, gardening and vehicle washing should be banned and grey water use should be a prerequisite for granting approval for registration. This is a medium-term adaptation measure which requires new by-laws. Further, increase of the green cover in all tourist establishments and destinations as well as approach roads should be recommended. Arrival of tourists to the country in accordance with projected climate change scenarios should be planned and developed niche packages for specific destination is one of the best adaptation measures that can be implemented.

3.7 Triggering inter sectoral climate change vulnerability

The irrigation sector of the country has a direct interrelationship with agriculture for sowing practices and in the maintenance of minimum water coefficients during different stages of particular crops. The failure to maintain these coefficients results in crop damages as well as saltwater intrusions during the driest seasons. Scarcity of water during prolonged droughts, especially in the dry zone, negatively impact the feeding grounds (pastures) for fodder to the livestock rearing by farmers. The disturbances to agricultural based livelihoods trigger internal migration of farmers to other labour markets such as construction, taxi driving and security.

Spillages of large quantities of water during high-intensity rains damages irrigation infrastructure, agricultural crops and other vegetation. Lack of irrigation water affects the spread of communicable diseases through food, water and vector-borne diseases. Lack of water availability also aggravates non-communicable diseases such as the Chronic Kidney Disease of unknown aetiology. The performance of inland fisheries is proportionate to the availability of irrigation water that is threatened by prolong droughts. Unplanned drainage patterns in urban dwellings and ad-hoc settlements as well as upland monoculture plantations tend to alter waterways and decrease river flow, resulting in greater salinity in estuaries which leads to a loss of fish and aquatic plant species. High sedimentation in coastal areas and reservoirs alters primary production, thereby triggering imbalances in the coastal and inland terrestrial ecosystems.

Extended droughts create cross-sectoral multiple stresses in agriculture, livestock, fisheries and water sectors that could eventually lead to undernutrition and vitamin deficiencies. Biodiversity concentrated in protected areas that are located in the dry zone are subject to numerous impacts. The forests could easily catch fire during droughts and damage biodiversity. Human settlements and water resources are also linked to access to safe drinking water and sanitation. During floods and droughts, water sources are subject to pollution by inundation or concentration of pollutants, thus creating further need for purification. The tourism sector relies on the availability of water resources. Some tourist attractions are based on unique experiences such as biodiversity and scenic beauty. However, climate change induced disasters such as droughts, floods, landslides and cyclones create negative temporal impacts on tourism in the short run.

CHAPTER FOUR

Mitigation Analysis and Options

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Mitigation Analysis and Options

4.0 Introduction

This chapter aims to identify the actions already taken and potential measures that can be implemented to reduce anthropogenic emission of greenhouse gases (GHGs) in different sectors at national level in Sri Lanka. The mitigation analysis was totally based on the GHG inventory in the chapter two of this report. Energy (electricity generation, transport and manufacturing industries, household and commercial), Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste are the sectors of this analysis.

4.1 Methodology

For each sector, two types of scenarios were constructed as baseline scenario and mitigation scenario, and it was done in accordance with the UNFCCC approved methodology. According to the aforesaid methodology, the baseline scenario assumes that no mitigation policies or measures will be implemented that are already in force and/or are legislated or planned to be adopted. The baseline scenario was developed as a projection of the emission levels from 2010 which is the base year to future emission levels up to 2030 for all the sectors studied.

The mitigation scenario was structured according to a set of criteria reflecting country specific conditions such as potential for large impacts of GHGs emission reduction, economic impacts, consistency with national development goals, potential effectiveness of implementation policies, sustainability of an option, data availability for evaluation and other sector specific criteria.

The data which were collected up to 2015 was used to construct the baseline scenario and mitigation scenario, and projected up to 2030.The projections were based on assumptions on population growth, GDP growth and other macro variables, which were obtained from official sources.

4.2 Sector specific mitigation assessment

4.2.1 Energy sector

Sri Lanka has been ranked in the mid-range of United Nations Human Development Index, while the annual GDP per capita is at GDP 3,698 US$ in 2017. The Government's drive to reach the upper middle-income level within this decade intensifies the role of energy sector in Sri Lanka's economy. Sri Lanka maintains a very low energy intensity of economy, using 0.05 tonnes of oil equivalent (toe) to produce 1000 US$ of GDP in 2017 (World Bank, 2017). This compares favourably with the global average of 0.13 toe, the South Asia average of 0.12 toe and a developing country average of 0.11 toe for the same year as reported by the (International Energy Agency, 2019). The challenge posed to Sri Lanka is to maintain this lower energy intensity, while accelerating economic growth. Energy intensity measured in terms of primary energy and GDP from 2000-2017 is shown in Figure 4.1.

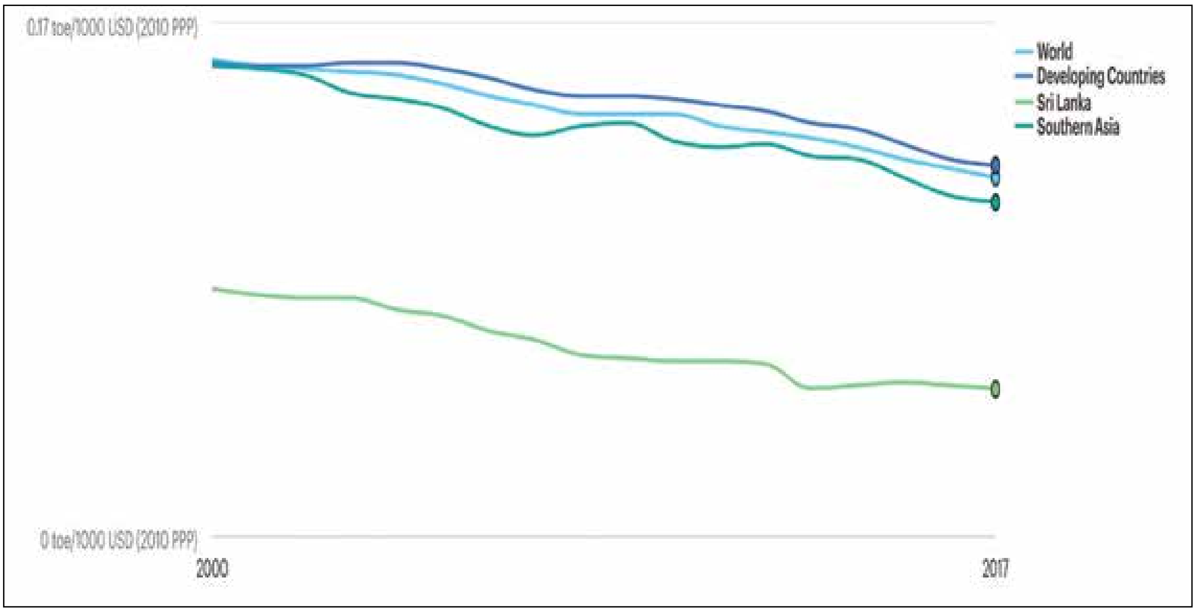


Figure 4.1 Energy intensity in terms of primary energy and GDP, 2000-2017

As of 2017, the largest energy consuming sector was the household, commercial and other sector, accounting for a share of 39.4% of the country's total energy demand. The transport sector's share of energy consumption which was mainly met through liquid petroleum products, accounted for 36.3%. The share of the industrial sector consumption was 24.3% (National Energy Balance, 2017).

The energy needs of the country are fulfilled either directly by primary energy sources such as biomass and coal, or by secondary sources such as electricity produced using petroleum, biomass, hydro power, refined petroleum products and non-conventional renewable energy such as solar and wind. Sri Lanka has reached the important milestone of 100% electrification, thereby fulfilling the goal of providing modern energy sources to all the citizens. Table 4.1 shows the primary energy supply by source from 2010 to 2017 in Peta Joule (PJ) and as a percentage % of the total (National Energy Balance, 2015 & 2017).

It is apparent in the table 4.1 that biomass (fuelwood, charcoal, agricultural residues, coconut husks etc.) is the second largest energy supply source, satisfying a greater portion of the cooking energy requirements of the domestic sector. While hydropower has already been extensively developed for electricity generation, studies have indicated that there is a large potential for wind and solar power development. Further, studies are presently underway to establish the availability of offshore petroleum resources. The total amount of electricity generated in 2017 was 15,004.2 GWh out of which 69% was from thermal plants (National Energy Balance, 2017).

Economic growth amidst universal access requires the energy supply capacity to be steadily increased. The growth in demand can also be managed by improving the efficiency of energy conversion. Continued efforts to maintain a low energy intensity status would require to be rewarded with a lower burden on the economy and environment. Increased efforts from demand side management through policy-driven incentives are required to meet this goal amidst high economic growth.

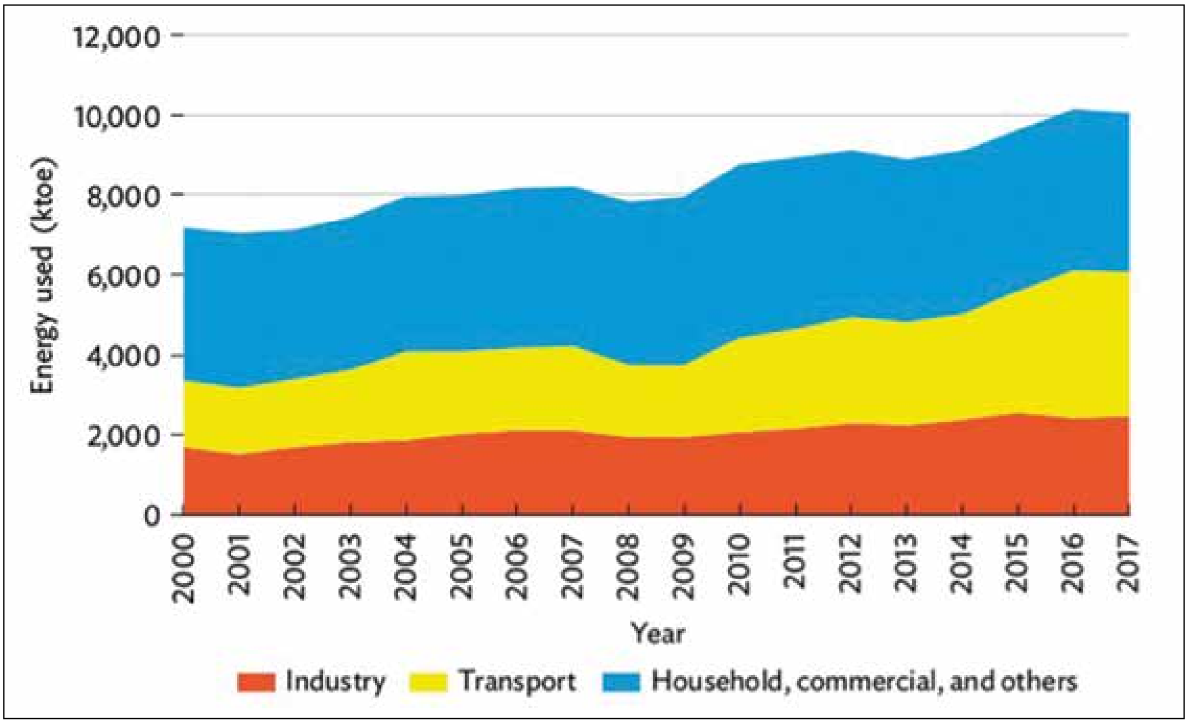
Table 4.1 Primary energy supply by source (2010-2017)

Year	Unit & %	Energy Type					Total
		Biomass	Petroleum	Coal	Major hydro	New Renewable Energy	
2010	PJ	207.4	185.1	2.5	50.1	7.5	**452.7**
	%	45.8	40.9	0.6	11.1	1.7	
2011	PJ	207	205.8	13.6	40.4	7.5	**474.3**
	%	43.6	43.4	2.9	8.5	1.6	
2012	PJ	203.5	218.5	19.1	27.4	7.6	**476.1**
	%	42.8	45.9	4.0	5.7	1.6	
2013	PJ	201.6	171.8	20.1	60.4	12	**465.9**
	%	43.3	36.9	4.3	13.0	2.6	
2014	PJ	205.6	190.8	38.5	36.7	12.6	**484.2**
	%	42.5	39.4	8.0	7.6	2.6	
2015	PJ	202.2	202.6	51.9	49.3	15.3	**521.4**
	%	38.8	38.9	9.9	9.5	2.9	
2016	PJ	196.3	239.3	54.9	35.0	12.6	**538.0**
	%	36.5	44.5	10.2	6.5	2.3	
2017	PJ	192.9	232.0	56.9	30.9	16.2	**528.9**
	%	36.5	43.9	10.8	5.8	3.1	

Source: National Energy Balance 2015 & 2017

The National Energy Policy and Strategies (NEPS) in 2019 presents how Sri Lanka plans to meet the challenge of developing and managing the energy sector to ensure delivery of reliable, cost-effective and competitively priced energy services from diverse sources to fuel the economy. In its 2017 revision of the NEPS, the government has set targets to ensure energy security, least-cost energy supply, access to energy services, conservation of energy, improvement of energy efficiencies, care for the environment, increase of renewable energy, good governance in the energy sector, and opportunities for innovation and entrepreneurship. It places significant emphasis on the reliability and affordability of both indigenous and global energy supplies. Strong emphasis was placed on developing the increasingly competitive newly assessed resources for electricity generation such as solar and wind. Biomass is a convenient fuel for household use and a dependable resource for industries which can help Sri Lanka to be an energy empowered nation by developing strategies and conversion technologies to use this vast indigenous resource. Whilst continuous efforts will be made to strengthen the petroleum sector from upstream resource development to downstream diversification, initiatives will be made to elevate the status of electricity as a major energy source. The energy transition in the transport sector, from liquid petroleum to other energy resources will be actively pursued.

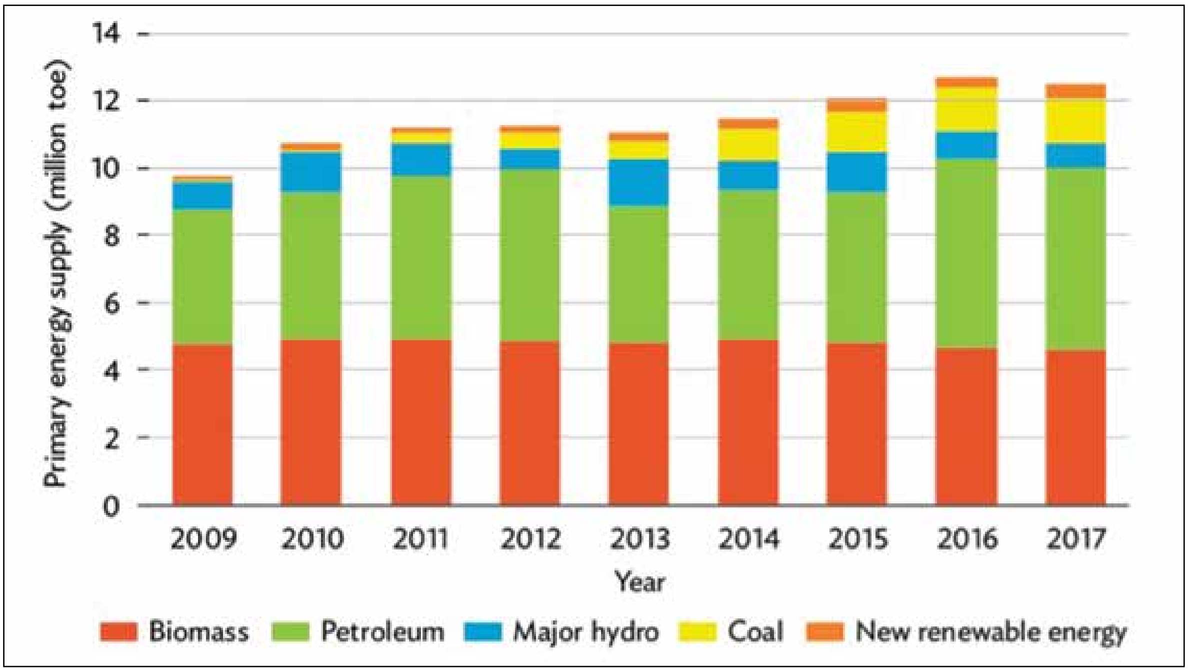
Whilst securing land resources for important energy infrastructure elements such as gas terminals, electricity generation sites and transmission corridors, energy storage will be taken as a prime carrier to transcend the space and time boundaries which constrained the traditional energy systems. Aligning Sri Lanka with Goal 7 of SDGs, this policy would contribute to achieve universal access to affordable, reliable, sustainable, and modern energy for all. The policy will also contribute to reduce the dependence of Sri Lanka on fossil fuels to below 50% of the primary energy supply and to reduce the specific energy use across all end use by 20% of the 2015 level by 2030. This policy will pave the way to realize the vision of Sri Lanka in achieving carbon neutrality and a complete transition of all the energy value chains by 2050. According to the Sri Lanka Energy Assessment Strategy and Road Map (2019) the total energy used (ktoe) had increased from 8,500 in 2010 to 10,000 in 2017, an increase of 17.6% as shown in Figure 4.2.



Source: Sri Lanka Sustainable Energy Authority

Figure 4.2 Energy use by sector 2000-2017

Of the sectors using energy, the highest consumer is household, commercial and others followed by transport and then industry. The variation of primary energy supply by different sources from 2009 to 2017 is shown in Figure 4.3.



Source: Sri Lanka Sustainable Energy Authority

Figure 4.3 Primary energy supply 2009-2017

The share of renewable energy (comprising biomass, major hydro and non-conventional renewable energy) in the primary energy mix is about 46% in 2017, showing a 5.8% reduction, compared with 2015. The stagnant supply and demand for biomass, especially in household and commercial sectors, is the reason for the declining contribution of renewable energy to the national energy mix, despite growing contributions of hydropower and new renewable energy sources used for electricity generation. Figure 4.4 shows the GHGs emissions contribution of energy sub sectors in 2010.

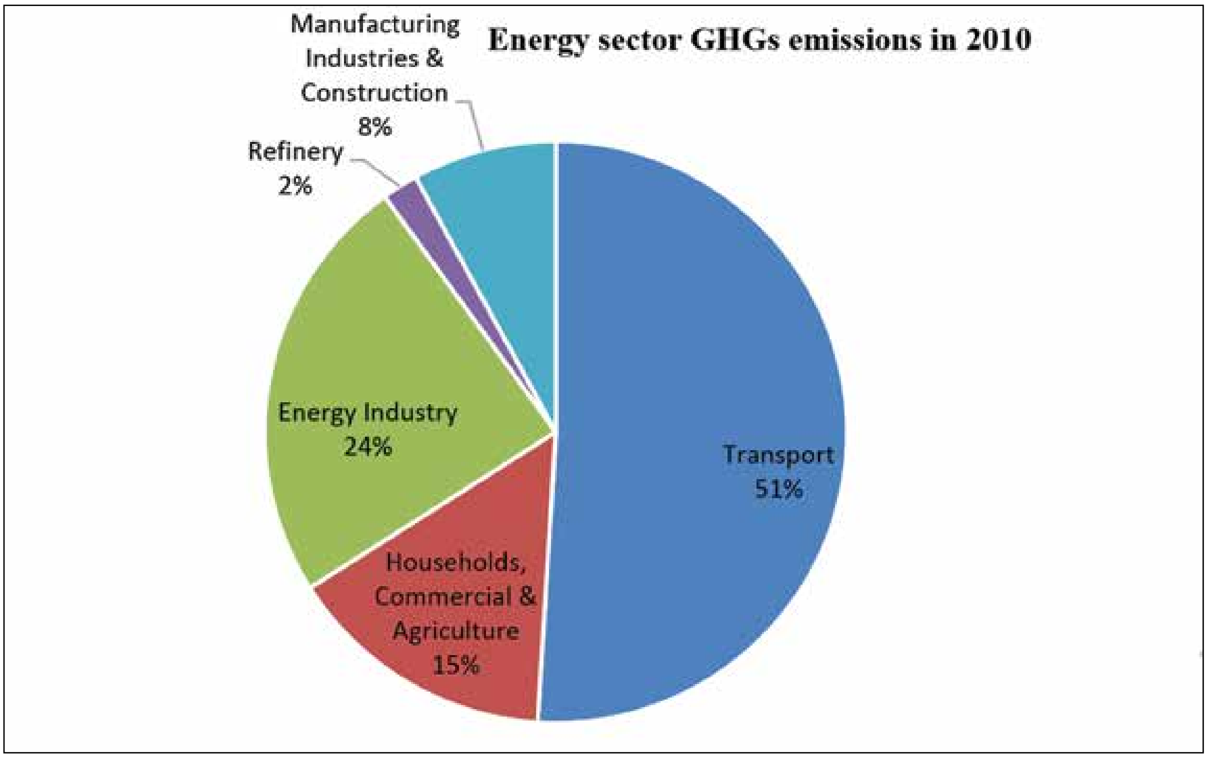


Figure 4.4 Energy sector GHGs emissions in 2010

Figure 4.5 shows the baseline scenario for projected emission from the energy sector (energy industry, transport sector and other sectors) from 2010 to 2030 based on the current trends.

