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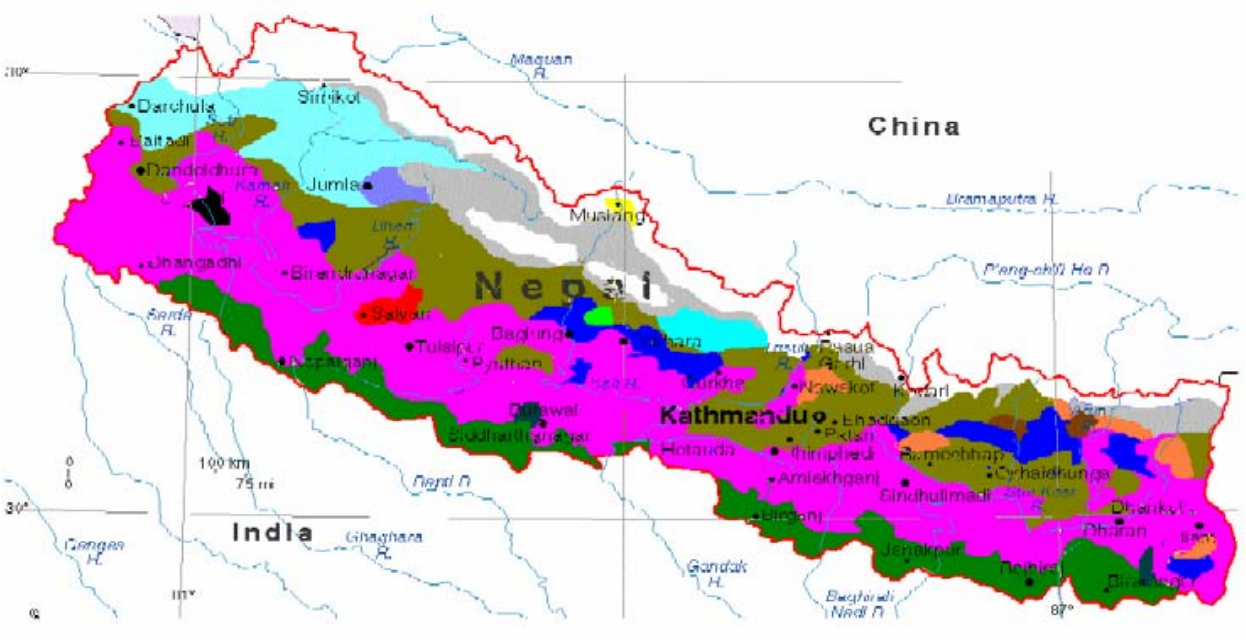

Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change

His Majesty's Government of Nepal

Ministry of Population and Environment

Singhadarbar, Kathmandu, Nepal

http://www.mope.gov.np

UNEP

July, 2004

The Prime Minister

Kathmandu
Nepal

July 1, 2004

Foreword

The Ministry of Population and Environment is the focal Ministry for climate change activities in Nepal. The task of managing climate change issues is however national in scope and requires an integrated approach. The National Climate Change Committee (NCCC) consisted of representatives from government, NGOs, and private sector was established as a multi-stakeholder committee to advise government on policies and strategies needed to prepare the country for climate change.

On behalf of His Majesty's Government of Nepal, I wish to congratulate all those involved in the long process of preparing the Initial National Communication Report. I specially appreciate the work done by the Project Steering Committee and the Sub-Committee in providing technical and policy guidelines to the project and preparation of final version. I would like to avail this opportunity to sincerely thank the GEF, UNEP and UNFCCC Secretariat for their financial and technical support to this cause of national concern. Your active participation in the deliberations was vital to the success of this project.