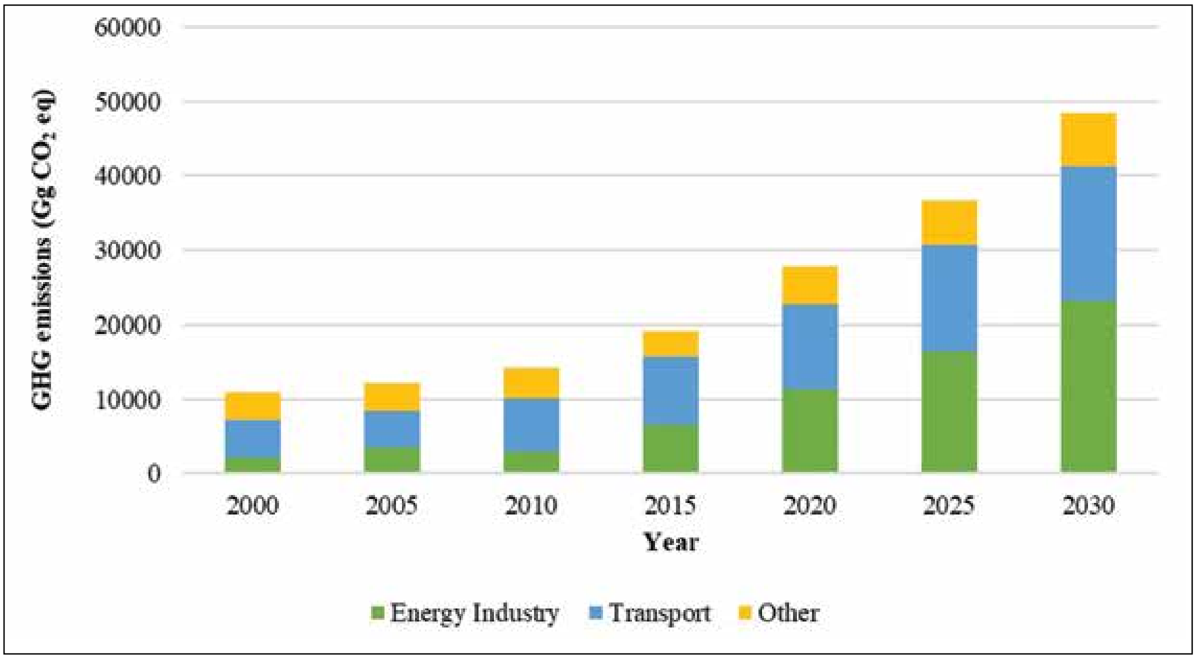
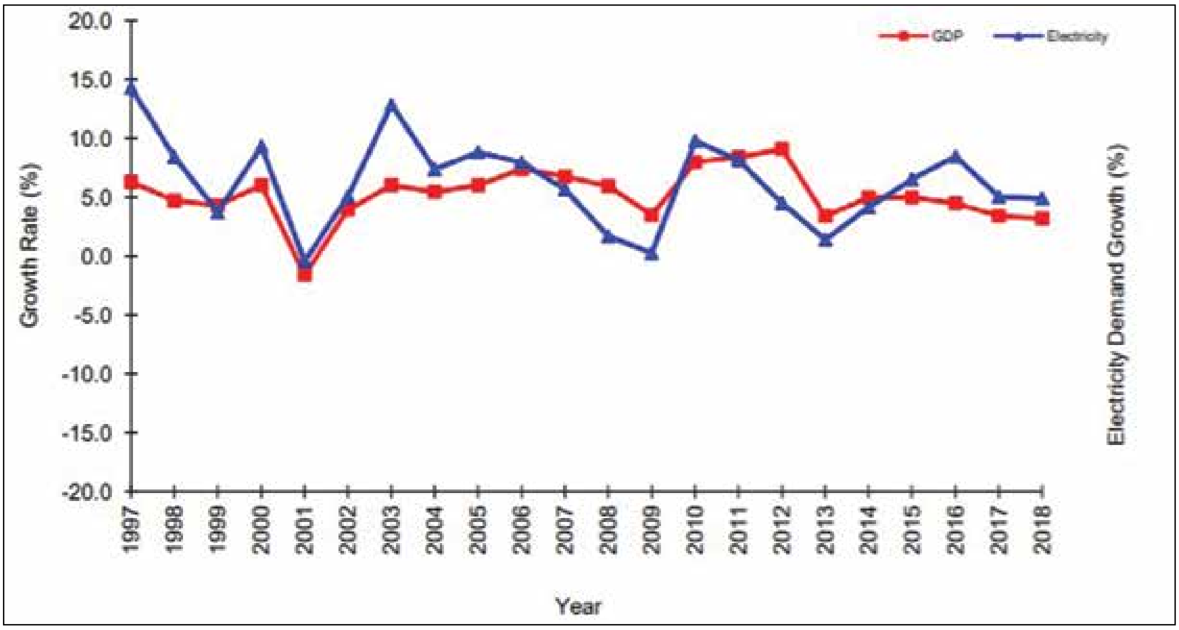


Figure 4.5 Baseline scenario for GHG emission of energy sector

4.2.1.1 Electricity Generation

Electricity demand growth rate in the past has most of the times revealed a direct correlation with the growth rate of the country's economy. Figure 4.6 shows growth rates of electricity demand and GDP from 1997 to 2018.



Source: LTGEP 2020-2039

Figure 4.6 Growth rates of GDP and electricity sales

Baseline scenario: The impacts of electricity generation on the environment is due to one or several factors including particulate emissions; gaseous emissions (CO_2, SO_X, NO_X etc.); warm water discharges into streams, rivers or sea; liquid and solid waste (sludge, ash); inundation (in the case of large reservoirs) and changes of land use. Particulate and gaseous emissions are of primary importance in the case of electricity generation using fossil fuels. During the preparation of this report, the real-time data related to GHG emissions in electricity generation up to 2015 was collected. The GHG emission trends from 2015 to 2030 was taken from the Long Term Generation Expansion Plan (LTGEP) of 2015-2034 as it had projected same using several parameters including population and GDP growth. According to the LTGEP, demand for electricity will increase from 11,516 GWh in 2015 to 25,598 GWh in 2030. The annual growth will increase from 4.1% in 2015 to 4.9% in 2030. Accordingly, electricity generation will increase from GWh 12,901 in 2015 to GWh 28,410 in 2030. In the LTGEP base case scenario, coal will be the major source of power having its share reaching 40% by 2020 and 60% by 2034. The contribution of renewable energy sourced power will increase to 40% by 2025 and then decline to 35% by 2034 (LTGEP, 2015-2034). Figure 4.7 shows the GHG emissions in the baseline scenario for electricity generation.

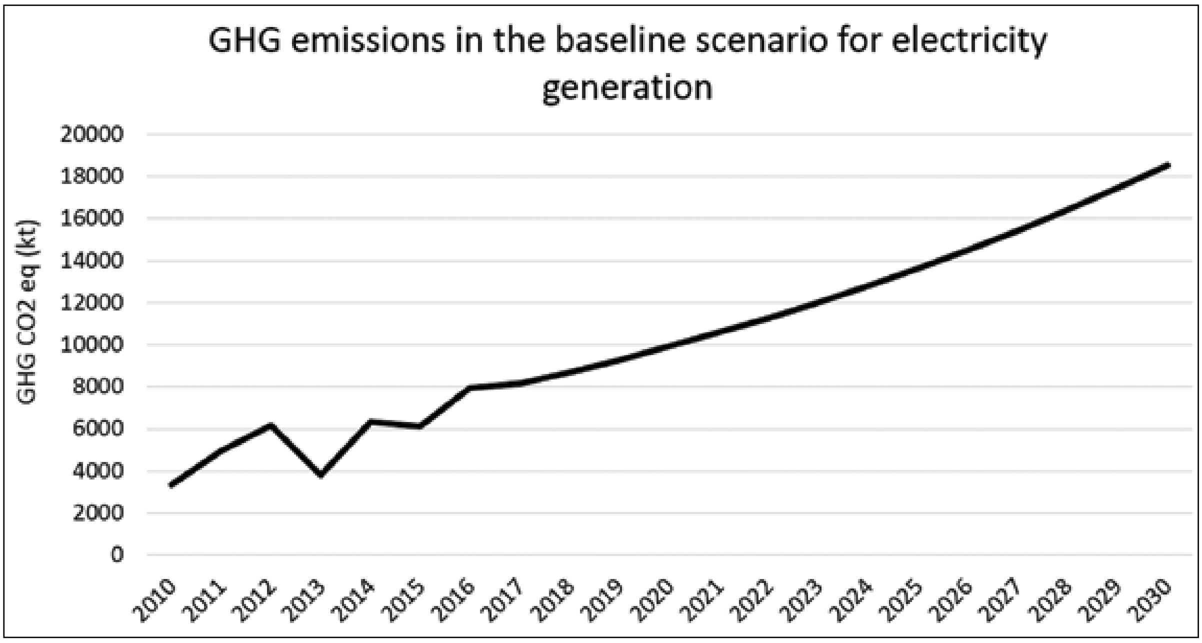
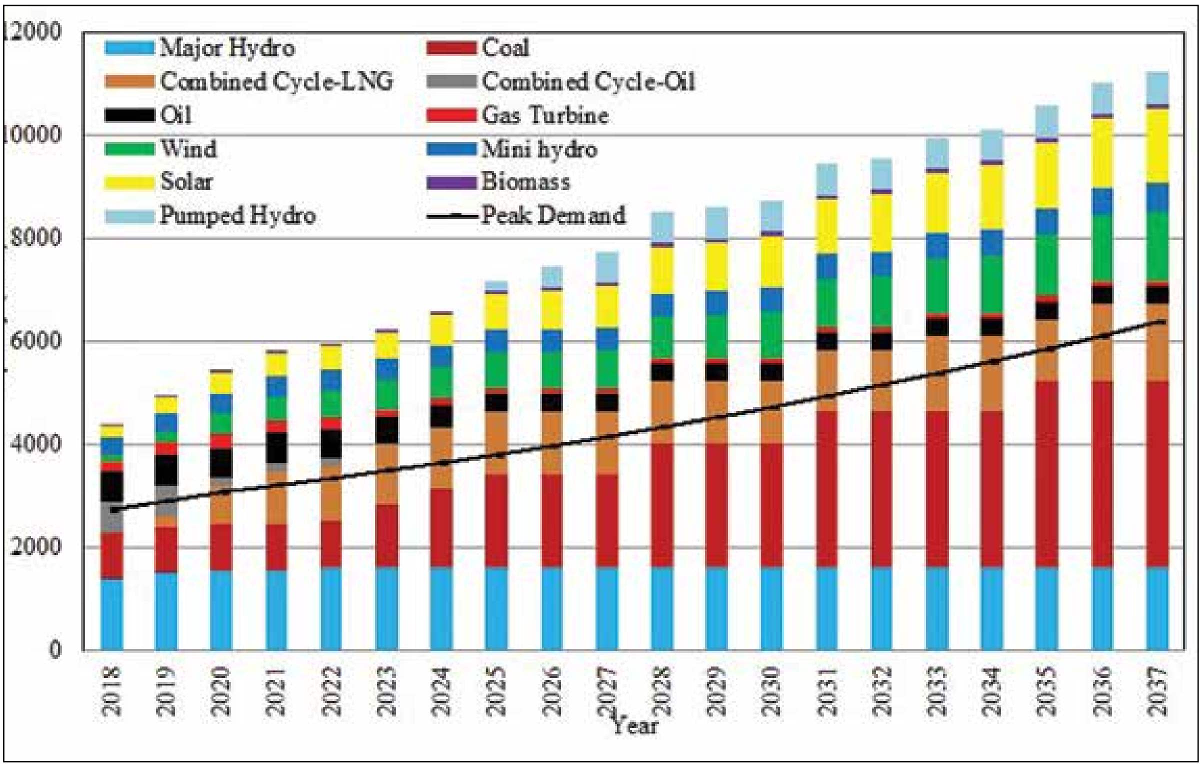


Figure 4.7 GHG emissions in the baseline scenario for electricity generation

Mitigation scenario: The mitigation scenario is based on the directions for reduction of GHG emissions by increasing the share of the renewable energy and introduction of Liquid Natural Gases (LNGs), loss reduction in electricity transmission and distribution and demand side management. According to the LTGEP (2018-2037) which was used for the development of the mitigation scenario, substitution of 4,700 MW of coal power with renewable energy sources and the introduction of LNGs (1400 MW) for thermal power generation in place of petroleum by 2030 are significant. The details of the current interventions are; (a) maximizing hydro potential in the country through the remaining large and small hydro power projects; (b) development of wind parks in the potential sites mostly in the northern and north-western coastal areas in the country for the generation of about 300 MW; (c) promotion of solar power generation of about 500 MW in different modalities (solar roof-top, solar parks etc.); and (d) a significant increase in biomass power generation.

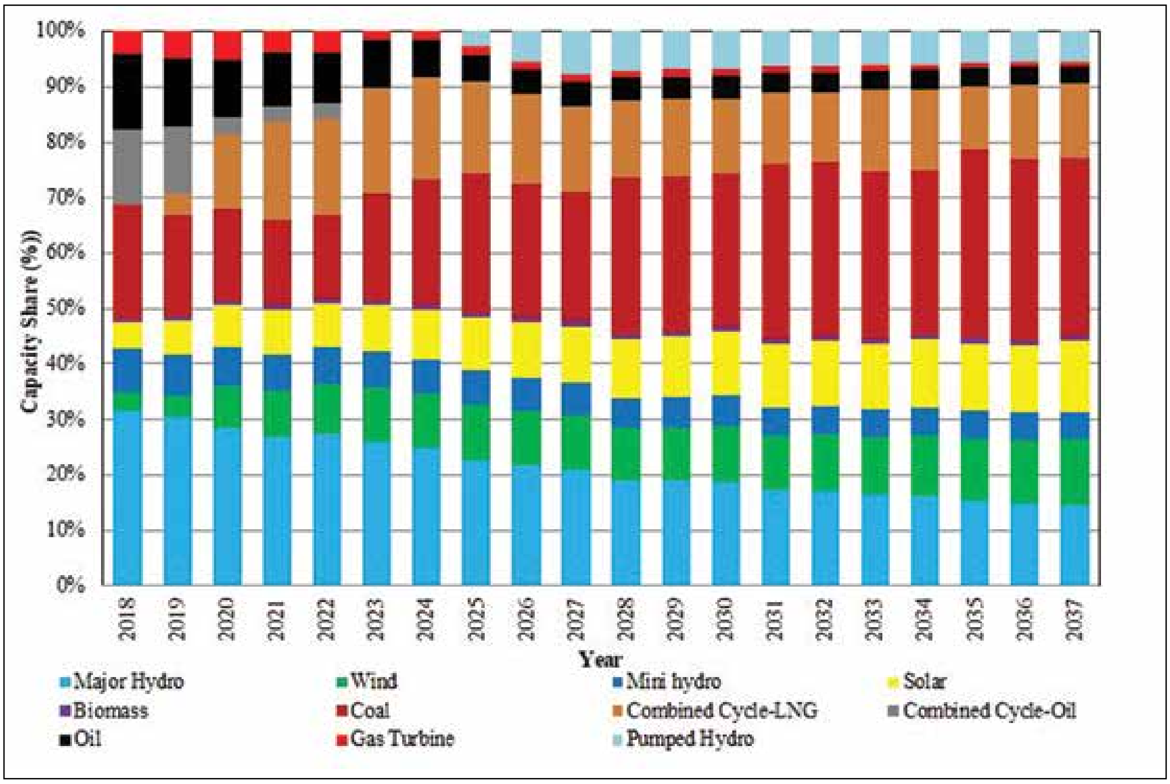
Cumulative capacity by plant type and the capacity share (%) over a period of 20 years from 2018 - 2037 are shown in Figures 4.8 and 4.9.



Source: LTGEP, 2018-2037

Figure 4.8 Cumulative capacity by plant type from 2018-2037

Sri Lanka's Nationally Determined Contributions (NDCs) submitted to the UNFCCC in 2016, enumerated targets aimed at increasing the use of renewable and sustainable forms of energy, resulting in a 20% reduction of GHG emissions (36,012 Gg) from the energy sector during the period 2020 -2030 as compared to 2010. This breaks down to 4% unconditional reduction and 16% conditional reduction. According to the LTGEP of 2018-2037, about 50% of total demand will be met by renewable sources.



Source: LTGEP, 2018-2037

Figure 4.9 Capacity share (%) of 2018-2037 period

Demand Side Management (DSM): In accordance with the International Energy Agency, the energy efficient technologies will contribute substantially towards achieving carbon neutrality by 2050 (Sri Lanka Sustainable Energy Authority - http://www.energy.gov.lk). A Presidential Task Force on energy DSM was established and nine thrust areas have been identified for assessment; efficient lighting, efficient fans, efficient motors, efficient refrigerators, energy management systems, eliminating incandescent lamps, efficient air conditioning, green buildings and efficient pumps and the likely contribution to reduce the GHGs by 2020 has been calculated to be 1,895 Gwh (www.energy.gov.lk/ODSM/odsm.html). Figure 4.10 shows the mitigation scenario drawn against the baseline scenario.

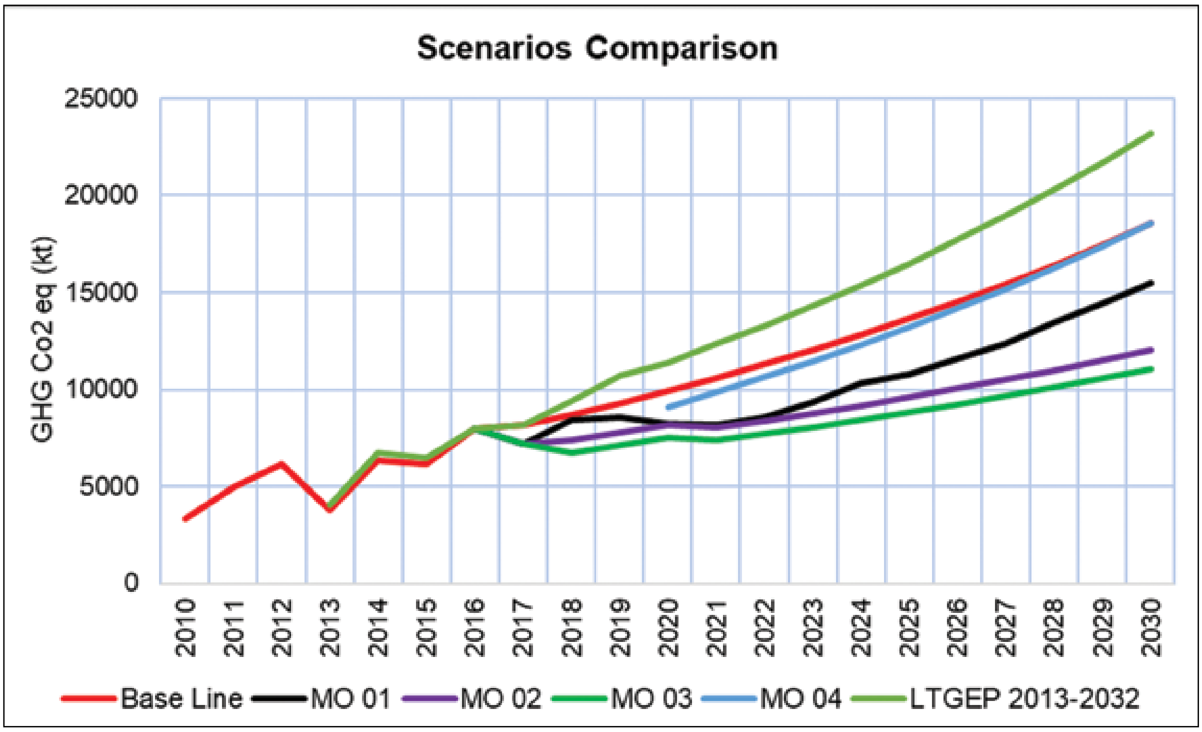


Figure 4.10 Mitigation scenarios composed against the baseline scenario

MO - Mitigation Option

MO 01: reduction of transmission loss and addition of renewables in LTGEP 2018-2037

MO 02: addition of a 1,400 MW of LNG in LTGEP 2018-2037

MO 03: 1,400 MW of LNG and DSM in LTGEP 2018-2037

MO 04: 20% emission reduction by NDCs of 2016

According to the Figure 4.10, the net saving emissions by 2030 in the mitigation scenario is 8,100 Gg CO_2-eq against to the baseline scenario.

4.2.1.2 Transport

Sri Lanka depends heavily on its public transport system with buses and trains while sea and air transport having only a limited presence. The private transport is primarily made up of cars, vans, three wheelers and motor cycles. The transport sector has played a crucial role in Sri Lanka's economic and social progress. In 2003, the sector contributed 10% of the country's GDP and generated about 4% of employment. By 2012, its contribution to GDP had increased to 14% (Department of Census and Statistics, 2015). However, the sector is also responsible for a large majority of the country's GHG emissions, about 51% of the total emissions in the energy sector are from transport (Figure 4.4). The various modes of transport prevalent in the country are discussed as follows;

(a) Road Transport

Sri Lanka road transport accounts for about 93% of the land transport. There are 12,496,337 km of A and B class roads and expressways. Over 70% of traffic in Sri Lanka uses the road network.

In 2012, the demand for passenger travel was around 80 billion passenger-kilometres (pkm) per year of which road transport accounted for 93%. About 97% of freight traffic measured in ton/km was also done by road (ADB, 2012). Therefore, roads dominate Sri Lanka's transportation landscape. There is a progressive increase of different modes of land vehicles from 2012-2016 (Table 4.2).

Table 4.2 Vehicle population of Sri Lanka from 2012-2016

Year	2012	2013	2014	2015	2016
Motor Cars	499,714	528,094	566,874	672,502	717,674
Motor Tricycle	766,784	850,457	929,495	1,059,042	1,115,987
Motor Cycles	2,546,447	2,715,727	2,988,612	3,359,501	3,699,630
Buses	91,623	93,428	97,279	101,419	104,104
Dual Purpose Vehicles	280,143	304,746	325,545	365,001	391,888
Motor Lorries	323,776	329,648	334,769	341,911	349,474
Land Vehicles - Tractors	315,520	326,292	333,362	343,339	353,624
Land Vehicles - Trailers	53,020	55,286	57,298	59,426	63,088
Total	**4,877,027**	**5,203,678**	**5,633,234**	**6,302,141**	**6,795,469**

Source: Department of Motor Traffic, 2016

According to the Table 4.2, during the period of 2012-2016, the vehicle fleet of motor cars increased by 43%. Motor tricycles (three wheelers) and motorcycles increased by 45% during this period. The increase in the bus fleet was modest at 13.6%. In terms of fuel consumption, 71.3% of the cars used petrol, 10.3% used diesel, 17.6% were hybrid cars and 0.8% were fully electric by 2016.

(b) Railways

Sri Lanka Railways with 1,450 km of track played a dominant role in passenger and freight movements in the past. Currently, it operates with only 200 diesel locomotives along with 46 diesel power sets. Despite the fact that the number of Passenger Kilometres had increased from 2010 onwards according to the Sri Lanka Railways Performance Reports.

(c) Ports

The port of Colombo is the country's main commercial port among the four major ports (Trincomalee, Hambanthota and Galle) and is considered to be one of the premier ports in Asia. After economic liberalization of Sri Lanka in 1977, the introduction of a port expansion programme, along with the onset of containerization and transhipment cargo, led to the growth of port traffic at an average rate of 6.5% per year. By 2010, port traffic in Sri Lanka had reached the equivalent of four million containers of twenty-foot equivalent units (ADB, 2012).

(d) Air Travel

Sri Lanka has 05 international airports and 11 domestic airports. The national carrier operates international routes while there are private carriers operating domestically. The civil aviation sector has shown considerable growth in recent times, through most of this growth has come from international passenger and cargo movements.

Policy and institutional environment for transport sector: The Draft National Policy on Transport in Sri Lanka (2017) set out government interventions in ensuring that existing and potential mobility needs within the country to be met safely and efficiently at least cost to the economy by using the minimum amount of resources and causing least impact on the environment. Sustainable priorities from this and other policies are summarized in Table 4.3.

The main objectives which are in support of climate change mitigation interventions in transport policy are (a) encouragement of the use of public transport, high occupancy vehicles and non-motorized transport; (b) reduction of the dependency on petroleum fuels for the country's mobility requirements; (c) reduction of vehicles circulating within urban areas in order to make a greater proportion of limited road space available for high occupancy vehicles; (d) utilization of high priority bus lanes, light transit systems (trains) or bus rapid transit (BRT) systems; and (e) provision of tax rebates for new technologies such as hybrid vehicles and new sources of fuel such as bio-fuel. The use of online platforms for e-commerce, e-education and other e-services should reduce the passenger load on the roads and railways, thus contributing to significantly reduce the GHG emissions. This would be somewhat offset by the energy requirements of digital technologies.

Table 4.3 Sustainable transport priorities based on existing policies

Pubic Modes of Transport	Large scale development and introduction of efficient public transport systems such as BRT, LRT and MRT systems leading to a modal shift from private to public modes of transportation
Alternative Vehicles	Increased adoption of electric and hybrid vehicles running on alternative fuels such as electricity, biofuels etc.
Urban Congestion and Pollution	Reduce traffic congestion and air, noise pollution in urban areas especially the Colombo Municipal Area through increased adoption of public and alternative modes of transportation
Energy Security	Achieve greater diversity of fuel sources and reduce dependence on imported sources of fuel especially petroleum
GHG Emissions	Reduce GHG emissions from the transport sector through the adoption of alternative clean fuel vehicles and public modes of transport, decreasing its reliance on fossil fuels

Baseline scenario: The data from 2010-2015 were collected for setting the baseline scenario for transport sector. These data were extrapolated to the year 2030. The Figure 4.11 shows the baseline GHG emissions in transport sector (road and railways only) projected from 2010-2030.

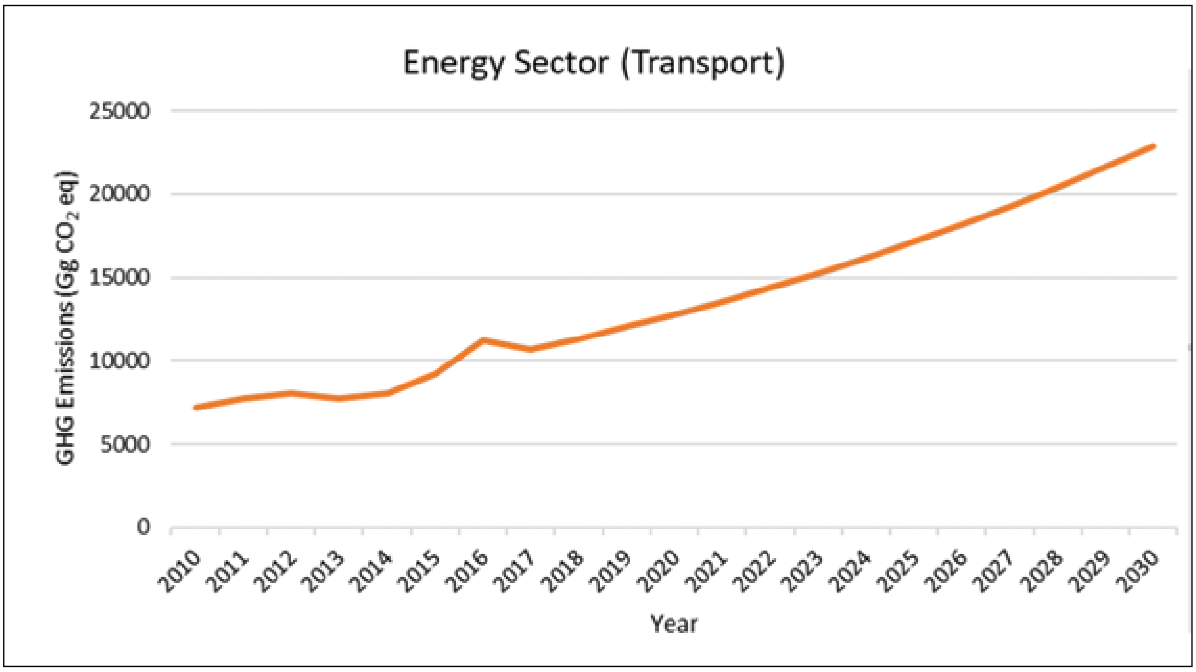


Figure 4.11 Baseline GHG emissions in transport sector from 2010 - 2030

Mitigation Scenario: The NDCs of Sri Lanka submitted to the UNFCCC in 2016 includes the activities that could be undertaken to reduce GHG emissions in the transport sector. They are (a) avoidance/reduction of journeys; (b) modal shift; (c) improvement of energy efficiency of modes of transport and vehicle technologies; and (d) fuel improvement. Among these, a greater emphasis was placed on the modal shift to increase the share of public transport which is supported by policies and action plans. The public transportation contributions to the entire transport sector is about 55% in 2020. It is expected to decrease to 47% by 2030 in the base case (Megapolis Transport Masterplan, 2016). However, in the mitigation scenario which is designed taking into consideration, the road and rail modes of transport are drawn on the premise that public transport share would increase to 62% by 2030 through the interventions mentioned above. An emphasis is also placed on efficiency improvements in new vehicles using improved fuel which emit fewer GHGs. The GHG emissions of approximately 81g CO_2/passenger km is expected to be reduced to 73g CO_2/passenger km. The more specific and detailed actions to be taken are as follows;

(i) Urban transport system development for Colombo Metropolitan Region and Suburbs (COMTrans) taking into consideration the transport corridors, high transport volumes, urbanization level, population density and network functions as envisaged in the JICA Transport Plan for COMTrans projected up to 2035.

(ii) Preparation and operationalization of Transport Nationally Appropriate Mitigation Action to introduce electric buses for the Galle Road Bus Rapid Transit.

(iii) Megalopolis and Western Development Master Plan where proposed interventions in the Plan would improve transportation and thus reduce GHG emissions in the long run. This entails: (a) more flexible working hours; (b) vehicle parking management; (c) intersection control; (d) traffic flow management; (e) public transport improvement; (f) restructuring public bus service; (g) modernization and improvement of the quality of the buses and services; (h) improvement of office and school bus services; (i) regulation and improvement of door-to-door taxi service; (j) development of multi modal transport hubs; (k) railway electrification and modernization; (l) new rapid transit systems; (m) introduction of new water transit system in inland water ways; (n) capacity improvement by development of road links; (o) capacity improvement in existing expressway network; (p) improvement of walkability in roads; (q) intersection controls to reduce vehicle emissions; (r) construction of new expressways; (s) encouraging bicycle use for travelling; (t) increase of electric vehicle rapid charging centres; (u) encouraging the use of electric vehicle through tax incentives offered; and (v) encouraging online services such as e-commerce, e-education and other consumer services which reduce vehicles on the roads and railways.

Figure 4.12 shows the GHG emissions in the mitigation scenario which has taken into account the modal shift to public transport, efficiency improvement of fuel types, use of electrical and hybrid vehicles, and reduction of the use of transport compared with the baseline.

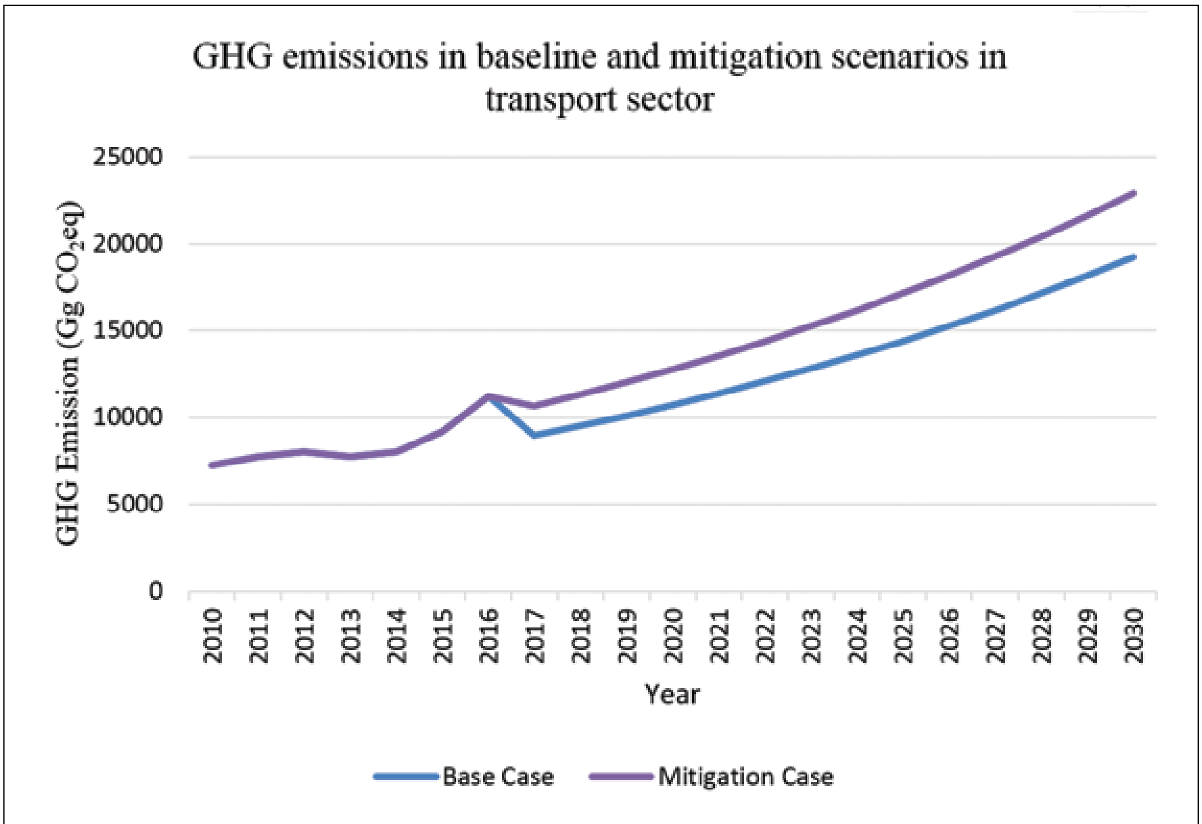


Figure 4.12 Projected GHG emissions baseline and mitigation scenarios

According to the Figure 4.12, the net saving in the emissions by 2030 in the mitigation scenario is 3,668 GgCO_2-eq compared with the baseline scenario.

4.2.1.3 Household, Commercial and Manufacturing Industries

Baseline: Industrial production growth in Sri Lanka averaged 5.24% from 2004 until 2017, reaching an all-time high of 35.2% in July 2010 and a record low of 11.4% in April of 2016. Of the types of industries, manufacturing of food products (35.2%) and wearing apparels (19.8%) were significantly greater than rest of the groups. The minimum contribution to the production index comes from manufacturing of leather and related products (0.3 %) from 2010-2015. The share of different types of industries, as measure of index of production from 2010-2015 is shown in the Figure 4.13.

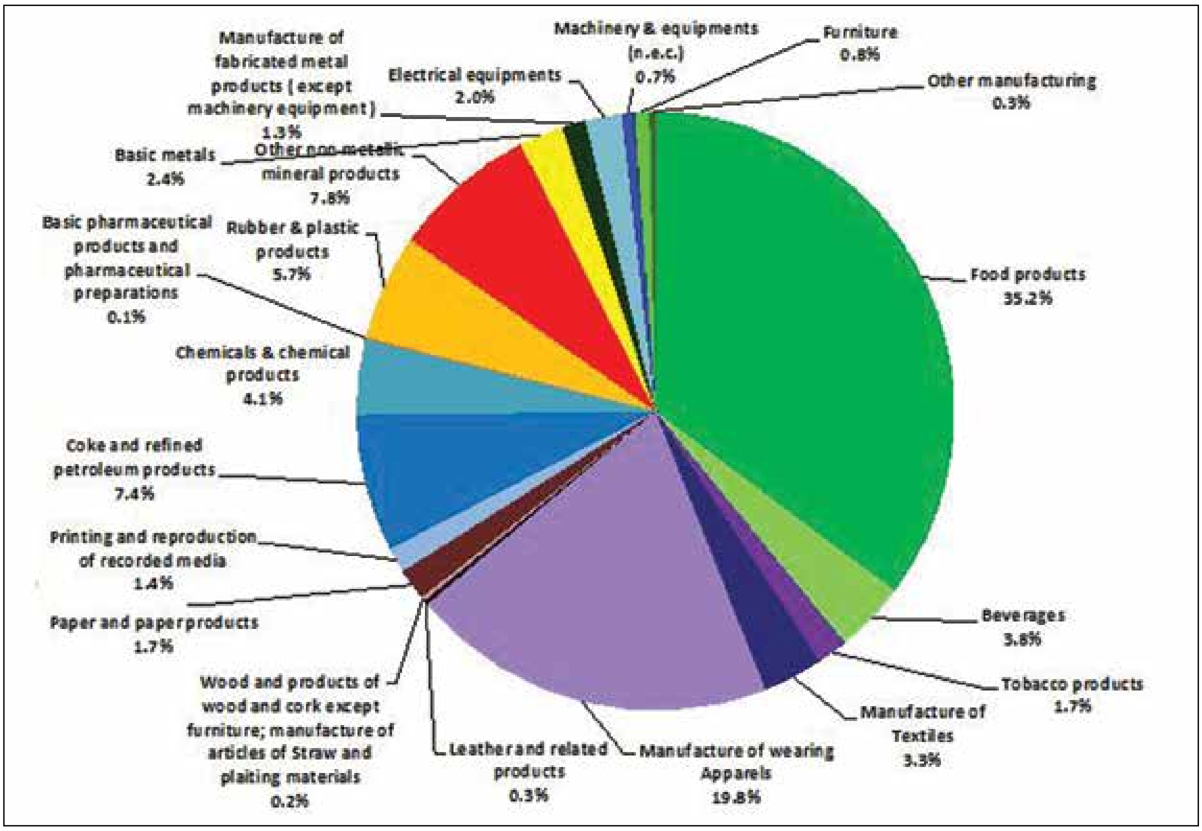


Figure 4.13 The share of industries as a measure of index of production, 2010-2015

In industry sector, there had not been any regulatory action for the reduction of GHG emission rather than on voluntary basis. Later on, the following actions have been taken with a view to enhance the standards of the sector and also to reduce GHG emissions such as consolidation of cleaner production in industries, establishment of eco-industrial parks, ISO certification of industries, and introduction of National Green Reporting System (NGRS) etc. Energy labelling had been proceeded with single appliance i.e. CFL bulbs. Sector specific energy consumption benchmarks were prepared for certain sectors based on limited sample studies.

The NGRS was introduced by the Ministry of Environment with the objective to facilitate the manufacturing and service sector to periodically measure and report their sustainability performance with respect to economic, environment and social aspects in order to continually improve their production policies and services, relationship with stakeholders and enhance their image while contributing towards the sustainable development in the country.

Baseline scenario: The data from 2010-2015 were collected for setting the baseline scenario for this sector. These data were extrapolated to the year 2030. It was assumed that the activities proposed in the Haritha (Green) Lanka Action Plan and its products including consolidation of cleaner production in industries, fuel switching and use of efficient motors where applicable and certification of industries, have been considered. Figure 4.14 shows the baseline scenario up to 2030.

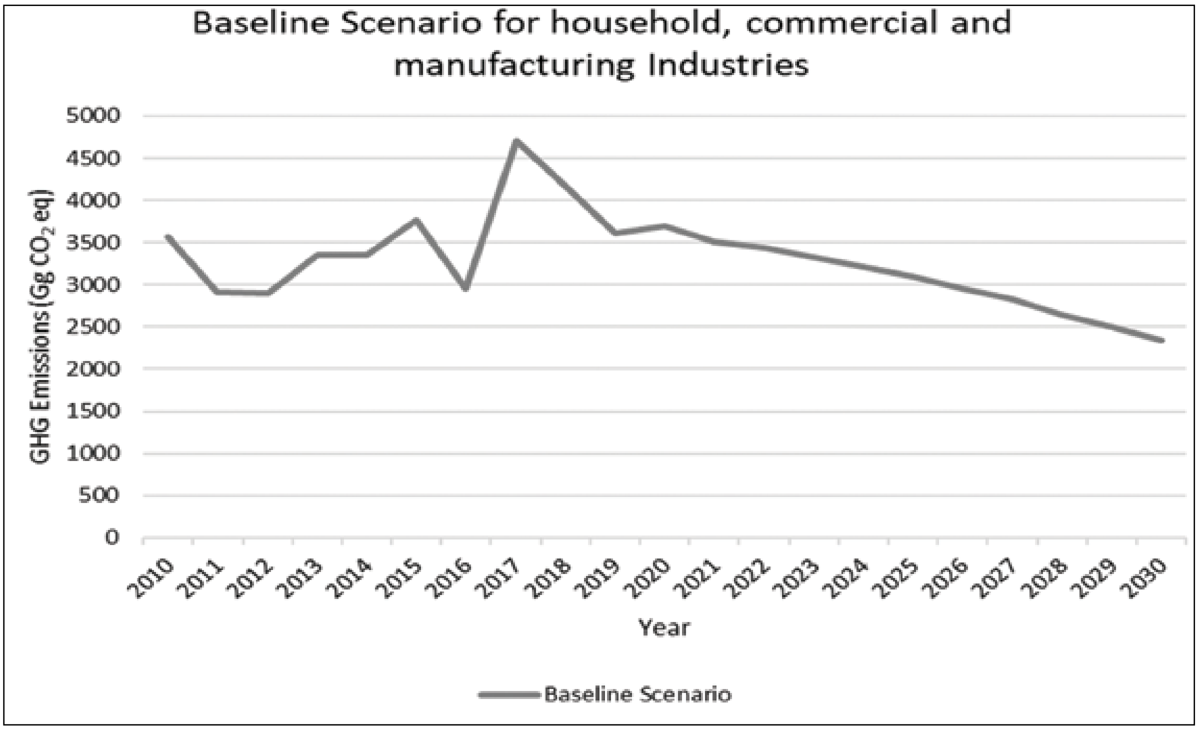


Figure 4.14 Baseline scenario for household, commercial and manufacturing industries

Mitigation scenario: The mitigation scenario was developed based on the assumption that the proposed NDCs submitted by Sri Lanka to the UNFCCC in 2016 will be implemented during the period 2020-2030.