Sher Bahadur Deuba

(Sher Bahadur Deuba)
Prime Minister
and
Minister for Population and Enviranment

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PREFACE

The increasing threat to humanity and the eco-system due to Climate Change arising from anthropogenic emissions of Greenhouse Gases (GHGs) to the atmosphere was recognized by the global community with the adoption of UN Framework Convention on Climate Change at Rio Earth Summit in June 1992. The Conference of the Parties of this UNFCCC involving both developed and the developing countries committed towards efforts in formulating and implementing programs containing measures to reduce anthropogenic emissions by sources and to enhance removal by sinks of all GHGs, and measures to facilitate adequate adaptation to Climate Change. As a Party to the UNFCCC, Nepal has realized the obligation to the Convention and is making efforts towards reducing emissions of GHGs by regulating anthropogenic activities in this country. Nepal has refined the environmental policies, enacted or amended the legal regime of environment to encourage the people, at large, to implement environmental management activities and programs. The forest policy, for example, has reemphasized forest management through community approaches with the objective of maintaining and/or improving the carbon sink, and promoting adaptation measures. The forest law has, thus, re-enforced people's empowerment for forest management. Furthermore, Nepal has also implemented the Forestry Sector Master Plan, Agricultural Perspective Plan, and the National Conservation Strategy with people's participation. The Environmental Laws also contain several provisions to mainstream Nepal's development efforts towards sustainability.

This National Communication document is an effort in compliance with the Convention obligation of Nepal in addressing Climate Change and its impacts in country. It also deals with other important issues such as vulnerability and adaptation, research and development, technology transfer and public awareness as well as the policies and measures being implemented in the country. It came into being through collective and laborious efforts of experts from numerous government institutions and university in the country, who deserve our deep appreciation; it also fulfils one of Nepal's important commitments as a Party to the UNFCCC.

The support provided by the Global Environment Facility through the United Nations Environment Program in the preparation of this Initial National Communication is highly commendable. With this support, Nepal has been able to enhance its institutional capabilities and to prepare to meet future challenges. The experiences gained from preparing this Communication document suggest the need for future development of technical, institutional and human resources to improve our work, particularly in the areas of vulnerability and adaptation. Because of the importance of the water resources and agriculture to the country, Nepal finds itself highly vulnerable to Climate Change, particularly from the receding of snowbound areas and from extreme weather conditions. Even though the GHGs emission of Nepal in the global context is negligible, based on the principle of common but differentiated responsibilities, Nepal is fully committed to cooperating with international communities to minimize the impacts of Climate Change while conforming to its obligations under the United Nations Framework Convention on Climate Change.

July 1, 2004

(Mohan Bahadur Karki)
Secretary

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Acronyms

ABP	Agri-Business Marketing and Statistical Division
AEPC	Alternative Energy Promotion Centre
AIJ	Activities for Joint Implementation
APP	Agricultural Perspective Plan
ARRPEEC	Asian Regional Research Program in Energy, Environment and Climate
AWMS	Animal Waste Management System
BAU	Business-As-Usual
BOD	Biological Oxygen Demand
C	Carbon
CAAN	Civil Aviation Authority of Nepal
CBS	Central Bureau of Statistics
CCCM	Canadian Climate Change Model
CDM	Clean Development Mechanism
CDR	Central Development Region
CEDA	Center for Economic Development and Administration
CFL	Compact Fluorescent Lamp
CH_4	Methane
CMST	Country Management Study Team
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
COP	Conference of the Parties
CTL RUN	Control Run
DDC	District Development Committee
DFRS	Department of Forest Research Survey
DMS	Demand Side Management Measures

DOC	Degradable Organic Compound
EDR	Eastern Development Region
EIA	Environmental Impact Assessment
EPA	Environment Protection Act
EPC	Environment Protection Council
EPR	Environment Protection Rules
FL	Fluorescent Lamp
FRISP	Forest Resource Information System Project
FWDR	Far-Western Development Region
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFD3	Geophysical Fluid Dynamics Model
Gg	Giga gram
GHG	Greenhouse Gas
GIS	Geographical Information System
GJ	Giga Joule
GLOF	Glacier Lake Outburst Flood
GTZ	German Technical Assistance
GWP	Global Warming Potential
HFAM	Hydro-comp Forecast and Analysis Model
HMG	His Majesty's Government
HRD	Human Resource Development
ICIMOD	International Center for Integrated Mountain Development
IEE	Initial Environmental Examination
JI	Joint Implementation
IOE	Institute of Engineering
IPCC	Inter governmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LEAP	Long Range Energy Alternate Planning