The NDCs for industrial sector include modernizing and facilitating industries to follow recognized standards for GHG emission reduction i.e. environmental management systems; fuel switching; improvement of industrial energy, water and raw material efficiency; application of eco-efficiency and cleaner production; greening the supply chain; introduction of high efficiency motors; etc. In addition to the above, switching into cleaner fuel sources such as LPG and applying ISO 50001 for energy management systems were considered.

Figure 4.15 shows the mitigation scenarios in household, commercial and manufacturing industries against the baseline scenario for the period of 2010-2030.

4.3 Industrial Processes and Product Use (IPPU) Sector

According to the UNFCCC categorization, IPPU category includes mining industry, chemical industry, metal industry, non-energy products from fuels and solvent use, electronic industry, product uses as substitutes for ozone depleting substances, and other product manufacture and use. In Sri Lanka, the cement industry, lime industry, brewing, refrigerant replacement and refinery improvement have been selected under this category.

Baseline scenario: As per the GHG Inventory in this report, the IPPU sector contributes to 2% of the total emissions of the country. Cement and lime production are the major contributors to the IPPU sector and it is a share of 74%. In the construction of the baseline scenario, the data on cement and lime industries from 2010-2015 were taken and extrapolated to 2030 based on population growth, GDP and other trends in the industry. Figure 4.16 shows the baseline scenario in this sector.

Mitigation scenario: The mitigation scenario for the IPPU sector which is mainly focused on clinker production, is mitigated by two main approaches: reduction of clinker content in cement by using additives, such as fly ash and slags, and reducing the content of cement in the final application by replacing a portion of cement with suitable substitutes. The main cement manufacturer in Sri Lanka uses around 4,000 MT of sorted non-recyclable polythene fraction of the Municipal Solid Waste in 2020 in its cement kiln which is called co-processing and it is hoped to increase this to 12,000 MT by 2022. A further increase of 10% is expected by 2030.

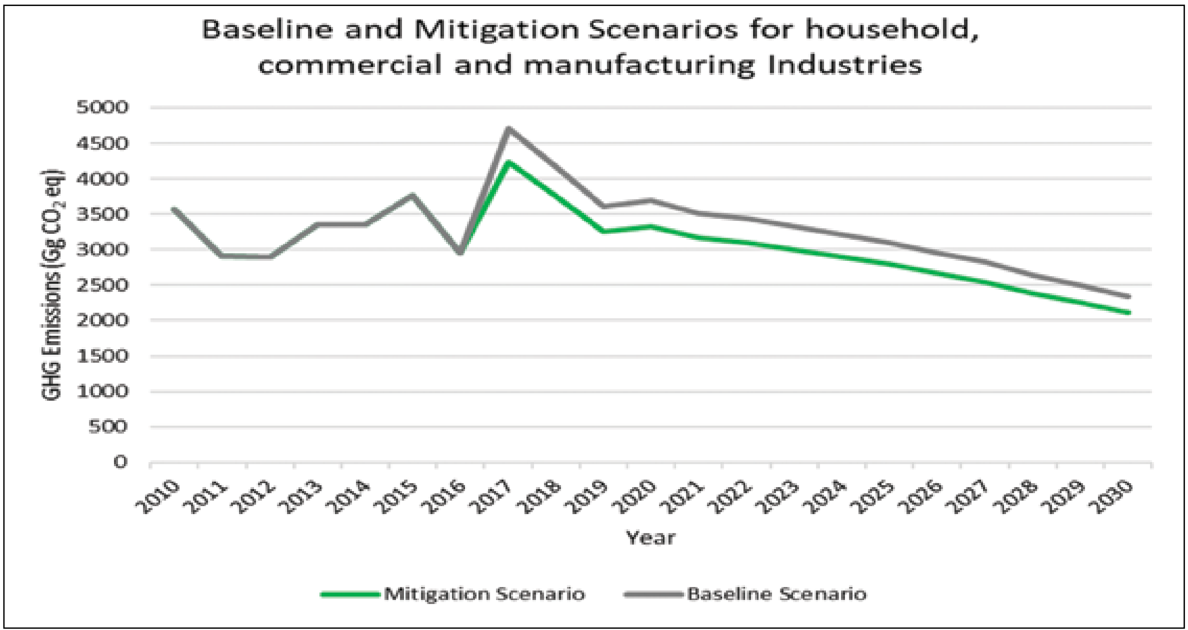


Figure 4.15 Baseline and mitigation scenarios in household, commercial and manufacturing industries

According to the Figure 4.15, the net saving GHG emissions by 2030 in the mitigation scenario is 342 Gg CO_2-eq compared with the baseline scenario.

In 2018, 100,000 tonnes of fly ash was used as a substitute to clinker by cement producing company in Sri Lanka. Though the company wants to increase the use of fly ash usage, the limitation in supply of fly ash hinders its efforts to further reduce the GHG emission. For the mitigation scenario, it is assumed that the proposed coal power plants for the power generation will provide additional fly ash for the clinker production facility in 2024. Hence, the GHG emission would be reduced by 5% from the baseline scenario.

At present, the addition of steel slag is mainly done form cement manufactured using imported clinker. This is due to the fact that the slag has to be imported and its use in mixing facilities near the ports is more economical than transporting to the local clinker producing facility. It is assumed that the use of the slag in the clinker producing plant will result in a further reduction of 5% of GHG emissions from the baseline scenario. Accordingly, a total of 11.8% GHG emission reduction from IPPU sector (10% from clinker production and 1.8% from other industry categories) could be projected in the mitigation scenario, as shown in Figure 4.17.

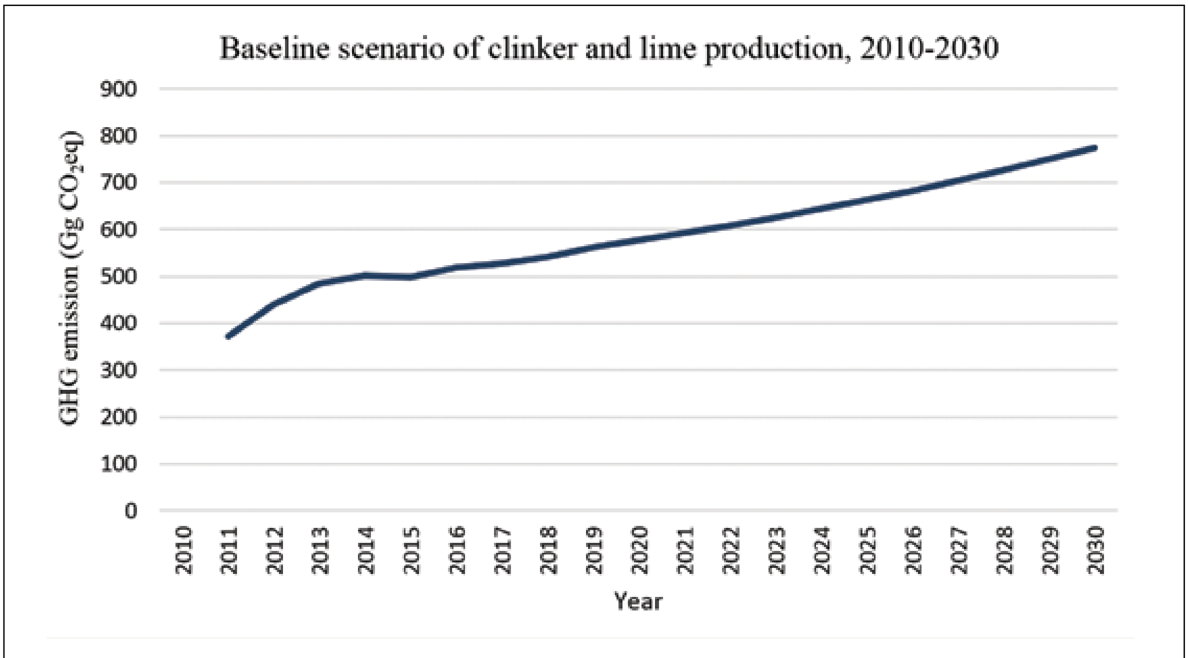


Figure 4.16 Baseline scenario of clinker and lime production, 2010-2030

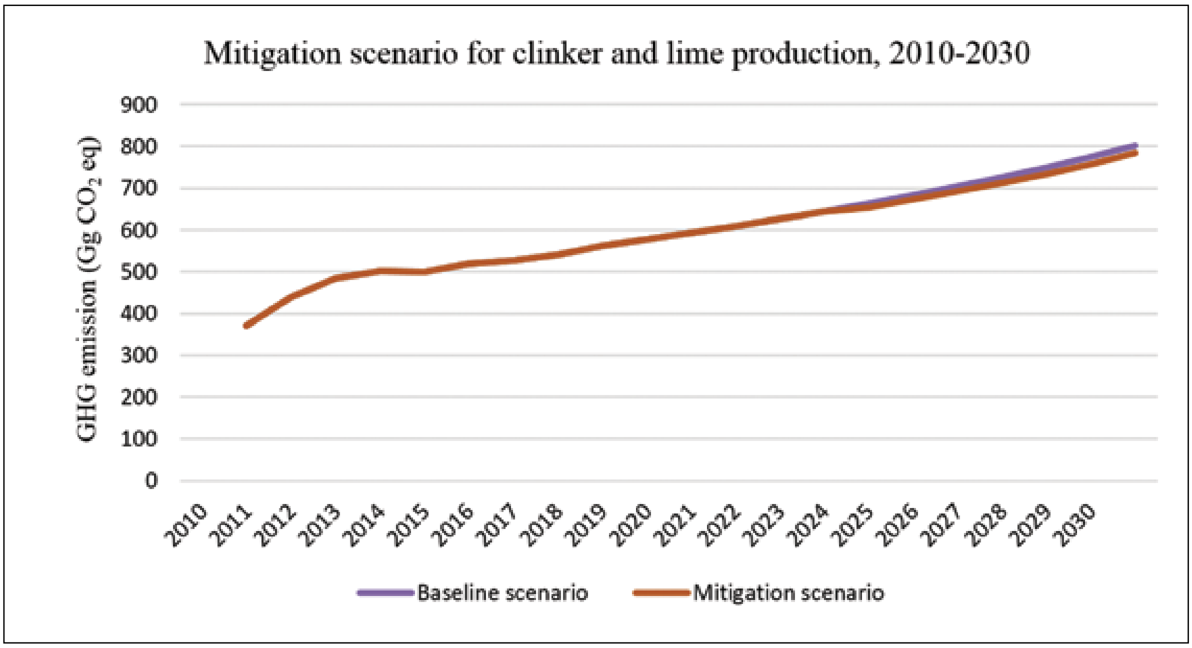


Figure 4.17 Mitigation scenario from clinker and lime production, 2010-2030

According to the Figure 4.17, the net saving GHG emissions from IPPU sector by 2030 in the mitigation scenario is 85 Gg CO_2-eq compared with the baseline scenario.

4.4 Waste sector

Municipal Solid Waste (MSW) generation in Sri Lanka is around 6,500 to 7,000 Mt/day and half of which (3,500 Mt/day) is collected (Mannapperuma, 2017). Western Province accounts for 59% of the country's MSW generation and the other eight provinces contributed the remaining 41% into the total waste generation as at 2017. In general, the composition of biodegradable waste in the country is around 57.6% of MSW, i.e. a relatively high organic composition. The daily waste generation in the Western Province is expected to be 3,583 Mt and 4,073 by 2020 and 2030 respectively.

There are about 112 compost facilities at present in the country and the total processing capacity of them reached 542 tonnes/day resulting from the *Pilisaru Project* and supported by the National Solid Waste Management Support Centre (Ministry of Local Government and Provincial Councils, 2018). The Western Province has 21 compost plants and the remainder are spread over other eight provinces.

Health care waste generation, primarily from hospitals consists of hazardous as well as non-hazardous waste and amounts to 25 Mt/day. Health care waste management is outsourced to a private company while small scale incinerators and metamizers (a hybrid autoclave technology) are operated in hospitals scattered around the country.

The National Water Supply and Drainage Board (NSWDB) operates 10 common commercial waste water treatment plants located in the Export Promotion Processing Zones and 11 common household waste water treatment plants elsewhere in the country. It had planned to cover 3.5% of households in the country in its pipe-borne sewerage facilities by 2020. Waste water discharge by industries is regulated by the National Environment Act No. 47 of 1980.

Baseline scenario: The GHG emission of the waste sector is expected to increase from 854 Gg CO_2-eq/yr and 123 Gg of fossil CO_2 in 2010 to 1,340 Gg CO_2-eq/yr and 175 Gg of fossil CO_2 in 2030. Methane and Nitrous Oxide emissions from human sewage were calculated based on population growth in Sri Lanka and the protein consumption factor of 26.93 kg per capita per year. The baseline scenario was constructed extrapolating the GHG emission data collected from 2010-2015 based on population growth and GDP up to 2030. The current trends in waste management including open dumping, recycling and composting were taken into consideration in this context. Figure 4.18 shows the baseline scenario in the waste sector.

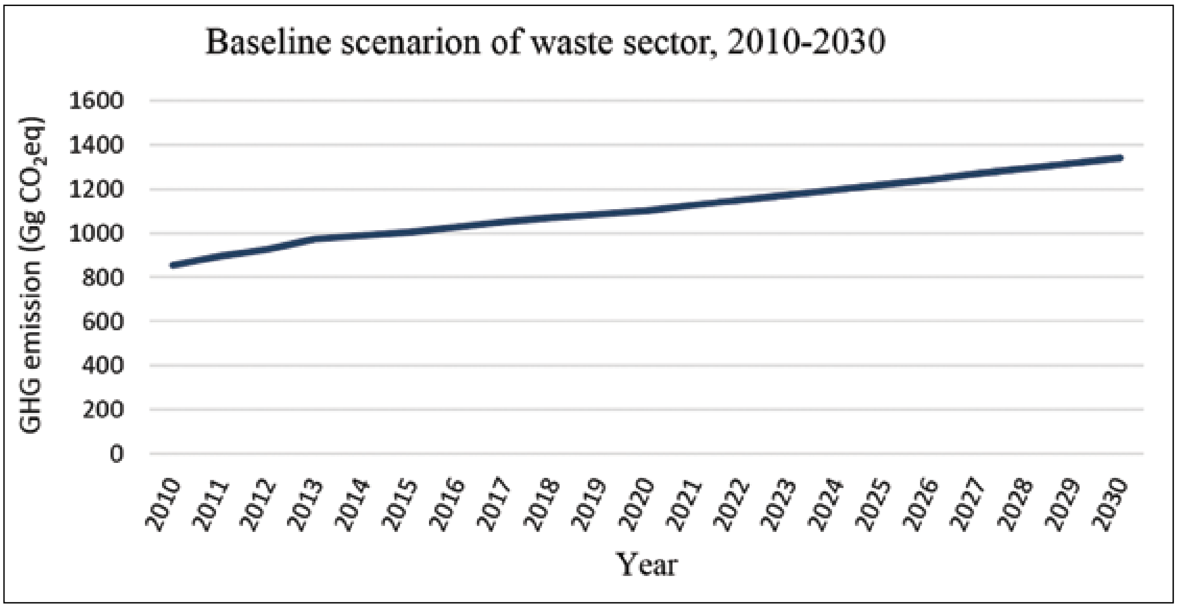


Figure 4.18 Baseline scenario of GHG emission in waste sector

Mitigation scenario: The NDCs for the waste sector include introducing source separation system at the household level and improved SWM collection; improving composting for each local authority and increasing organic fertilizer for agricultural purposes by providing facilities to control quality and stimulating a market for produced compost; introducing energy generation from waste (waste to energy programmes); improving waste collection by designing and implementing comprehensive solid waste management strategies for 40% - 60% Local Authorities by 2030; monitoring of waste management activities; and system management of industrial / hazardous and clinical waste. The 3R system (Reduce, Reuse and Recycle) should be introduced to all Local Authorities along with improved composting facilities in Local Authorities where the waste collection is below 30Mt/day. In areas where waste collection is more than 30 Mt/day, technologies such as incinerators, waste-to-energy systems and mechanically operated composting systems were also identified.

With the current solid waste generation pattern mentioned above, a significant increase is shown from 2020-2030. Therefore, the Waste Management Authority of Western Province (WMAWP) prepared targets for MSW treatment and disposal in the Western Province for the period of 2016 to 2020. The Plan anticipated disposing 83% of waste in landfills, 9% in compost preparation and 8% totally recycled. Updated targets for MSW treatment and disposal in the Western Province (2017-2023) are given in Figure 4.19.

According to the Master Plan, open dumping of waste in the Western Province will be significantly reduced and waste will be collected in mass disposal enclosures in Local Authorities, with some used for waste-to-energy projects.

In parallel to the Master Plan, two new compost facilities will be established with solid waste processing capacities of 100 Mt/day and 350 Mt/day at Karadiyana and Muthurajawela respectively. The Ministry of Provincial Councils and Local Government is planning to establish Kawashima (aerobic, screw type) composting facilities, each with a capacity of 50 Mt/day in all provinces. All these projects are considered in the mitigation assessment of the waste sector. The commissioning of composting plants at Karadiyana, Muthurajawela and all provinces could reduce GHG emission by 1,029 Gg CO_2-eq over the period of 2020 to 2030.

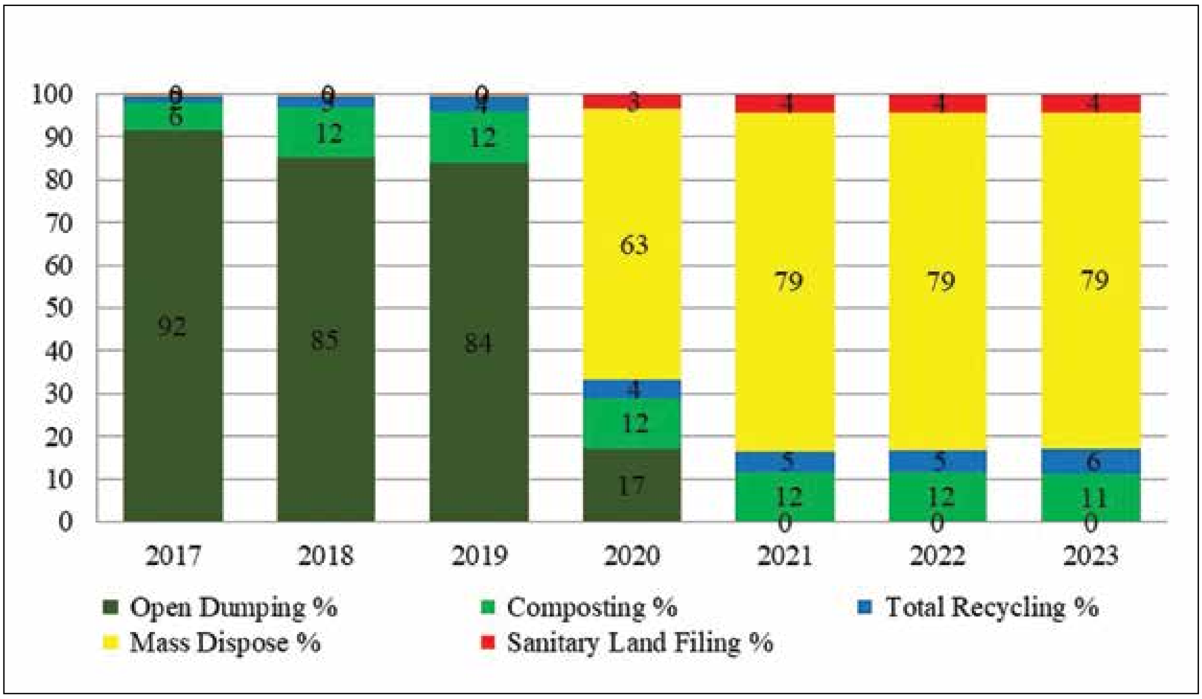


Figure 4.19 Targets for MSW treatment and disposal in Western Province as per Master Plan of WMAWP for the period of 2017-2023

Waste-to-energy projects proposed in the Master Plan of WMAWP have the potential to reduce GHG emissions by 4,780 Gg CO_2-eq/yr during the period of 2020-2030. Further, waste-to-energy projects proposed have the capacity to reduce GHG emission by 2,448 Gg CO_2-eq/yr from each. The total GHG emission reduction potential from above activities proposed for solid waste sector is therefore, 7,708 Gg CO_2-eq/yr in 2030.

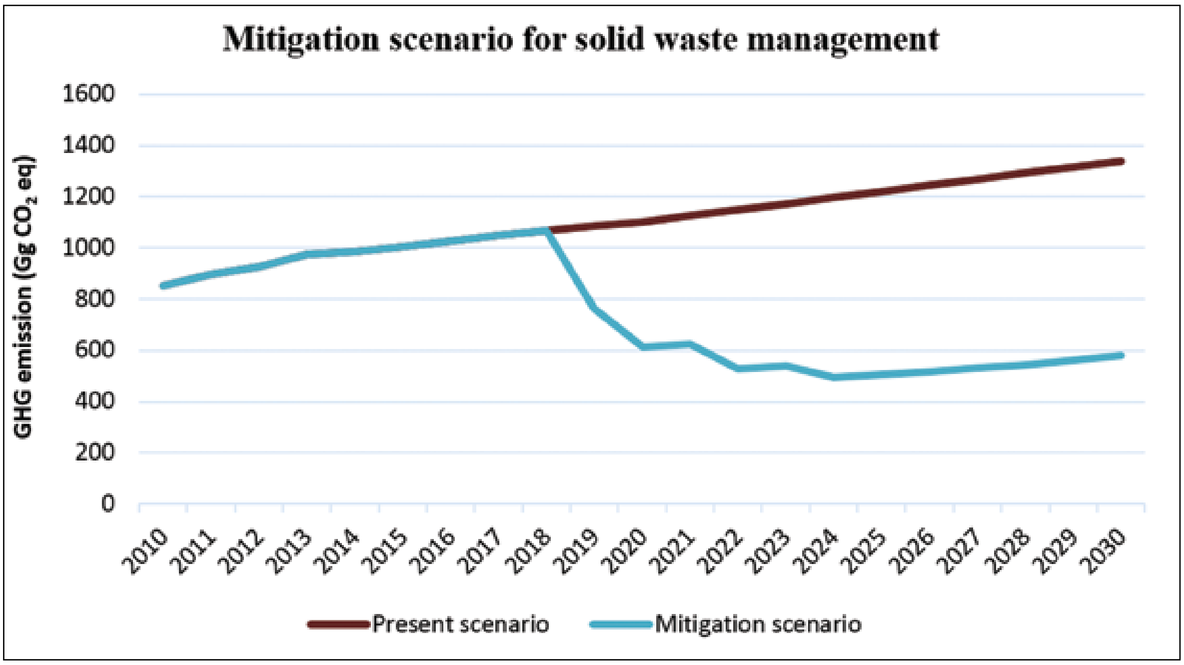


Figure 4.20 GHG emission in solid waste sector (Gg CO_2-eq/yr) under baseline and mitigation scenarios

4.4.1 Waste water

Domestic waste water emitted 472.83 Gg CO_2-eq in 2010. It is assumed that 25% of septic tanks would be converted to bio-energy pits by 2030 in urban and semi-urban areas of the country where waste collection is carried out. Further, it is proposed that organic waste generated from these households would also be utilized in bio-energy pits. New regulations are required to accommodate bio-energy pits in the country in the future instead of domestic septic tanks.

With regards to GHG emissions, it is envisaged that approximately 30% of emissions could be reduced by the proposed activity compared to the GHG emission in 2030 under baseline scenario. Further, Nitrous Oxide generation will be avoided through anaerobic digestion of organic waste from households. The sludge resulting from the anaerobic digestion could be utilized as a soil fertilizer. The conversion of septic tanks into bio-energy pits is having the potential to reduce GHG emissions by 1,468 Gg CO_2-eq during 2020-2030. Figure 4.21 shows the GHG emissions reduction from conversion of domestic waste water tanks into bio-energy pits.

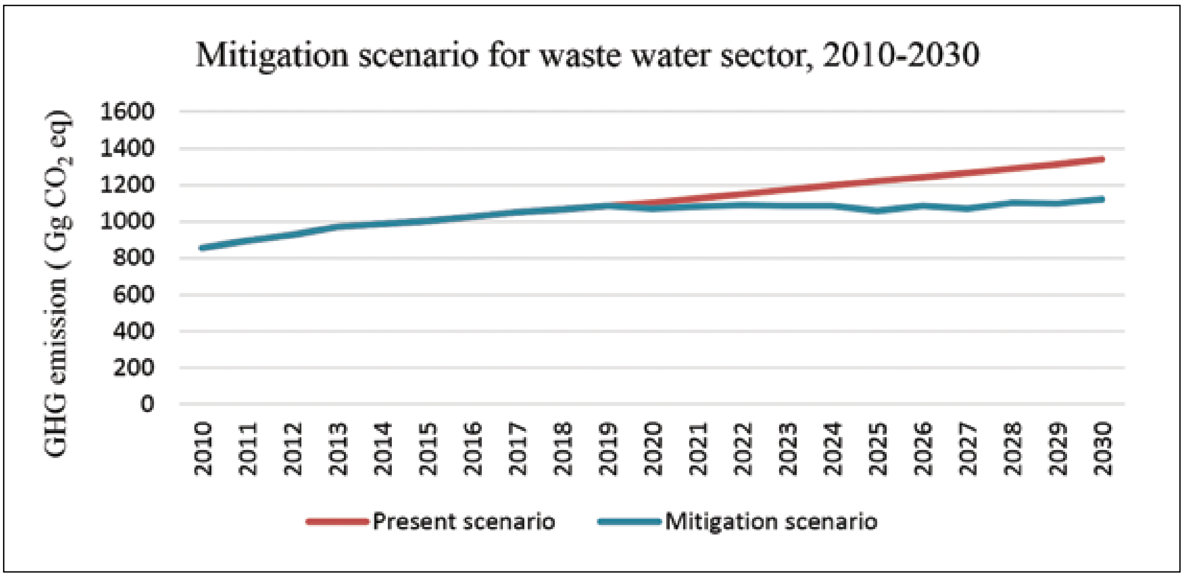


Figure 4.21 GHG emission in waste water sector under present (baseline) and mitigation scenarios

The total net saving in the waste sector under baseline and mitigation scenarios is shown in Figure 4.22.

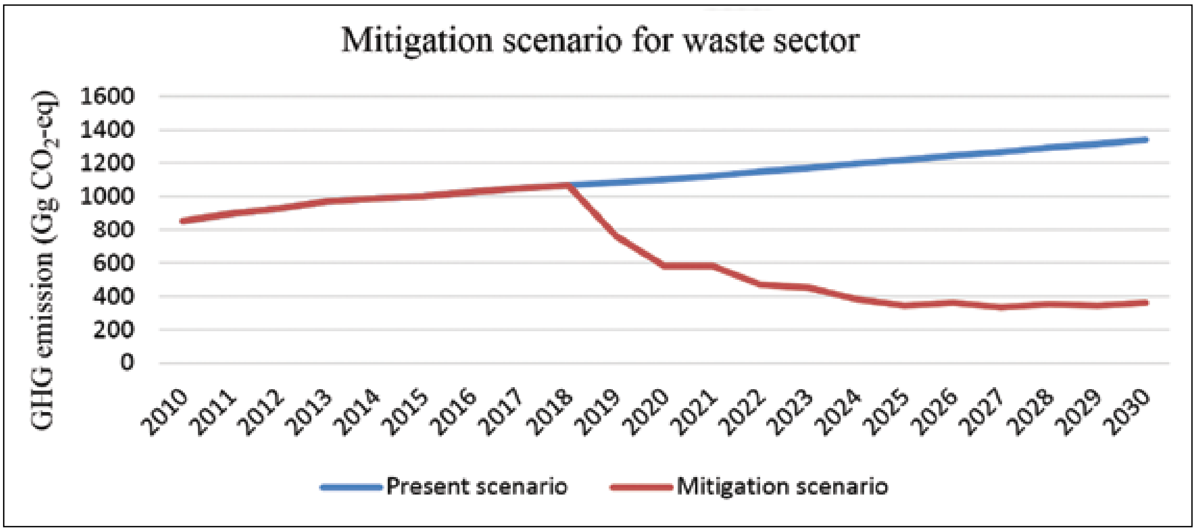


Figure 4.22 GHG emission in waste sector under baseline and mitigation scenarios

According to the Figure 4.22, the net saving in the emissions in 2030 in the mitigation scenario is 974 Gg CO_2-eq compared with the baseline while total GHG emission reduction is 9,176 Gg CO_2-eq for the period of 2020 to 2030.

4.5 Agriculture, Forestry and Other Land Use (AFOLU) sector

4.5.1 Agriculture sector

Agriculture sector consists mainly of crop and animal production systems. Total annual extent under paddy cultivation for both seasons *Yala* (South West monsoon) and *Maha* (North East monsoon) has been a range of 1.0 -1.2 million ha. However, cultivated extent during 2016 and 2017 was reduced greatly due to drought conditions. The paddy cultivated areas as a percentage is 58% in the dry zone, 22% in the wet zone and 20% in the intermediate zone.

Cattle, buffaloes, swine, and poultry dominate the animal husbandry in the country. The demand for livestock is on the increase. Hence, livestock-based GHG emissions can also be expected to grow up.

Baseline scenario: Paddy cultivation and livestock farming contributed significantly to the GHG emissions in the agriculture sector. The area of 949,800 ha is of rice cultivation in 2010 and it has progressively increased to 1,097,000 ha in 2018 and is projected to increase to about 1,338,000 ha by 2030. With regards to the GHG emissions from rice cultivation, it showed an increase from 1,250 Gg CO_2-eq in 2010 to 1,335 Gg CO_2-eq in 2015 (the average GHG emission rate in CO_2-eq is 1.45/ha). With regards to the livestock, the population of dairy cattle, poultry and swine can be considered as significant. Livestock comprising of cattle, buffalo, swine and poultry had increased in numbers from 15,694,425 in 2010 to 18,225,080 in 2015 (DCS, 2015).

Baseline scenario was constructed only for the rice cultivation up to 2030 based on the trends in population increase and GDP. Figure 4.23 shows the baseline scenario for the GHG emissions in rice cultivation from 2010 to 2030.

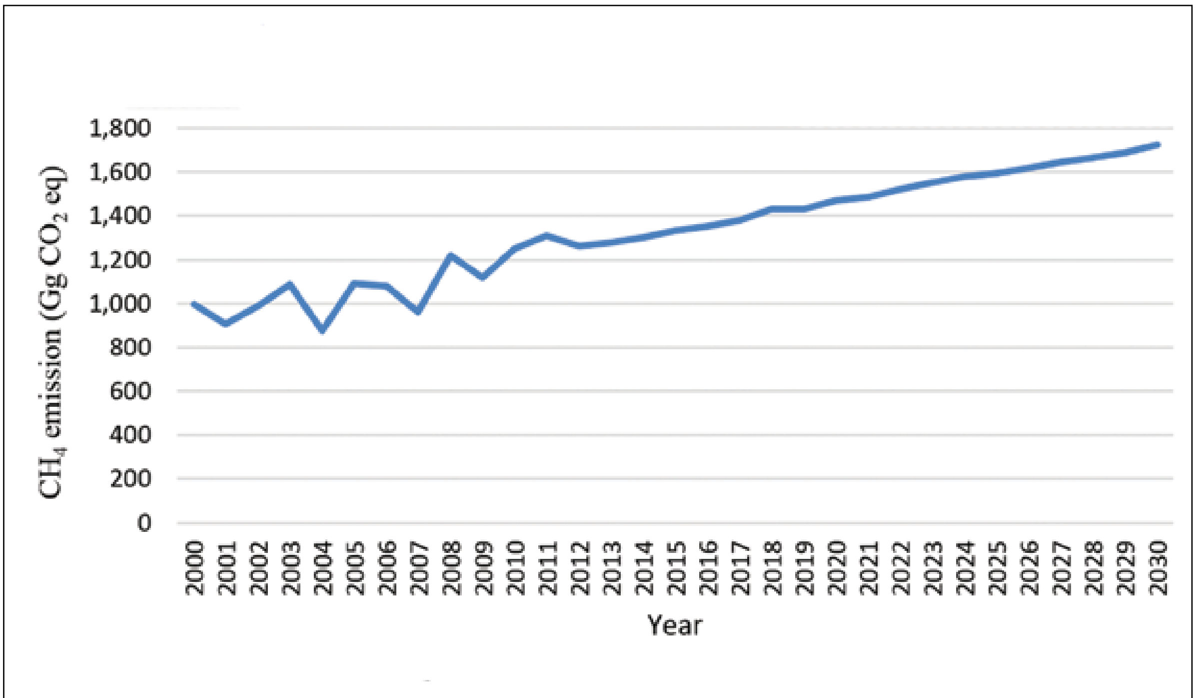


Figure 4.23 GHG emissions of rice cultivation in baseline scenario, 2010-2030

Mitigation scenario: In the presence of climate vulnerability, the country's future food requirements, productivity variation and changes in the cost of production in different macro-climatic regions etc. will also change in the future. In response to these future changes, agriculture experts' opinion implies a reduction of the area under rice cultivation by about 10% (0.9 million ha) or setting aside part of that land previously hitherto restricted to rice cultivation for higher-value-priced crops such as maize, soya beans, mung beans, etc. Agriculture development plans also intend to use fertilizer more efficiently and effectively, thus curtailing the emissions of GHG as Nitrous Oxide. In view of the above intended mitigations, at least two mitigation scenarios can be emulated;

(a) Mitigation scenario 1: This has been developed to relegate rice cultivation to only high potential areas/ seasons, e.g. focus on rice cultivation during the *Maha* season when water is plentiful and shift to higher-value crops in the *Yala* season when water is scarce. With the required productivity improvements such as efficient application of fertilizer and other technological enhancements, the expected rice demand can be met. The expert assumptions are that emissions will be reduced by 5% by 2030 due to increased productivity and decreased cultivated area.

(b) Mitigation scenario 2: Mitigation scenario 2 incorporates improved efficiency of fertilizer use for rice cultivation with improved farming techniques. Taking the recent trends into account, the Department of Agriculture plans to reduce inorganic fertilizer use in paddy cultivation by 10-15% and introduce site-specific fertilizer recommendations as well as the use of leaf colour charts for fertilizer need assessment, promoting the use of compost approach and improved fertilizer types. It is also expected that the application of the 4R (right combination, right rate, right time, and right placement) will reduce GHG emissions. In this scenario, it is assumed that the urea application in rice cultivation will be reduced by 12.5% by 2030 compared to current rates (2016) and the emissions from rice cultivation will be reduced by about 10%. Figure 4.24 shows the two mitigation scenarios in rice cultivation compared to the baseline scenario.

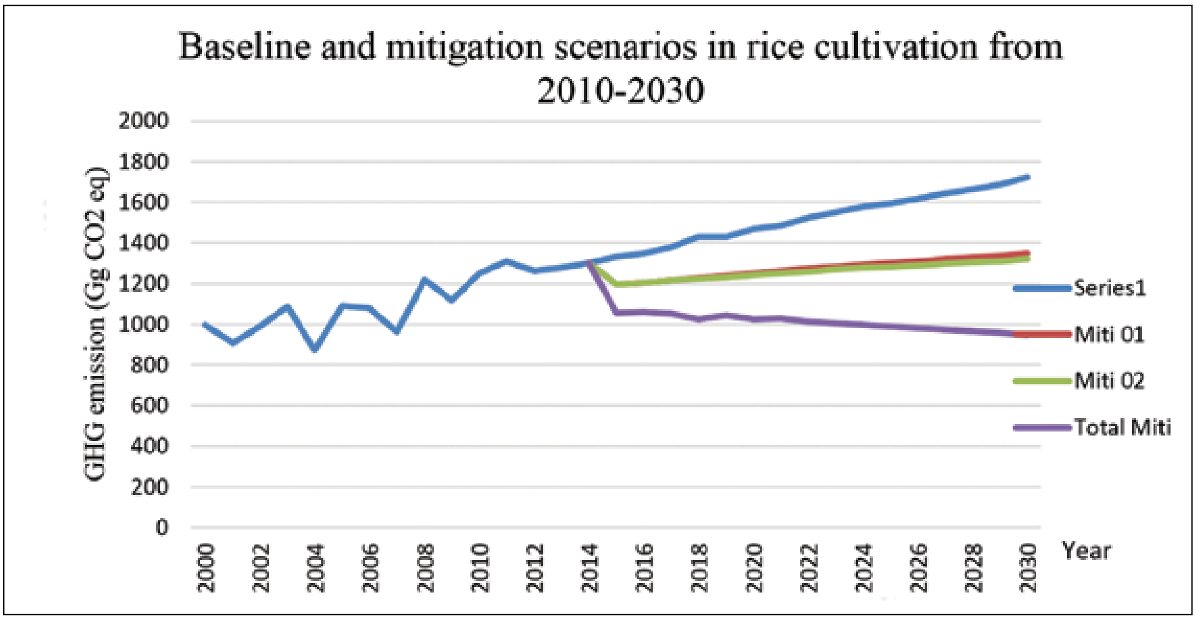


Figure 4.24 Baseline and mitigation scenarios in rice cultivation from 2010-2030

According to the Figure 4.24, the net saving GHG emissions by 2030 in mitigation scenario is 720 Gg CO_2-eq compared with the baseline scenario.

4.5.2 Forestry sector

By the dawn of the nineteenth century, Sri Lanka's forest cover was about 70% of the total land area. Since then, the forest cover has decreased progressively over the time.

The country's forest cover in 2015 was 29.87% of the total land area and comprise of 21.88% of dense forest, 6.26% of open and sparse forest, 1.43% savannah and 0.3% mangroves. Furthermore, home gardens occupy 13% and coconut and rubber lands occupy 8% (FD, 2015). The rate of deforestation at present is 5,000 ha per year. The deforestation is primarily due to change of forest land use to non- forest land uses for development projects and also due to illegal encroachment of forests. There are many policy and program level initiatives to conserve and increase the forest cover with the intention of increasing the carbon sinking capacities of forests.

Baseline scenario: In the construction of baseline scenario, the deforestation rate was taken as 8,000 ha per year from 2010-2015 and then reduced to 5,000 ha per year. Thereafter since there were many projects and programs in operation to conserve forests and reduce the loss. This trend was extrapolated to 2030 based on the population growth and GDP. In construction of the baseline scenario the natural forest cover, forest plantations and rubber plantation (as per the FAO definition) were considered. The trees outside the forests such as home gardens, coconut plantations, shade trees in tea plantations, avenue planting etc. were excluded. The standard UNFCCC emission factors were taken for the GHG emissions calculations for deforestation while the carbon sequestration capacities of natural forests were taken from published literature relevant to the tropical region. The Figure 4.25 shows the baseline scenario from 2010 to 2030 which shows the deforestation while Figure 4.26 shows the forest carbon dynamics in baseline scenario including emissions and sequestration.

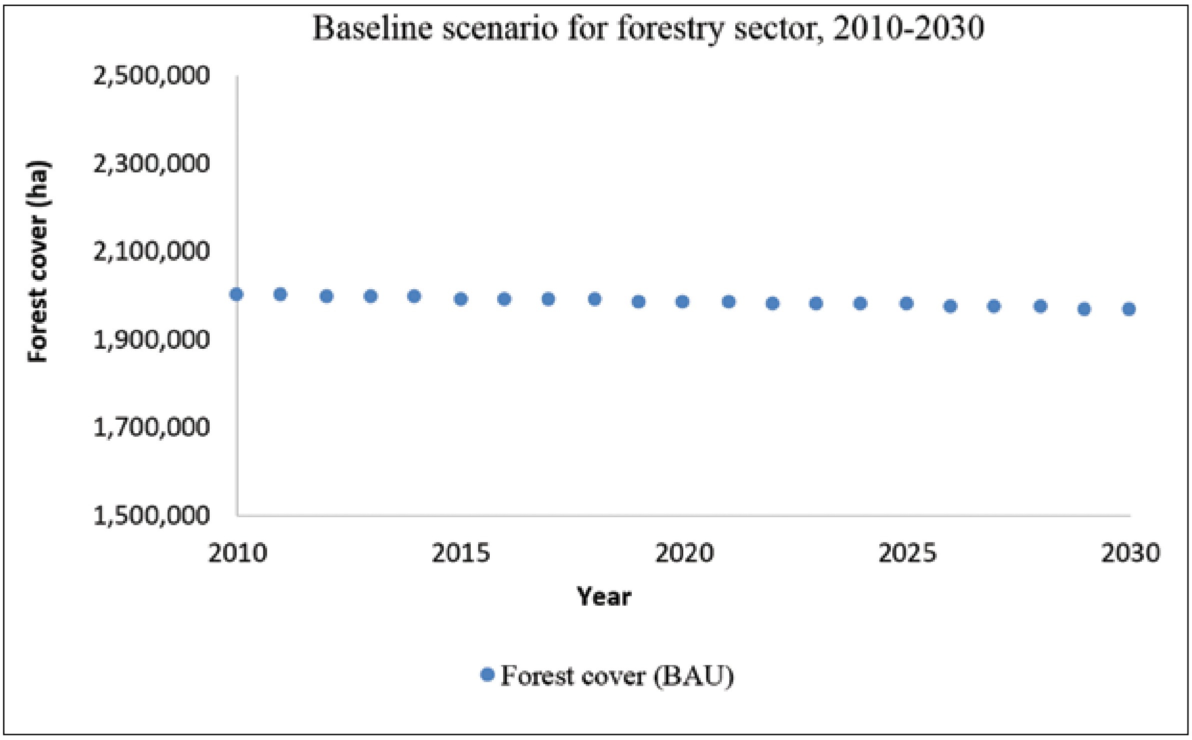


Figure 4.25 Baseline scenario for forestry sector, 2000-2030

Mitigation scenario: The mitigation scenario for forestry sector was developed based on the increase in forest cover from 29.87% in 2015 to 32% by 2030. Since trees/forests has the capacity to absorb/sequester atmospheric carbon dioxide into their life processes and be carbon sinks, increasing the forest cover and conserving the forests is of prime importance. It mainly focuses on the restoration and improvement of degraded forests and establishment of new forest plantations as well as the increase of rubber plantations.

Assuming gradual increase of forest cover due to reforestation and/or afforestation to reach the forest cover target of 32% by 2030, addition of carbon to the forestry sector was estimated. This increase in the forest cover will be done by planting of trees in areas where there is no forest cover or have a very degraded forests which cannot be considered under the definition of forests. It has been estimated that about 67,700 ha of land will be required to meet this target of 32% by 2030. In addition to new plantings, attempt will be made to conserve the existing forests and improve its carbon stocks. Figure 4.27 shows the expected increase in the forest cover in mitigation scenario as against to baseline scenario while Figure 4.28 shows the carbon sequestration of mitigation scenario in relation to baseline scenario.