LPG	Liquefied Petroleum Gas
LRMP	Land Resources Mapping Project
MCF	Methane Correction Factor
MOF	Ministry of Forest
MOPE	Ministry of Population and Environment
MOST	Ministry of Science and Technology
MPFSP	Master Plan Forestry Sector Project
MW	Mega Watt
MWDR	Mid-Western Development Region
NARC	National Agriculture Research Centre
NBSM	Nepal Bureau of Standards and Metrology
NE	North East
NEPAP	Nepal Environmental Policy and Action Plan
NCCC	National Climate Change Committee
NCCSG	National Climate Change Study Group
NCSD	National Commission on Sustainable Development
NFI	National Forest Inventory
NGO	Non-Governmental Organization
NH_3	Ammonia
NLSS	Nepal Living Standard Survey
NMVOC	Non-Methane Volatile Organic Compound
NOC	Nepal Oil Corporation
N_2O	Nitrous Oxide
NO_X	Nitrogen Oxides
NST	National Study Team
RCM	Regional Climate Model
RESTUC	Research and Study Center
RS	Remote Sensing
SADAN	Sustainable Development Agenda for Nepal
SAARC	South Asian Association for Regional Co-operation
SC	Steering Committee

SOE	State of Environment
SW	South West
SWDS	Solid Waste Disposal Site
TJ	Terra Joule
TU	Tribhuvan University
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and Adaptation
VDC	Village Development Committee
WATBAL	Water Balance Model
WDR	Western Development Region
WECS	Water and Energy Commission Secretariat
WIPI	Weighted Industrial Production Index
WSSD	World Summit on Sustainable Development
dm	dry matter
g	gram
ha	hectare
k	kilo
mha	million hectare
ppm	parts per million
t	ton
Tg	Terra gram

Executive Summary

Introduction

Nepal, along with over 150 other nations, signed the United Nations Framework Convention on Climate Change (UNFCCC) at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992. Nepal ratified the Convention on 2nd May in 1994, and this convention came into force in Nepal on 31st July in 1994.

This Initial National Communication sets out Nepal's obligatory contribution to international efforts to address Climate Change issues as a Non-Annex-I Party. It provides an overview of National Circumstances that influence Nepal's capacity to respond to the problem, and describes the Greenhouse Gas Emissions Inventory and Mitigation Options. This Communication also discusses developments with regard to Vulnerability/Impact and Adaptation issues, Policies and Measures taken, and the areas where Nepal still lacks the capacity to address Climate Change problems.

National Circumstances

Nepal is a small landlocked mountainous country located between the world's two most populous countries: China to the north and India to the east, west and south, with a total land area of 147,181 square kilometers. The elevation of the country increases from about 60 meters in the south to 8848 meters in the north at the peak of Mt. Everest. Nepal receives major portion of rainfall during summer monsoon from June to September.

Preliminary findings of Population Census 2001 put population of Nepal at 23.2 million with growth rate of 2.24 % per annum. GDP of Nepal at factor cost for the year 2001/02 is estimated at US$ 5446.4 million and annual per Capita GDP for the fiscal year is estimated at US$ 224 (Current). Nepal's urban population is expanding, thereby putting pressures on natural resources, especially in and around urban areas. Waste disposal and its associated health hazards are other serious concerns linked to the growing urban population.