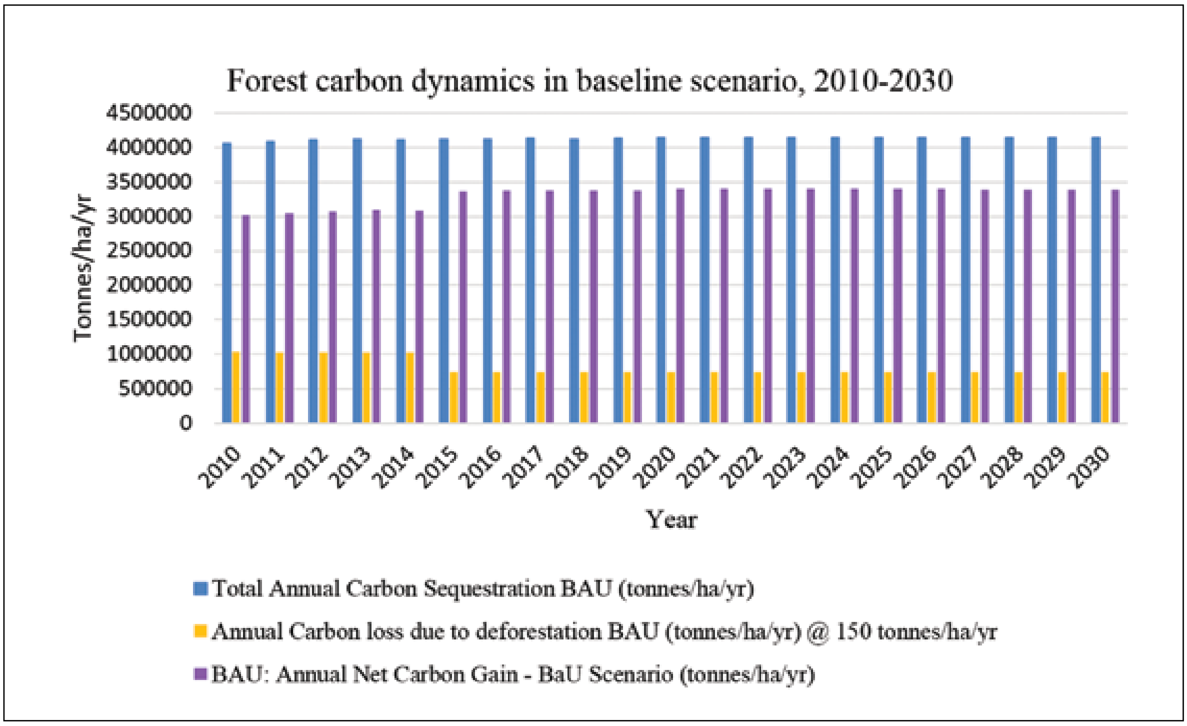


Figure 4.26 Forest carbon dynamics in baseline scenario, 2010-2030

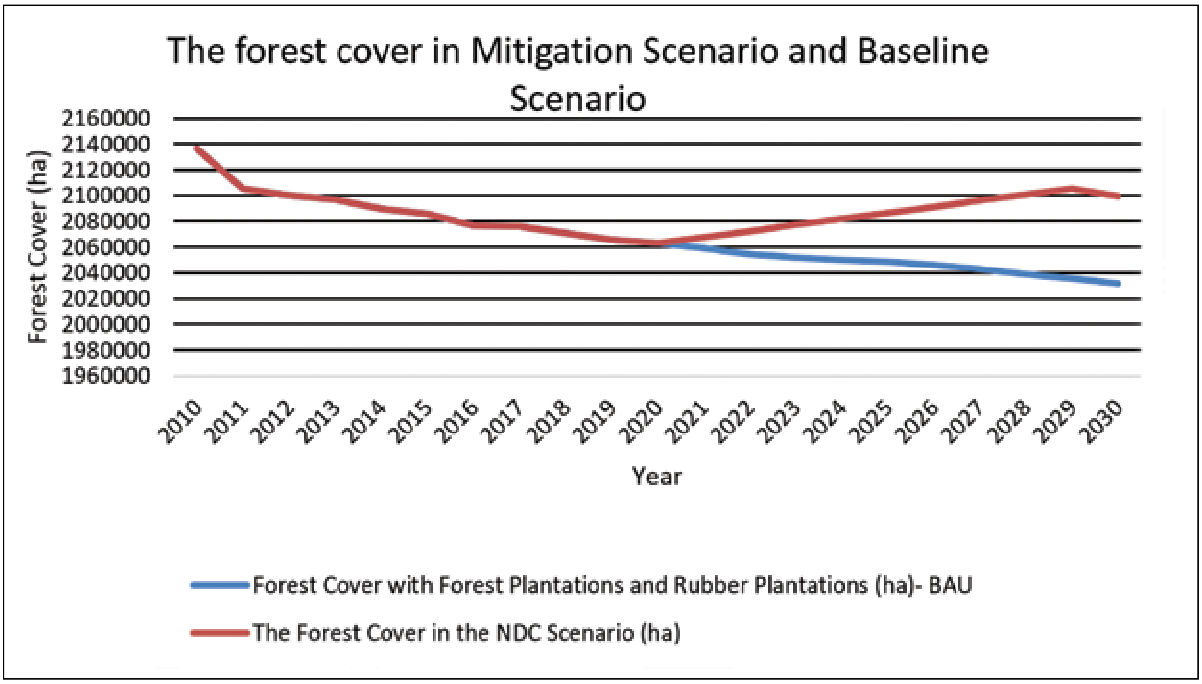


Figure 4.27 Forest cover in mitigation baseline scenarios, 2010- 2030

According to the Figure 4.28, the net savings in carbon emissions in mitigation scenario is 366 Gg CO_2-eq) compared with the baseline scenario.

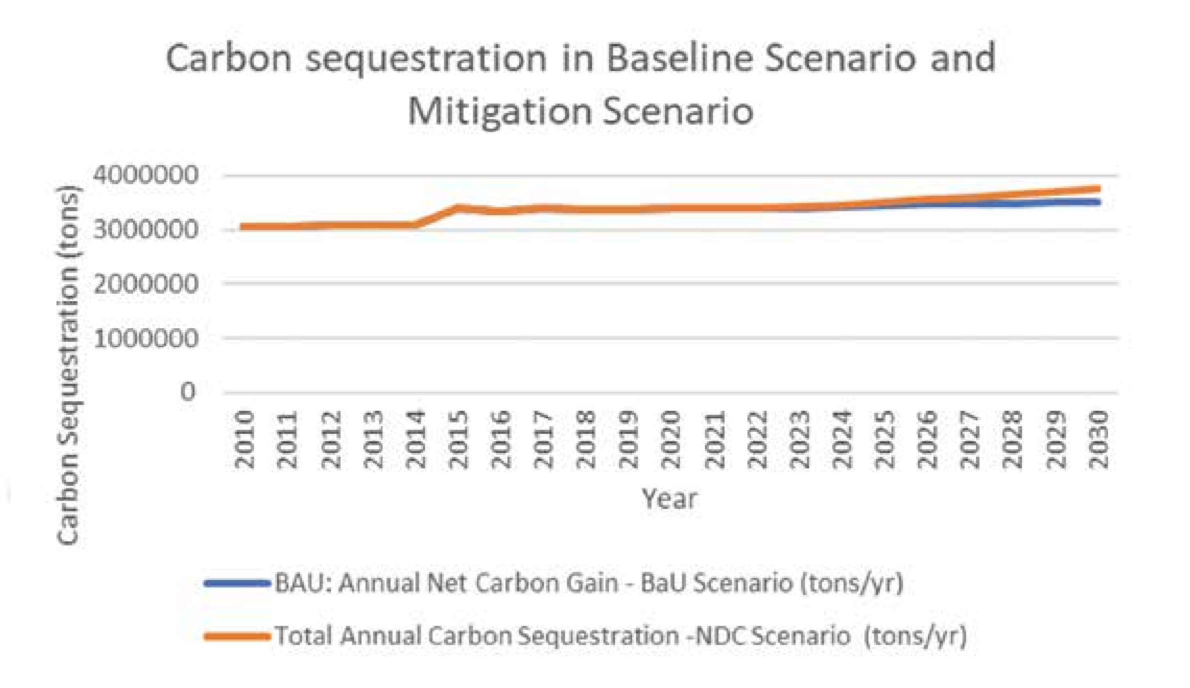


Figure 4.28 Carbon sequestration in baseline and mitigation scenarios, 2010-2030

4.6 Summary of GHG emissions savings

This section summarizes the total expected GHG emissions savings in all sectors by 2030. Table 4.4 presents Baseline emissions, emissions from the Mitigation Scenario, net GHG emission reductions and these reductions as a percentage of the baseline emissions. If all mitigation measures are implemented, Sri Lanka could achieve a 27% reduction in GHG emissions by 2030.

Table 4.4 Baseline emissions, emissions of the mitigation scenario and net GHG emission reductions by 2030

Sector	Emissions in baseline scenario (Gg CO_2-eq)	Emissions in mitigation scenario (Gg CO_2-eq)	Net emission savings (Gg CO_2-eq)	Reduction %
Energy: Electricity	18,500	10,400	8,100	44
Energy: Transport	22,923	19,255	3,668	16
Energy: Household, commercial and manufacturing industries	2,342	2,000	342	15
IPPU	869	784	85	10
Waste	1,340	361	979	73
Agriculture	1,700	980	720	42
Forestry	-3,507	-3,873	366	10
Total	**44,167**	**29,907**	**17,767**	**40**

CHAPTER FIVE

Education, Training, Awareness and Capacity Building

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Education, Training, Awareness and Capacity Building

5.0 Introduction

Strengthening education, training, public awareness and capacity building in respect of climate change provides a vital strength to the national focal point (Ministry of Environment) to the UNFCCC together with relevant stakeholders such as government, private sector, civil society organizations, universities and educational institutions, media and UN organizations etc., to address the impacts of climate change effectively. Already, certain efforts have been made in this regard by the above stakeholders, however still much remains to be done.

Over the past seven decades, Sri Lanka has continuously provided free education to its nation and physical facilities in schools have been vastly improved. Education in government schools is free and schooling till a student reaches 13 years of age has been made compulsory. Once a pupil passes the General Certificate of Education, Ordinary Level (GCE O/L) examination at the Grade 11, the pupil has to study for another two years preparing for the university entering examinations [General Certificate of Education, Advanced Level (GCE A/L)]. Those who are not qualified for university entrance they will joint for tertiary education at an advanced technical education institute. Others who fail at GCE O/L and GCE A/L examinations have the possibility to find the jobs in the technical and non-technical fields or revert back to their parents' livelihoods.

At the GCE A/L examination, there is a very stiff competition to gain admission to the state universities in the country even with some concessions are accorded to students coming from the remote districts. Some of the disqualified candidates for the state universities who have passed the GCE A/L join the private universities and other higher educational institutes or proceed to fee levying overseas universities for higher education.

5.1 Educational programmes on climate change

Education is a key component in enhancing the early adaptive capacity of a nation by instilling knowledge and skills needed for them to be ready to cope with moving environmental realities in the change of ecological, social and economic backgrounds. Hence, when a climate change consciousness foundation is laid in the minds of the children early at school, that will later turn to be a life-long consciousness of "where, when and how" the climate change around them takes place and what adaptation measures to be taken to improve climate resilience. Children are among one of the most vulnerable groups to the adverse impacts of climate change. They need not to be considered passive or helpless victims. Through education, project oriented actions, they can be made to contribute and make at least very simple mitigation and adaptation actions to be taken. In this regard, it should be noted that educating girls and women is one of the best ways of strengthening community adaptation measures to climate change. They are the ones who are disproportionately affected by the adverse impact of climate change. In many situations, females' livelihoods are dependent on climate sensitive sectors such as agriculture, water resources, livestock and forestry.

Steps have been taken by the National Institute of Education (NIE) to introduce environmental consciousness education up to the GCE A/L together with the programmes of education and social cohesion of the Ministry of Education in a process of introducing topics related to climate change. Teachers are being trained to teach climate change related subjects in schools. Education level and climate change competency level in the education system in the country are presented in the Table 5.1.

Table 5.1 Core competencies of climate change education in Sri Lanka

Education Level	Core competency in climate change	Competency level
Early Childhood (Nursery and Pre School)	Play group activities/access to environment	Level 1
Primary Education (1-5 Grades/years)	Play group, simple games, field observations, environmental interest activities	Level 2
Junior Secondary (6-9 Grades/years)	Basic understanding of science and its keywords, ecological understanding	Level 3

Education Level	Core competency in climate change	Competency level
Secondary (10-11 Grades/years)	A certain extent of understanding and moral development	Level 4
Senior Secondary (12-13 Grades/years)	Understanding on issues, impacts and potential solutions	Level 5
University degree level	Approach to research and advanced skills	Level 6
Professional and non-university education	Enhance the professional practices	Level 7
Postgraduate education	Research elaborations	Level 7
Vocational training	Moral/skills development	Level 4/5
Technical education	Skills development	Level 5
Advance technical education	Advanced skills	Level 6

At the University level, faculties of Agriculture, Science, Engineering, Humanities and Social Sciences (Arts) in many universities are teaching subjects related to climate change to undergraduates. It is to be noted that there is a growing interest among university graduates even to do postgraduate research studies on climate change adaptation and mitigation.

5.1.1 Technical, Vocational Education and Training

Technical, Vocational Education and Training (TVET) plays an essential role in addressing climate change as only the skilled workers and experts can deal with energy and resources in their jobs and at their work places efficiently and sustainably. Efficient use of energy and resources in a job is not only the responsibility of specialists, but also for every employee. Hence, solutions for related issues have to be provided through training. This can be done by the TVET comprised of 402 public sector training centres, 400 private and NGO training centres and a large number of non-formal TVETs providing training in Information Technology (IT). As the whole, the job-oriented training courses that they offer need to incorporate climate change related training courses as well. University of Vocation Technology is the degree awarding arm of TVET system in Sri Lanka, which is presently conducting 13 vocational technology related degree courses. These degree courses have only one climate related course unit in the third year, namely the Environmental Management and Cleaner Production Course.

The universities in the country have the enormous potentials to introduce several climate change mitigation and adaptation courses and degrees. This change requires to be fulfilled by the professionals in designing appropriate courses concerning climate change processes, vulnerability to impacts, mitigation, adaptation, loss and damage estimates and other related issues and ultimately the public will minimize and adapt for climate change risks. Further, many universities have organized the post graduate diploma on climate change for giving the opportunities for students for studying the impacts on climate change and researchers.

5.1.2 Non-formal education on climate change

Formal education is normally delivered by trained teachers in a systematic manner within the schools, higher education institutes or the universities. Non-formal training is through an organised training process that occurs outside the formal learning environment.

There is convincing evidence of successes coming from the non-formal education strategies adopted by Sarvodaya Sangamaya, Sanasa Campus for Cooperative and Development Studies, Sri Lanka Technical Institute, ‘Diyagala Boys Sri Lanka’, Mahila Samithi of Sri Lanka, Red Cross Society and Christian Children’s Fund etc., where the technical skills, service oriented activities, personal development programmes, para-professional development activities and vocational development activities are reasonably well imparted to their trainees through non-formal system of education. There is a great opportunity to provide many facets of climate resilience and awareness through these organisations using their non-formal education techniques and methods.

5.2 Trainings on climate change

Government, semi-government and private sector institutions including non-governmental organizations offer climate change related short-term training courses for the students, officials and general public. The Central Environmental Authority (CEA) offers pioneer environmental training programmes to school principals, teachers, environmental pioneers and school eco-project implementers. In these trainings, climate change information has been shared to make aware them to build resilience. In addition, many government organizations prepare educational materials to adapt for address impacts on climate change such as prolong droughts, flash floods, sea level rise and promote home gardening to enhance family food security, establish green parks, organise environmental promotional exhibitions etc.

During the past years, NBRO has conducted four types of training programmes through its human settlement planning and training division in collaboration with Divisional Secretariats, Plantation Human Development Trust, Urban Development Authority and Disaster Management Centre. The purpose of these programmes is raising awareness and providing training on disaster risk reduction. Planning officers, *Grama Niladharies*, masons and senior school children were the participants in these programmes which included information on hazard resilient housing construction to deal with human settlement issues in landslide-prone areas.

The Centre for Environmental Studies in the University of Peradeniya has been organising short training courses on climate change. The module of these courses has been developed to teach about the impacts of climate change and its consequences, giving a better understanding of this phenomenon.

The National Cleaner Production Centre (NCPC) publishes its trainings schedule in their website (www.ncpcsrilanka.org). Accordingly, climate change related training programmes have been conducted every year through courses such as quantification of GHG emissions and calculating carbon footprint according to ISO 14061-4. Further, Education training and awareness division of the Ministry of Environment conducts numerus training programmes on environmental issues including climate change for different stakeholders such as school children, teachers, media and university students etc,..

Considering the climate change consequences to the environment, Dilmah Conservation Group identified a need for improving the space and capacity for local level field research on the causes and consequences of climate change in Sri Lanka. As a result, Dilmah Company's founders and scientists from universities has established a research station, at Dilmah's Queensbury Estate in Nawalapitiya, Sri Lanka. The station was set up to address the dearth of scientific research of climate change in Sri Lanka, thereby facilitating the development of climate change adaptation and mitigation strategies.

Dilmah Research Centre invites scientists from universities, state and non-governmental agencies, for the purpose of understanding climate change in Sri Lanka, including current and possible future changes in climate, and options for mitigating and adapting to those changes, especially to benefit the plantation agriculture.

Figure 5.1 Dilmah Research Centre on Climate Change at Queensberry Estate, Nawalapitiya, Sri Lanka

5.3 Public awareness programmes

Awareness programmes on climate change have been conducted by the government, semi-government institutions, NGOs, private sector, media and public movements. Ministry of Environment conducts numerus awareness programmes in different parts of the country in collaboration with relevant institutions and other respective divisions of the Ministry.

The Climate Change Secretariat (CCS) being the operational focal point to the UNFCCC, it has been mandated to raise awareness and build capacities of all the strata of the society to address climate change issues in the country. In this context, various types of awareness creations and knowledge products are made. Among them, general awareness for school children, subject specific awareness for vulnerable communities, adaptation measures for practitioners including farmers, planters, architectures, hoteliers, industrialists etc,. and mitigation options among the energy developers, transport operators, waste managers, industrialists and livestock practitioners. Further, awareness materials like leaflets, story boards, broachers, posters, video clips, documentaries and short films are perpetually produced to make aware the general public through electronic, printed and social medias.

The Department of Coastal Conservation and Coastal Resource Management creates awareness in coastal conservation with the participation of beach-users with distribution of leaflets, booklets, holding debates among groups of school children etc. The Central Environmental Authority focussed largely on changing attitudes, improving knowledge and enhancing skills of citizens to face climate change.

The Disaster Management Centre (DMC) also conducted awareness workshops among school children and communities on how to face post disaster situations. The Forest Conservation Department conducts pilot projects to assess the emissions reduction impact on forest-based livelihood development activities with the involvement of local stakeholders. Further, DoM and NBRO conduct awareness programmes for different stakeholders on climate forecasting and land slide risks including early warnings.

A wide cross section of NGOs promotes public awareness on climate change through research, advocacy, education, training and media coverage at community level. The Centre for Environmental Justice advocates a “Civil Action Plan” for cooperation of all civil society organizations to reduce disaster risks. The Green Movement of Sri Lanka working with grass-root level communities propagate sector-wise best practices in building disaster and climate resilience at rural level.

Further, several awareness creational events are organized by the SLYCAN Trust with special reference to youth engagement, gender involvement, loss and damage, local and provincial engagement on climate change. Janathakshan (Gte) Ltd also conducts awareness programmes on resilience building of vulnerable communities to meet the adverse impacts of climate change and potential GHG emission reductions through innovative and indigenous technologies.

5.4 Capacity building on climate change

In order to address climate change issues at grass root level effectively, in vast scaled capacity buildings on adaptation measures for communities have to be conducted while the field level officials and officials who are working at district, provincial and national level government institutions should be empowered with required knowledge and climate smart technologies. At present, capacity buildings on climate change are taken place in ad hoc manner. However, the major role is presently played by the government and semi government institutions. Infrastructure development and distribution of equipment where the vulnerability to climate change adverse impacts are being provided by the government and such grass-root level activities have been gradually increased to build resilience in most vulnerable communities, sectors and areas.

The CCS of the Ministry of Environment has taken the leadership in the country for building capacities of different stakeholders to address climate change issues. In this context, various kinds of capacity building programmes for different stakeholders are conducted by the CCS specially related on calculation of GHGs emissions and removals, vulnerability assessment and adaptation measures, technology assessment needs, carbon market mechanisms, identification of research needs, nationally determined contributions and its emission reductions targets, preparation of project proposals for funding, calculation of carbon footprints, preparation of national communications and Biennial Updated Reports etc,..

Further, as it was expected to incorporate provincial data and information into this communication, the stakeholder consultations were conducted for all Provincial Councils of the country to make them well aware of on-going climate change programmes and activities for obtaining their inputs and increase capacities for addressing climate change issues in the respective Province with the intension of establishing a Provincial Climate Data Portal for future communication purposes.

Furthermore, capacity building programmes were conducted to establish the development of provincial climate institutional set up for the preparation of Provincial Adaptation Plan (PAP) for each Province focusing on provincial vulnerability and resilience building needs and climate data collection mechanism. Establishment of a Climate Cell under the purview of the Chief Secretary would enable the Government of Sri Lanka to accurately and timely contribute their situations in the national communications reporting.

The capacity building programmes were successfully held to enhance the capacities of the stakeholders who involve in the national communication preparation process to effectively contribute for climate change reporting.

Education, training, public awareness creation and capacity building play very pertinent roles in building resilience to meet the adverse of climate change and the minimization of its consequential losses, and reduce potential GHGs emissions and increase removals.

CHAPTER SIX

Technology Transfer, Research and Systematic Observations

CHAPTER SIX

Technology Transfer, Research and Systematic Observations

6.0 Introduction

This chapter presents activities or steps taken to integrate climate change considerations into relevant social, economic and environmental policies and actions in accordance with Article 4, paragraph 1 (f), of the Convention. The developed country parties to the UNFCCC are required, as per articles 4.3 and 4.5 of the Convention, to promote, facilitate and finance the transfer of, or access to, environmental sound technologies and know how to developing country parties, to enable them to implement the provisions of the Convention. Further, it is encouraged to provide information on climate change research and systematic observations, including their participation in and contribution to activities and programmes, as appropriate, of national, regional and global research network and observing systems. Non-Annex I parties to the Convention are encouraged to provide information on research related to programmes containing measures to mitigate climate change; programmes containing to measures to facilitate adequate adaptation to climate change; and the development of emission factors and activity data. This chapter describes activities carried out in the last decade in compliance with these requirements on technology transfer, research and systematic observations.

6.1 Technology transfer

Technology has been defined by Inter-governmental Panel on Climate Change (IPCC) in its Special Report on Methodological and Technological Issues in Technology Transfer (IPCC, 2000) as "a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change". Further, it highlights technology transfer as a process of learning to understand, utilize and replicate the technology, including the capacity to choose it and adapt it to local conditions and integrate it with indigenous technologies.

Article 4.5 of the UNFCCC states that developed countries "shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country parties, to enable them to implement the provisions of the Convention". Pursuant to decision 4/CP.7, its annex, and the implementation of Article 4, paragraph 5, of the Convention, Non-Annex I Parties such as Sri Lanka, are encouraged, in the light of their social and economic conditions, to provide information on activities relating to the transfer of, and access to, environmentally sound technologies and know-how, the development and enhancement of endogenous capacities and measures relating to enhancing the enabling environment for development and transfer of technologies.

Sri Lanka was able to leverage bilateral, regional and multilateral cooperation, including development banks, UNFCCC related funds, and the UN system for technology transfer related to climate change adaptation and mitigation.

The UNEP Risø supported Sri Lanka to carry out a "Technology Needs Assessment" (TNA) in 2014 using the UNFCCC and UNDP handbooks on conducting TNA. The TNA was conducted to identify and assess environmentally sound technologies that can help to reduce the impacts of climate change and the rate of GHG emissions. Specifically, the TNA helps to identify barriers for deployment and diffusion of technologies and address policy and legal gaps to enhance the overall enabling environment, increase the capacity of local institutions and experts, and raise public awareness of climate change issues. The TNA identified climate change adaptation needs in five sectors; food security (agriculture, livestock, fisheries), water, health and coastal, and biodiversity, and for mitigation in three sectors; energy, transport and industry. Following the assessment, a Technology Action Plan for each sector were developed in 2014.

Further, Climate Technology Centre and Network (CTCN) provided technical assistance in 2018 to commence Climate Smart City Programme for Kurunegala City by identifying the adaptation measures and later on potential mitigation actions (2019) to be implemented through a roadmap.

The South Asian Association for Regional Cooperation (SAARC), to which Sri Lanka is a member country, provides a platform for setting the regional policy agenda, and promoting regional cooperation, including on climate change, disaster management, and environmental protection, among other development issues.

SAARC has adopted several frameworks and action plans, including on climate change, Comprehensive Framework on Disaster Management (2006-2015), and adopted the Thimphu Statement on Climate Change in 2010. The latter calls on member states to undertake advocacy and awareness programmes on climate change, to promote the use of green technology, and best practices to promote climate resilient and low-carbon, sustainable and inclusive development of the region.

Sri Lanka is also a member of another sub-regional body – the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC). BIMSTEC's Centre for Weather and Climate was established following the signing of a Memorandum of Association (MoA) in 2014 among the BIMSTEC member countries. The purpose of this Centre is to build capacity of member countries, enhance observation capability, and encourage cooperation between BIMSTEC member countries for weather and climate prediction especially to develop an early warning system for weather and climate related disasters.

Sri Lanka shares knowledge as well as benefits from expertise and experience sharing through the Asian Disaster Preparedness Centre (ADPC), a regional body that brings together the national disaster management organisations of member countries to facilitate the implementation of disaster and climate risk management. Key institutions of Government of Sri Lanka such as the DoM, Disaster Management Centre, National Building Research Organization, are currently technical partners of the ADPC.

Sri Lanka is also a member of the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia, which was established in 2005 as a Tsunami early warning system in a multi-hazard framework for Southeast Asia and the Indian Ocean. Along with Bangladesh and the Maldives, Sri Lanka adopted a regional programme to establish and operate the early warning system. At present, Sri Lanka National Centre for Climate Applications (SNCCA), inaugurated in 2019, serves the South Asian region as the RIMES Sub-Regional Hub for Climate Applications. SNCCA shares technical, institutional, and policy pathways to integrate climate risk management into risk reduction and development processes.

On enhancing endogenous capacities, technologies and know-how, and measures relating to enhancing the enabling environment for development and transfer of technologies, the country has implemented several projects. One of the major projects by the Government of Sri Lanka (GoSL) is the "Rooftop Solar PV Power Generation Project", which provides electricity consumers with long-term debt financing for installation of rooftop solar photovoltaic power generation systems, and also allows private consumer to sell excess energy to the grid (from 2016 onwards).

6.1.1 Technology transfer for addressing climate change

Main requirement is the educational and outreach activities in order to change management practices suited to an ever-changing dynamic climate is the main factor one should consider before implementing the new technologies to fulfil the gap of knowledge. Technology is required to introduce interactive tools and simulation models in local languages to practice and develop the methods in day to day activities.

Agro-forestry is an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land. An alternative is to extend agro-forestry in the country to increase climate resiliency, provide different sources of income, and reduce land erosion. Tools required to identify physical characteristics (including altitude, rainfall, slopes, water supplies, soil condition, visible erosion, relative humidity) for building resilience of agriculture. Ecological Pest Management is one of the technological approaches for increasing the strengths of natural systems to reinforce the natural processes of pest regulation and improve agricultural production.

Diversification of income generation to reduce vulnerability and enhance resilience could be obtained by mixed farming. Technologies need to identify the suitable mixing varieties and implement the suitable farming practices.

Then agricultural officials should identify appropriate species for plants taken into account physical characteristics. Measurements should be taken to calculate the inputs and outputs of the agriculture system (including yields of trees and crops, and labour requirements). Surveys should be carried out for land use planning and land tenure reform and socio-economic benefits assessment in order to sustainable agricultural practices. Crop diversification and introduction of new varieties are the technologies to develop conservation farming. Technology needs required to the development of new and improved crop varieties arise where attractive native species can be used to increase productivity.

Advanced software, tools and models required for effective analysis of long-range weather forecasting for agricultural planning and crop recommendation based on the agro-ecological suitability should be introduced. Also, introduction of effective land and water management techniques for central highlands and other marginal areas to minimize land degradation and to improve land and water productivity due to climate change adverse impacts are recommended. Introduction of crop calendar for timely cultivation of crops, mulch cultivation techniques to reduce the water evaporation, soil testing tool kits for farmers to apply fertilizer based on the soil quality should be introduced.

Introduction of conservation techniques for water and soil is another proposed technology in agricultural field. Technologies are required to enhance irrigation efficiency and/or expand irrigation, development of major and minor tanks, dredging of tanks filled with sediments in order to increase the capacity of tanks. Also, ancient tank cascade system should be improved to save the rainwater and reduce water scarcity in the dry zone. Sealing techniques of irrigation channels to reduce water absorption and increase the vegetation cover to reduce water evaporation are another technology to be applied.

Drip Irrigation is a technology to save water when water is sufficiently unavailable. Drip irrigation involves dripping water into the soil at very low rates (2-20 litres/hour). Sprinkler irrigation system for small and large-scale watering is one of the water efficient and climate smart water management techniques that can be used for sustainable farming where the water scarcity is prevailing. Introduction and promotion of water harvesting techniques such as rooftop rainwater harvesting in dry zone, and technology needs to improved water filtration techniques are encouraged. Aerial surveys and remote sensing technology should be introduced to determine the most vulnerable areas for water scarcity.

Flood-proofing structures needs to be introduced to reduce the impacts of coastal flooding. This may include elevating structures above the floodplain, employing designs and building materials which make structures more resilient to flood damage and preventing floodwaters from entering structures in the flood zone, amongst other measures for mitigating flash floods.

Improving knowledge of agricultural machinery, training and capacity building among farmers are required to promote conservation farming techniques in areas where vulnerable to climate change. Slow-forming terraces are constructed from a combination of infiltration ditches, hedgerows and earth or stone walls to decrease superficial water run-off, increasing water infiltration and intercepting the soil sediment. Conservation tillage is new and developing technology to conserve the soil nutrients and increase the water retention capacity.

Adopting suitable breeding technologies considering the experience and predicted climate change scenarios in different agro climatic regions to achieve sustainable livestock production systems are essential. Technology related to introducing improved breeding under environmental stresses such as extreme droughts and extreme floods is required. Livestock disease management is one of the technological interventions to reduce disease through improved animal husbandry practices.

Technology needs such as establishment of environment friendly sustainable livestock farming practices, introduction of different breeds to different climatic zones in Sri Lanka and introduction of genetically modified rumen bacteria in animal farming are required. Feed optimization in animal farming, introduce specific agents and dietary additives, instead of C-3 and C-4 grasses and adaptation of temperature and fire tolerance grass (Eg: Gini grass) for the foods of the animals are also required.

In order to minimize the impacts of landslides, settlements and land use changes in landslide-prone and other vulnerable areas are discouraged.

Bio technology for new rubber varieties could be developed to withstand extreme climate and to reduce the loss of tapping days. Further, rain guards to overcome the dampness of the tapping panel should be used and thereby reduce the loss of tapping days in the wet zone.

In the coastal sector, beach nourishment, flood hazard mapping, flood-proofing and ecological barriers are some of technologies that can be applied to minimize the coastal ecosystem degradation. Beach nourishment, which refers to the artificial addition of sediment of suitable quality to a beach area that has a sediment deficit is the main option to reduce coastal erosion. Reduces the detrimental impacts of coastal erosion, provide a buffer to protect coastal infrastructure and other assets from the effects of coastal erosion and storm damage and help retain the natural landscape of the beach are the advantages of beach nourishment.

Artificial sand dunes and dune rehabilitation, storm surge barriers and closure dams, use of Sea Dikes are encouraged to protect low-lying areas against inundation. Land claims and seawalls are hard engineered structures with a primary function to prevent further erosion of the shoreline.

Technology needs to reduce the distribution and transmission losses addressing line losses together reduce both capacity and energy requirements which will eventually reduce the electricity generated. There are some challenges in improving distribution network such as efficient grid infrastructure challenge and high maintenance cost for modifications in the system. Already in the TNA (2014) it has identified three common barriers which are likely to impact upon successful transfer and diffusion of the prioritized technologies in the energy sector. These include (i) High capital cost and difficulties to access finance (ii) Economic feasibility either not examined or relevant information not available (iii) Technology either not established at the desired scale or not fully developed.

Further, it is recommended some measures to overcome these barriers such as fiscal policy reforms aiming at reducing costs of Renewable Energy and Energy Efficient project related fabrications and constructions; Activate the provisions in the Sri Lanka Sustainable Energy Authority Act to create a fund to support Renewable Energy and Energy Efficient projects by imposing a cess on all imported fossil fuels; Assign a multidisciplinary team of experts including economists and engineers to conduct economic feasibility studies and disseminate study results; Commercialize the production and marketing of "Gliricidia Sepium" leaves through supporting R&D.

Amongst the barriers identified for technology transfer in industry sector are high capital costs, lack of adequate financial resources and incentives, insufficient regulatory framework and inadequate enforcement, lack of and limited capacity in existing institutions, lack of skilled personnel for technology implementation and inadequate training for maintenance, poor operations and maintenance facilities, absence of standards, codes and certification, inadequate information, awareness, feedback and difficulties in comprehending technical contents. The measures recommended to overcome these barriers are government tax policy reforms as appropriate to enable reducing capital costs for high efficient and sustainable technologies; appropriate financial instruments and credit facilities, tax concessions and subsidies; provide green credit facilities on concessionary terms for greening the industry. streamline biomass supply process; technical education and awareness creation, training and skills development; avail service of international certification agencies to set up local standards; energy labelling and setting standards, and promoting climate smart technology through Energy Associations, Industry Associations and industrialists.

In order to minimize GHG emission in waste sector, innovative technologies for sanitary land fillings, waste to energy projects, waste segregations, waste recycling, organic fertilizer production, waste water treatment plants should be introduced. Incineration is the main technology that uses in Sri Lanka for clinical waste management. Waste segregation techniques and assessment of waste parameters and introducing the pyrolytic incinerators are the technologies to be introduced.

Water and environmental sustainability are considered as key factors for food security and the main focus at that time was to store water within reach of the people for cultivation and drinking. In this respect, rehabilitation of ancient tank cascade system in the country blending traditional knowledge with modern technology to ensure water availability in a drought period for agriculture and rainwater harvesting on rooftops for drinking and household uses are recommended.

Human settlement could be categorized as urban settlements, rural settlements and estate housing which need separate technology interventions for separate settlement category. Vulnerability risk maps using Remote Sensing and Aerial Photogrammetry technologies should be prepared to identify the suitable areas for settlements, identify suitable construction methodology such as food proofing technology to elevate structures above the floodplain, employing designs and building materials which make structures more resilient to floods. Decentralised Community-run Early Warning Systems are a set of coordinated procedures through which information on foreseeable hazards is collected and processed to warn the possible occurrence of a natural phenomenon that could cause disasters.

Energy efficiency and renewable energy technology related applications in the tourism sector are praiseworthy. Nature based solutions for tourist destinations and accommodations would be encouraged.

6.2 Research on climate change

A seminal piece of research carried on climate change risks faced by the country is the study that conducted by the Climate Change Secretariat with the technical assistance of the Asian Development Bank. The study, 'Climate Change Risks in Sri Lanka 2018', was conducted at the Divisional Secretariat level (or in other words sub-district level) and covered the entire country. The study's methodology identified 31 variables and four main hazards to assess the climate change impacts on hazards and key economic sectors. The study assessed the exposure, vulnerability and risk of each sector to four main hazards (drought, flood, landslide and sea-level rise) and provided the generated values for each component of the vulnerability. The findings of the study, along with the vulnerability assessments carried for the Chapter Three of Third National Communication, can help in developing national, provincial and also local level strategies for climate change adaptation.

Several universities and research institutions in the country conduct special courses on climate change. Further, many research symposiums on climate change are organized by different institutions in the country. There is a growing interest on climate change research among students and academia.

Further, sector-specific research on the impact of climate change is promoted by the private sector, especially in the tea sector. Localized research on climate change are conducted for Sri Lanka's tea and other export crops with useful data on climate change trends. The Dilmah Conservation Group has established the 'Dilmah Conservation Centre for Climate Change Research and Adaptation' (for more information please refer Section 5.3 of Chapter Five). The Centre provides the space for researchers, policy makers, planters, farmers and civil society organizations to collaborate and conduct research and studies for minimizing the adverse impacts of climate change in order for ensuring both quality and yield of tea.

6.2.1 Research needs for addressing climate change

A wide range of research on adaptation measures to meet the adverse effects of climate change have already been conducted within the realm of agriculture. However, extensive research should be carried out to obtain a comprehensive picture before implementing adaptation and mitigation actions including technology transfer for agriculture. Research needs in paddy cultivation are cost benefit analysis of local species to propagate local varieties among the local communities, physiological responses against with the changing climate parameters such as growth, yield, nodulation patterns, hard seed formation, and screening of existing traditional varieties. Comparable productivity study on Alternate Wetting and Drying (AWD) and traditional methods of paddy cultivation of Sri Lanka are also vital. Further, research on suitable measures to manage excess water in paddy fields for minimizing methane emission are required.

Identification of appropriate crop and tree species for vulnerable areas to adverse impacts of climate change which can be used for agroforestry and to identify the input and output of agroforestry systems, and development of models to investigate socio economic benefits in agroforestry practices are essential for research in agriculture. Identification of appropriate drought resistance species for vegetation cover in tea plantations is needed. Research on new rubber varieties which can sustain for extreme climates and identify suitable land and climatic areas (less affected with rain) that are compatible with new rubber varieties are required.

In the livestock sector, disease management using traditional methods and the variance of pest growth against climatic parameters are needed to be studied. Further, research in this sector should be conducted to identify and develop high resistant varieties for biotic and abiotic stresses, heat stress, droughts, floods, salt water intrusion and pest diseases.

Research needs in water sector are establishment of systematic observations for climatic variables, surface and ground water quality surveillance, salinity intrusion, efficient rainwater harvesting methods, extent of lands affected by sea level rise and river flow regimes. Further, finding the ways and means of motivating people for rainwater usage is another research area in the water sector. Research should be conducted on climate change concerns on wetland rehabilitation, restoration, conservation of coral reefs, sea grass beds, mangroves and sand dunes in coastal areas. Also, research on promotion of bio char as a stimulant to organic fertilizer to ensure water retention capacity increased are to be conducted.

Research and piloting on soil conservation techniques that can be reduced the land degradation in central highlands, traditional knowledge and practices of sustainable farming that can be coped up with adverse impacts of climate change, and identifying tolerable crop varieties which can withstand to climate change for different agro-ecological regions should be conducted. Study the applicability of conservation tillage technology is required to promote the tillage practices among the farmers.

Research on assessing and preparing for the increased health risks due to climate induced vector borne and zoonotic diseases are urgent need to address adverse impacts on human health. Further, research on current extent of waste production and types of health-care waste, estimated future waste production and waste handling are required to identify the potential of GHG emission reduction. For the waste water treatment, new biological technologies such as aerobic biological treatment methods; SBR (Sequencing Batch Reactor) and MBBR (Moving Bed Bio Reactor) and developed anaerobic biological treatment methods should be used in future applications are to be researched. Utilize composting (Aerobic waste treatment), especially in regions with a demand for soil conditioners and vermicomposting are other research areas in composting. Research on low / zero emitting composting techniques for municipal solid waste are essential. Research on organic fertilizer production process and usage in relation to standard, quality, crop productivity, nutrition content/ration, efficiency, compositions etc are also essential.

Research should be conducted to identify most efficient building materials for construction of housing and other infrastructure in line with Green Building Guidelines.

Research on improvement of energy efficiency transport modes, sustainable fuels as biofuel and vehicle technology for reducing greenhouse gas emission in the transport sector should be conducted. Studies on different traffic management practices, alternative fuels, fuel quality standards, passengers' behaviours, use of information and communications technology (ICT) as an alternative to travel for employments and personal matters as an effective demand management instrument in urban transport are timely. Further, country specific emission factors for vehicle types and models, and emission controllable instruments should be identified. Furthermore, research on country specific emission factors to calculate greenhouse gas emissions in energy, industry, waste, forestry, agriculture and livestock sectors should be conducted.

Research on efficiency and further expansion of renewable energy sources (solar, wind, biomass, biogas, tidal waves, etc..) and grid connectivity are essential for reducing greenhouse gas emission in energy sector.

Research on fuel switching to sustainable biomass energy and improve user efficiency by increasing feedstock quality, operation and maintenance practices, system design and automation in industry sector are the research to be carried out in the future. Carry out rapid assessments of tri-generation potential for replacing fossil fuels in industrial parks are also needed.

6.3 Systematic observations on climate change

Sri Lanka has the infrastructure to carryout systematic observations and provide data for weather forecasting. The country has 37 automatic weather systems deployed at regional meteorological stations and collaborative stations. Parameters are measured at every minute and data is sent to the Head Office of DoM in Colombo at every 10 minutes via INSAT 3-E satellite.[2] In addition, there are also two Automated Weather Observing Systems. There are 487 rain gauge stations across the country. Data is regularly obtained from 410 stations. These stations are maintained by the DoM in collaboration with government institutions, non-governmental organizations, and voluntary observers. In addition, 40 agrometeorological centres, with limited hardware, technical, advisory support from the DoM, have been established and managed by various institutions. These centres collect weather related data, as well as obtain measurements on evaporation and collect data from different depths below the surface. These data are primarily utilized for agro meteorological purposes.