Agriculture is the mainstay of the economy, providing a livelihood for over 80 % of the population. About 80 % of the total population depends on the forests for daily fuel wood supply. Forests and shrubs cover 52,283 sq km, which amount to 39.6 % of the total area of Nepal. Although Nepal occupies only 0.03 % of the total land surface of the earth, it has nearly 4.3 % and 8.5 % of mammalian and bird species of the world's total respectively. The immense bio-climatic diversity in Nepal supports more than 35 forest types. Nepal is one of the richest countries in terms of water resources where the monsoon contributes plenty of rainfall. About 6000 rivers and streams including three major basins namely Sapta Kosi, Karnali and Narayani basin drain the country. The annual run off from total drained areas is estimated to be 202 billion m^3.

Inventory of Greenhouse Gases in 1994/95

Nepal's decision to become a Party to the UNFCCC was both urgent and timely, and compiling a GHG inventory is an essential commitment of the country. National inventory of anthropogenic Greenhouse Gas emissions by sources and removal by sinks was compiled for the 12 month period beginning July 1994 and ending June 1995 as the base year to match with the official fiscal year of Nepal and to be in line with the recommendation of the Conference of the Parties of UNFCCC for the reference year. The Revised IPCC guidelines of 1996 were followed as the methodological basis for estimating GHG emissions and sinks while conducting this national GHG inventory.

In accordance with the IPCC Guidelines, Nepal's GHG inventory is divided into five main categories: Energy Activities, Industrial Processes, Agriculture, Land-use Change and Forestry, and Waste Management. The national GHG inventory represents emissions data for three gases having direct Greenhouse effects: Carbon dioxide, Methane and Nitrous oxide.

Carbon Dioxide (CO_2)

Net emissions of CO_2 in the country were estimated at 9747 Gg for the base year 1994/95. The total CO_2 emission from fossil fuel consumption in the base year was estimated at 1465 Gg. The biggest contributor, e.g. Transport sector, shares 31%, Industrial sector 27%, Residential sector 22%, Commercial sector 11%, and the remaining 9% is shared by Agriculture sector.

Total CO_2 emissions from Land-use Change and Forestry in the base year 1994/95 were 22895 Gg, out of which 14,738 Gg of Carbon dioxide were sequestrated due to the biomass growth. Thus, net emissions of CO_2 from the Land-use Change and Forestry sectors were about 8117 Gg in the base year 1994/95.

The production processes that emit CO_2 include cement production, lime production, and lime stone consumption and soda ash production. In 1994/95, total Carbon dioxide emission from cement production process was 163 Gg and that from lime production was about 2 Gg. Besides, as emissions from the remaining production processes were insignificant, those have not been included in the report.

Methane (CH_4)

In 1994/95, total Methane emissions in Nepal were estimated at 948 Gg out of which 867 Gg emissions came from Agriculture sector, in which enteric fermentation in livestock accounted for 527 Gg. Also Methane emissions from rice cultivation and livestock manure management were estimated to be 306 Gg and 34 Gg respectively. Methane is also produced from energy related combustion activities, such as biomass burning, incomplete combustion of fossil fuel etc. For the base year 1994/95, Methane emissions from these sources were estimated at 71 Gg. Lowest amount of Methane emissions (10.47 Gg) were estimated from solid waste disposal and wastewater treatment.

Nitrous Oxide (N_2O)

Nitrous oxide is a chemically and radiantly active Greenhouse Gas that is produced naturally from a wide variety of biological sources such as soil and water. While actual emission of N_2O is much smaller than CO_2, it is approximately 270 times more powerful than CO_2 in trapping heat in the atmosphere when looked over a 100 year time horizon.

The major source of Nitrous oxide emission in 1994/95 was agriculture soils from where 27 Gg of this gas were released to the atmosphere. Also, 2 Gg of N_2O emissions were estimated from the manure management for the same year. Besides, Nitrous oxide is also produced from energy related combustion activities. Nitrous oxide emission from this activity was estimated

to be 1 Gg. Indirect N_2O emission from human sewage was estimated to be 1.10 Gg for the base year 1994/95.

Greenhouse Gas Mitigation Options

In developing countries like Nepal, the program of GHG emissions reduction and the adaptation to Climate Change should be integrated with other national and sectoral development plans and programs for preservation of the environment.

GHG Mitigation Measures for Energy Sector

The main options identified in the energy sector, for example, are energy efficiency through demand-side management and technology improvement as well as switching from high to low carbon content fuel sources. Nepal has been implementing to date several energy management programs, which help mitigation of CO_2 emissions. Among them are:

- Demand-side Management
- Energy Conservation Program
- Fuel Switching
- Renewable Energy Use

GHG Mitigation Measures for Forestry Sector

Preservation and conservation of forests to help reduce emissions and the implementations of reforestation and afforestation activities to enhance carbon sinks are possible options in the forestry sector.

Mitigation option development and assessment have followed the findings of GHG emission inventory study undertaken in Land-use, Land-use Change and Forestry and Agriculture sectors. They are aimed at reducing carbon emission and increasing carbon sequestration in Nepalese forests. Three scenarios, short-term (2010), mid term (2020) and long term (2030) have been developed to examine the potential carbon sequestration and response option. To implement appropriate and effective responses to Climate Change, the following are the priorities for Nepal.

1. Improved technology to reduce fuel wood consumption;
2. Rehabilitating the degraded lands through afforestation and reforestation;
3. Promote sustainable forest management in leasehold and community forests particularly in the middle hills and the Siwaliks;
4. Increasing of the CO_2 uptake from the atmosphere (by converting low productive land into grassland and range lands);
5. Promote habitat management for the protected wild animals and plants with particular focus on buffer zones development and management;
6. Explore opportunities for carbon trading both at domestic and international level, and develop accounting framework for measuring potential changes in forest biomass stocks.

These options together with their financial and economic implications need to be examined carefully to establish the GHG abatement potentials.

GHG Mitigation Measures for Agriculture Sector

There are several technical options aimed at reducing CH_4 emissions in agriculture. These include improved management of water, farm residues and chemical fertilizers, selection of appropriate rice cultivars, and changes in cultivation techniques and practices. Since the agriculture sector in Nepal presently supports more than 80 per cent of the households in the country, one must ensure that any measure introduced to control CH_4 emissions does not jeopardize their livelihood. Nevertheless, substitution of green manure or readily decomposable organic matter with pre-fermented organic matter as well as the use of Ammonium sulfate as nitrogenous fertilizer instead of urea could diminish Methane emission by 11 to 23 %. In the livestock sector, options to reduce CH_4 emissions include changing the feed mixture, using chemical treatments to improve digestibility, and expanding pasture and forage conservation. Besides, lower enteric Methane emission from changing herd composition would partly offset the increasing trend in fecal Methane emission arising from the growth in dairy cattle and poultry population.

Finally, reasonable and practicable options for Mitigation have been identified as technology upgrading through a concerted effort of awareness creation, education, and incentives, as policy intervention. Since GHG emission reduction is not the priority for Nepal, it is very important that mitigation measures should go hand in hand with development efforts. Besides, the nation should be vigilant in terms of attracting CDM projects for implementation of mitigation options. Most important of all is the institutional capacity building to be able to identify projects, explore markets and monitor progress if a CDM project is implemented.

Vulnerability and Adaptation

In the assessment of the climatic condition of Nepal, a tendency towards increased seasonal and annual air temperatures was observed for the last few decades here. Observed annual trend of temperature rise per decade was found to be 0.41^{o} C while seasonal rising trend for temperature during pre-monsoon, monsoon and winter periods were 0.43^{o} C, 0.43^{o} C and 0.37^{o} C per decade respectively.