2 Department of Meteorology, Sri Lanka, 'The General Structure of Real-Time Weather Forecasting System' https://www.meteo.gov.lk/index.php?option=com_phocadownload&view=category&download=3:booklet&id=1:astronomy&lang=en

Department of Meteorology consists of 20 meteorological stations representing all districts of Sri Lanka. Each station 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 0000GMT according to the standards of World Meteorological Organization (WMO). The DoM has a better spatial distribution of rainfall measurement with about 350 rainfall stations installed throughout the country. Rainfall data are recorded every day at 0830 am.

Automatic Weather System (AWS) after the Tsunami has been established under the supervision of DoM to mitigate natural disasters. 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 directly go to the Global Climate Observing System (GCOS).

Agro-meteorological network started in 1976 for agricultural development purposes. The Department of Agriculture collects weather data in agro-climatic zones continuously and shares with the DoM. 42 agro-meteorological (agromet) stations to collect data on sunshine hours, evaporation, soil temperature at various depths and solar radiation have been established and recorded twice a day at 0830 in the morning and 1630 in the evening. The weekly summary of the Agromet data are available to the public in the website of the DoM.

National Aquatic Resources Research and Development Agency (NARA) is the top national institute assigned with the responsibility of carrying out and coordinating research, development and management activities on the subject of aquatic resources in Sri Lanka. NARA has established island wide systematic information centers. Temperature sensors are located in Pigeon Island and Bar Reef Sanctuary and 1-hour interval data are recorded.

Further, tidal stations are located in Colombo, Kirinda, Mirissa, Trincomalee to measure the sea level. Wind data are recorded at Mirissa and experimental level data are recorded at Kirinda. Wave rider buoys are used to collect the Wave Height. Nutrients and plankton types are analyzed in every visit to the ocean (Nearly Once a month) (NO_3, NO_2 as nutrients). Further, sediment analyses are carried out and Current Speed is recorded using Recording Current Meters.

The research areas covered by NARA are ocean warming, ocean acidification and sea level rising. Ocean acidification research carried out in 2018, identified that oxygen minimum zones are spreading and estimated the rate of acidification.

Further, Department of Irrigation in Sri Lanka measures the reservoir status, river water level and rainfall. Observations are mainly focused on forecasting agricultural patterns.

NBRO is the premier research & development institute established in 1984. NBRO also functions as the national focal point for landslide risk management including landslide investigation and risk assessment, preparation of hazard zoning maps, monitoring rainfall and ground movements and issuing landslide early warning.

6.3.1 Systematic Observations for addressing climate change

Systematic observations required for assessing the vulnerability and determining adaptation measures are; continuously measuring and monitoring of climate change related parameters such as rainfall, temperature changes, wind patterns, moisture content, water evaporation, evapotranspiration, water quality and ground water level, and sea level rise by local weather and monitoring stations.

Analysing, monitoring, and modelling of metrological data for long time horizons related to agriculture and sustainable land management to identify most suitable areas for new cultivations. Continuous monitoring of nitrogen content in soil in different climatic zones in order to determine the fertilizer quantity to be applied. Monitoring of climate parameters to identify heat stress and extreme climatic conditions affecting livestock in localized environment should be systematically observed.

Systematic Observations on sea-level rise and wave surges are required to monitor continuously for building resilience of coastal resources and issuing alerts and warnings to the coastal community. Shoreline monitoring, exploration of coastal processes and erosion risks, formulation and design of shoreline stabilization, and project development in coastal areas are some of systematic observations needed.

CHAPTER SEVEN

Constraints, Gaps and Needs

CHAPTER SEVEN

Constraints, Gaps and Needs

7.0 Introduction

This chapter identifies the existing gaps and constraints for the preparation of national communications, and implementation of climate change actions. It also proposes actions to be implemented to address these gaps and constraints.

The guidelines provide that in accordance with national circumstances and development priorities, it is needed to describe any constraints and gaps, and related financial, technical and capacity needs, as well as proposed and/or implemented activities for overcoming the gaps and constraints, associated with the implementation of activities, measures and programmes envisaged under the Convention, and with the preparation and improvement of national communications on a continuous basis.

The methodology used for the preparation of this chapter has been through desk research, expert consultations, sectoral and national level stakeholder consultations for data collection, and national level consultation for validation of the findings. Through these activities, the stakeholders and experts contributing to the information and data collection have highlighted gaps in institutional structure, and coordination among different entities working on fulfilling obligations related to climate change activities; gaps in laws, policies, and regulations pertaining to adaptation and mitigation actions; gaps and lack of availability of data for adaptation and mitigation measures that focus on climate change impacts in Sir Lanka; gaps in capacity building and research; gaps in financial resources available and the amount needed to implement the activities related to climate change in the country.

Further, the activities conducted for the preparation of the TNC have identified gaps in data for the preparation of the chapters of the TNC, including adaptation and mitigation related data; constraints in accessing data exist nonetheless available for the preparation of the TNC; constraints in accessing findings of research on climate change conducted by different researchers, gaps in information related to climate finance, and constraints in accessing climate finance data and information.

Based on these gaps and constraints, the chapter proposes activities needed to address them. Activities that are highlighted among other are amending policies and regulations and development of a law for implementing activities related to climate change in Sri Lanka; capacity building activities on climate change for stakeholders; development of coordination and institutional structures for effective and efficient implementation of climate action; mobilizing climate finance to address support needs.

7.1 Gaps and Constraints under the Second National Communication

The Second National Communication (SNC) of Sri Lanka to the UNFCCC submitted in 2012 provides input on different gaps and constraints that exist in different sectors. Among those are:

i. Data gaps existing in different sectors which impact the preparation of the GHG inventory.

ii. Lack of quantifiable assessment of vulnerabilities in the report, which is difficult to be provided based on the findings of SNC.

iii. Lack of technology and technical capacity is indicated as a constraint that is existing in Sri Lanka which hinders the performance of obligations under the UNFCCC.

iv. Financial constraints for the implementation of climate change related activities for fulfilling the obligations under the UNFCCC.

These gaps and constraints have been studied in the preparation of the TNC, and additional gaps and constraints have been identified where relevant to provide a comprehensive overview of the existing gaps and constraints for the preparation of NCs and implementation of climate actions in Sri Lanka.

7.2 Gaps and constraints under the Third National Communication

This chapter has different data collection methods for gaining information on the existing gaps and constraints for climate action in Sri Lanka. This includes desk research, as well as a multi-stakeholder process which includes consultations with experts and multiple stakeholders as appropriate.

The key gaps and constraints identified in Sri Lanka for addressing climate change impacts, and fulfilling the obligations under the UNFCCC are described below from 7.2.1 to 7.2.12.

7.2.1 Institutional structure and coordination

There are multiple policies and plans related to climate change in Sri Lanka. Among these are the National Climate Change Policy of Sri Lanka, Nationally Determined Contributions (NDC) of Sri Lanka, National Adaptation Plan for Climate Change Impacts of Sri Lanka (NAP). They focus on adaptation, mitigation, and loss and damage, and other related obligations to which Sri Lanka has committed related to climate change.

However, a key gap that has been identified is an effective mechanism to communicate and coordinate among the different entities (government, private, civil society, academia and media) at national as well as provincial level. To ensure effective and efficient coordination for climate action among key stakeholders, it is important to;

i. Develop a clear mandate for improving the long-term coordination for inter-ministry and inter-institutional coordination on climate change including the roles and functions of each stakeholder in climate action, including and not limited to implementation of laws and policies relevant to climate change, activities under sectoral processes, as well as national, provincial and district level activities.
ii. Develop a coordination system for the preparation of NCs through a multi-sectoral approach, and with coordination between national and provincial levels.
iii. A coordination mechanism between national, provincial and district level for data sharing on climate change, and for the preparation of NCs as well as for other climate related activities.

7.2.2 Policies, laws and regulations pertaining to climate change

It has been identified that there are gaps and constraints in policies, laws and regulations for effective implementation to address climate change. In this respect, followings are important to be carried out;

i. Updating existing National Climate Change Policy of Sri Lanka addressing emerging climate change related concerns such as MRV, carbon trading and offsetting, data management, climate finance, etc..
ii. Enacting a law on climate change for Sri Lanka. It is important to note that Climate Change Commission Act for Sri Lanka is being drafted at present. It will be crucial for Act to have a clear mandate and powers vested in it empower effective ground level climate actions.
iii. Establishing a coordination mechanism under the proposed Act for the implementation of laws and policies that are related to climate change with robust actions against those violating the provisions of the Act.

7.2.3 Capacity Building and Research

There are gaps and constraints in capacity and technical skills on climate change related knowledge among the line ministries, departments and institutions. This prevents productive actions to be taken at sectoral levels, as well as reduces the effective engagement by stakeholders from these groups to engage in the national communication preparation. To address these gaps and constraints, it is required to;

i. Build capacity of stakeholders in the government sector, engaging in climate change related activities on the technical aspects relevant to climate change, as well as the preparation of NCs. This includes capacity building among stakeholders on, country specific emission factors, sectoral and provincial level GHG inventories which provides input to the national GHG inventory which is maintained by the Climate Change Secretariat (CCS) of the Ministry of Environment.
ii. Conduct training and capacity building workshops on the general overview of the UNFCCC process, as well as emerging concepts under the UNFCCC process such as concepts of loss and damage and the Warsaw International Mechanism (WIM,) measurement, reporting and verification (MRV), climate finance, implementation of the Paris Agreement and others as deemed appropriate.

iii. Capacity building of stakeholders on new findings of climate science and research such as the findings of the Inter-governmental Panel on Climate Change (IPCC) among others through consultations, briefing, sharing of knowledge products, etc.

iv. Capacity building workshops and sessions on how to address research and knowledge gaps on climate change, and development of a National Climate Change Research Strategy which will contribute to addressing gaps and constraints relevant to research on climate change in Sri Lanka. Among key sectors needing capacity building on research needs and support for research includes agriculture, fisheries, livestock, coastal and marine, biodiversity, water, health, human settlements, tourism, energy, industry, transport, waste, forestry etc..

v. Conducting capacity building activities related to economic diversification, integration of climate action into activities related to national development and planning, mainstreaming climate change into provincial development planning.

7.2.4 Data sufficiency for determining climate change actions

During the preparation of the TNC, it has been identified gaps in data for estimating greenhouse gas emissions for the Inventory and determining mitigation options, vulnerability and adaptation measures as well as loss and damage due to climate induced disasters. For GHG emission reduction, there has been several deficiencies which highlighted the need for accurate data in agriculture and waste sectors.

Further, it has been highlighted that there is insufficient of data for weather forecasting and developing scenarios, assessing climate change impacts, risks and vulnerabilities. In addition to this, other sectors have also highlighted the data gaps in health sector which was unable to provide data on deaths due to climate change impacts and in costal and marine sector which was unable to identify the existing impacts on coastal ecosystems.

Furthermore, it was also demonstrated that there exists gaps and constraints on inter-sectoral data sharing and coordination mechanism to share data. To address these gaps and constraints, it is required to:

i. Develop a data management and sharing policy, and a national data sharing mechanism including a mandate for sharing and ability to access data related to climate change.

ii. Develop a mechanism for data management and sharing through an inter-sectoral coordination and collaboration.

iii. Strengthen capacities for data collection, management and sharing among key stakeholders working on climate change, especially among key sectors highlighted through NDCs and NAP in Sri Lanka. The activities to be conducted are workshops on data collection processes, management and sharing; short courses on effective data management for climate change; selection of a designated officer in each line ministry, department or relevant institution for implementing climate change related commitments, and capacity building of the officials responsible for data collection, management and sharing.

iv. Make available competence human resources and required equipment, accessories, software and servers for data collection, management and sharing in each climate change related sector.

7.2.5 Technology and technical knowhow availability

There are different existing technical expertise for developing solutions to address climate change in Sri Lanka. This includes gaps in technical expertise for developing adaptation measures for vulnerable sectors, identifying appropriate mitigation options for potential sectors, as well as identifying co-benefits in between adaptation and mitigation actions and cost analysis of adaptation needs and mitigation actions. Activities proposed to address these gaps are:

i. Conduct regular sector-wise technology needs assessments through enhanced technology and technical knowhow.

ii. Inclusion of identified technology to address climate change adaptation, mitigation and loss and damage to annual budgets of relevant ministries to mobilise funding.

iii. Obtain technical assistance from external resources to develop innovative climate smart technology and demonstration.

iv. Empower human resources to gain expertise on climate smart technologies and access to technical knowhow for addressing the identified technology gaps to address climate change issues at sectoral level.

7.2.6 Climate finance need assessments

Costing climate actions and financial need assessments for implementing climate change related activities in Sri Lanka are the main gaps in climate financing. At present, there is no such an estimation made on the financial needs for addressing climate change in Sri Lanka. Although, there are activities that are conducted in ad hoc manner to address climate change adaptation, mitigation, and loss and damage, an overall financial needs assessment have not been conducted.

In addition to these gaps, there is a need to mobilize financial resources required to implement climate actions, comprehensively and holistically, and annual budget allocations are determined accordingly. For this purpose, it is important to address gaps in climate finance mobilization such as lack of engagement of private sector in climate financing, lack of capacity for mobilizing climate finance by the government, lack of national accredited entities to access multi-lateral climate finance, lack of technical capacity for developing project proposals to harness climate finance, etc.. To address these gaps, it is required to:

i. Identify and assess the climate finance needs for addressing climate change issues in Sri Lanka. As part of this exercise, key priority actions should be identified for vulnerability and adaptation need in each sector, based on which climate finance requirement should be assessed.

ii. Identify potential funding sources for particular climate action, and mobilise climate finance needed for Sri Lanka such as the Green Climate Fund (GCF), Global Environment Facility (GEF), Adaptation Fund, NAMA Facility, bilateral donors, private sector partnerships and other potential donors.

iii. Develop a multi-stakeholder driven climate finance coordination mechanism which identifies key climate finance needs, with the representation of key institutions that require climate finance including other key stakeholders.

iv. Build capacity of different stakeholders, especially private sector, to access the available funding sources through bankable climate change related proposals, and conduct trainings on developing project proposals targeting different key donors, and effective ways of mobilizing climate finance to Sri Lanka.

v. Facilitate the engagement of multiples stakeholders in mobilizing climate finance for climate actions, especially private sector for implementing climate change related activities through supporting the accreditation process of financial institutions such as the GCF, and engagement in accessing finance through processes such as the Private Sector Facility under the GCF, readiness support funding for National Implementing Entities under the Adaptation Fund.

vi. Conduct outreach activities, and mobilise private public partnerships for identified climate financial needs for Sri Lanka.

7.2.7 Climate change communication, awareness and climate literacy

Climate change communication, awareness, and climate literacy play a key role in addressing climate change. There are several gaps and constraints exist for climate change communication, awareness, and climate literacy in Sri Lanka. Among these are lack of climate change knowledge products in local languages; lack of capacity for Information Communication Technology (ICT) on climate change; gaps in technical capacity and climate literacy of communicators; gaps in science based evidence on climate change for communication. To address these gaps and constraints, it is required to;

i. Develop a comprehensive Climate Change Communication Strategy for Sri Lanka in a participatory and multi-stakeholder driven process.

ii. Conduct trainings and workshops for capacity building of key stakeholders on climate change for communication.

iii. Develop climate change awareness and educational material in local languages to facilitate increased engagement of the general public on climate change related issues.

iv. Create a network of climate change communicators, and key stakeholders who produce publications on climate change, sharing of updated scientific information and findings among the communicators in Sri Lanka.

v. Conduct climate change awareness programmes through trainings, seminars and workshops for multiple stakeholders including youth, school and university students at national, provincial and district level.
vi. Incorporate climate change into the school, university and tertiary education curriculars.
vii. Establish a technical team in the national focal point to the UNFCCC for promoting and facilitating climate change communication and awareness raising activities in Sri Lanka.

7.2.8 Stakeholder responsibility and effective participation, and focus on vulnerable groups in climate change implementation

While there are many stakeholders undertake climate change related activities in Sri Lanka, several gaps and constraints are in ensuring the representation of all sectors and groups of stakeholders in implementation of climate actions. Further, there is no strategy for engagement of vulnerable communities, a mapping of key stakeholders for climate change actions in Sri Lanka. There are also gaps and constraints in guidelines for stakeholder extended responsibility depicted for addressing climate change issues in their respective mandates.

However, committees such as steering committees, expert committees and cells have been established under thematic areas of climate change adaptation, mitigation and project wise. To improve stakeholder responsibility and effective participation, and focus on vulnerable groups in climate change implementation in Sri Lanka, the following actions are proposed to;

i. Develop a stakeholder engagement strategy for climate change activities in Sri Lanka.
ii. Conduct outreach and networking events to create awareness among stakeholders on ongoing climate change related activities, and foster partnerships for activities that are being conducted.
iii. Develop activities for specific stakeholders that have lower representation in the climate change related activities i.e. youth, women, children, vulnerable communities.
iv. Develop a set of guidelines for establishing a multi-stakeholder process for climate change related activities in Sri Lanka.
v. Develop activities annually for stakeholder engagement, and inclusion in decision making process and implementation, regular updating of activities and progress made in different climate change related projects.
vi. Mobilise funding for activities to promote stakeholder partnerships, networking, and outreach to different stakeholders in the climate change processes at national, regional and global level.

7.2.9 Making thematic submissions to the UNFCCC and country position on matters related to the UNFCCC negotiation process

The UNFCCC process regularly calls for inputs and submissions under its different thematic areas for countries to make their submissions. Sri Lanka faces constraints in making submissions for all calls which interlinks with the gaps in human resources in different institutions relevant to developing the submissions. This also interlinks with the gaps previously highlighted in technical expertise and the capacity building gaps on the UNFCCC process. To address this gap, it is required to;

i. Identify key technical experts on different thematic issues of the UNFCCC process.
ii. Conduct group meetings for thematic discussions, based on a mapping of submissions for the year.
iii. Develop regular thematic positions for Sri Lanka considering national policy directives and developmental priorities, and incorporate the existing country positions for each thematic issue when submissions are called for under the UNFCCC process.
iv. Conduct capacity building sessions for thematic experts and key stakeholders related to climate change and the UNFCCC process in order to develop country positions for issues related to the UNFCCC negotiation process.

7.2.10 Knowledge management

It has been recognized that difficulties for identifying knowledge products in a one-stop platform relevant to climate change impacts, vulnerabilities, actions and scientific findings in Sri Lanka, that there is a gap in a centralized, or publicly available portal for climate change knowledge management. Research findings, knowledge products are in different platforms, and constraints existing in accessing them when reporting climate change circumstances in the country. Further, there are gaps in coordination for accessing knowledge products that are available on climate change as they are insufficiently publicly available or published, or has restricted access due to improved technology unavailability and mechanisms which prevent them from being shared. To address these gaps and constraints, it is proposed to;

i. Function effectively the climate change research and knowledge repository that recently developed which allows generators of knowledge products to share their products which are accessible to those who are in search of climate change information.
ii. Develop a system of documenting climate change activities, and developing knowledge products as outputs of the activities conducted under the relevant authorities for sharing with other stakeholders.
iii. Mobilise and allocate climate finance for knowledge management related activities on climate change, for sectoral agencies through different financial flows in annual budgets, annual plans, project budgets.
iv. Identify and engage knowledge management experts to provide support for developing knowledge products on climate change.
v. Build capacity of key stakeholders for developing climate change related knowledge products, and developing a custom of knowledge management at national, provincial and district level, as well as through key stakeholders engaged in climate change related activities.

7.2.11 Monitoring and evaluation climate actions continuously

Considerable gaps and constraints exist in monitoring and evaluation (M&E) of climate actions in Sri Lanka. This is due to a lack of centralized mechanism/ coordinated system which is focused on climate change M&E. This process related to different aspects, which could be related to measurement, reporting and verification (MRV) process under the UNFCCC, where impacts of climate actions, allocation of climate finance for different climate related activities need to be monitored and evaluated in the performance based on the impacts of such initiatives. For Sri Lanka, at present MRV and M&E processes for climate actions are at an early stage and are being established under ongoing projects. To address the gaps and constraints under monitoring and evaluation process of climate actions identified are as follows;

i. Develop a MRV framework for climate actions in the country.
ii. Develop a climate financial flow targeting immediate and prioritized climate change actions for both adaptation and mitigation activities in Sri Lanka.
iii. Establish a multi-stakeholder MRV system for climate action which should be coordinated by the national focal point to the UNFCCC.
iv. Develop an inclusive mechanism of both MRV and M&E into the national reporting and communication system under the UNFCCC process.

7.2.12 Gender responsive climate actions

Gender consideration in policies and actions on climate change exists a gap in addressing gender responsiveness of climate change related activities in Sri Lanka. This is an element that has not been addressed through both NDCs in 2016 and NAP of Sri Lanka. Having identified this need, the Climate Change Secretariat of the Ministry of Environment has taken steps to develop a Gender Action Plan for Climate Change in Sri Lanka, which will be an overarching plan to ensure gender inclusiveness in climate actions. In order to ensure that these actions are effectively implemented, it is needed to;

i. Develop and finalize the Gender Action Plan for Climate Change in Sri Lanka.
ii. Establish a M&E system for gender-based participation for events and activities related to climate change.
iii. Ensure gender balance in project beneficiaries, and in decision making processes.
iv. Conduct capacity building and training workshops on the importance of gender responsiveness for climate change activities.
v. Conduct research on gender and climate change in order to integrate gender as a change agent for climate change intervention.

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