Also, significant increase in mean air temperature is projected in Nepal as a result of increased CO_2 concentration in the global atmosphere. CCCM and GFD3 circulation models project an increase in temperature from 1.4^{o} C to 5.8^{o} C with the doubling of CO_2. In both models, highest temperature rise is anticipated during winter and lowest in the monsoon period. However, a very high range of variations is shown in RCM model, starting with 0.5^{o} C rise in temperature in monsoon season and reaching the highest value of 15^{o} C in pre-monsoon season. In GFD3 model, precipitation was found to be increasing for all the seasons in general with a rising gradient from west to east in the country while the CCCM model showed negative gradient of precipitation from west to east during winter but followed the trend of GFD3 model in annual and other seasons. Trend analysis of observed precipitation showed that during monsoon, post monsoon and in annual scenario, negative trend had dominated western Nepal more than eastern Nepal. Most of the Terai belt except in the eastern region had negative trend for all seasons. A Climate Change of this nature is expected to influence the economy and on natural resources of the country to a considerable degree.

Agriculture Sector

In an agrarian country like Nepal with staggering increase in population and food demand, even a slight decline in annual food production is a matter of great concern. Although majority of the people depends on agriculture, this sector is adversely affected by the loss of top fertile soil due to soil erosion, landslides, and floods. Therefore, soil loss is one of the major causes of decline in agricultural production in Nepal. The negative effects of Climate Change may further aggravate this situation. Therefore attention has been focused to visualize the food scenario in the light of Climate Change. Rice, wheat and maize are the most dominant cereal crops of Nepal; a picture of the likely performance of these three crops have emerged from results of present studies.

Vulnerability assessment of Rice yield showed that at 4^{o} C temperature and 20 % increase in precipitation, there could be yield increase only from 0.09 to 7.5 % and beyond that the yield would continue to decline. However, temperature rise had mixed reaction in the case of wheat as the actual yield of wheat showed increased output in western region of Nepal with the rise of temperature but decline in other regions. Similarly, temperature rise had negative effects on maize yield as it was found to decrease with increase in temperature. Though temperature rise had more negative effects on maize yield, the trend was almost similar to wheat. However, rice, wheat and maize responded positively under double CO_2. Wheat potential went as high as 60 %, rice yield 21 % and maize yield 12 % under double CO_2 condition.

Thus, this study has suggested that there are still many uncertainties in the climate scenarios of GCMs and RCM as there are several constraints and limitations identified in the models. At a preliminary stage, however, adaptation measure to Climate Change could be approached by intensifying the conservation of drought resistant crop varieties by improving cropping practices to conserve water; and by promoting crop diversification. Several aspects of the vulnerability and impact analysis in agriculture sector can also be improved, for example, development of improved climate scenarios, development of more suitable crop models, and search for alternative analytical approaches. These should be done before a more meaningful adaptation analysis could be made and recommended.

Water Resources Sector

The vast water resource potential of Nepal has considerable importance in the economic development of the country. However, Nepalese river basins are spread over such diverse and extreme geographical and climatic condition that the potential benefits of water are accompanied by risks. Besides, Climate Change could add a new dimension to water management: Though the available surface water of Nepal (202 km^3) could fulfill the demand of the country up to the end of 21^{st} century, the availability of only 26 km^3 water in dry season shows that water scarcity is eminent in Nepal unless water resources are properly managed. Besides, rising temperatures have caused glaciers to melt and retreat faster. Receding glaciers mean an increased risk of the sudden flooding following glacial lake outbursts.

Hence, the present vulnerability/impact analysis of water resources with aspect to the changes in climate was carried out using Water Balance model and Deterministic model to the three major (snow-fed) river basins namely, the Karnali, the Narayani, and the Kosi and in one (rainfed) small Bagmati river basin. No major change in the hydrological behavior was found in the scenarios of increase in temperature up to 4^o C. However, the impact analysis showed that even a small change in precipitation had resulted into higher percentage of changes in discharge compared to the percentage changes in precipitation.

Considering the average vertical lapse rate of 6.5^oC per kilometer, it was found that almost 20 % of the present glaciated area above 5000 meter altitude are likely to be snow and glacier free area with an increase of air temperature by 1^o C. Similarly, 3^o C and 4^o C rise in temperture could result into the loss of 58 % and 70 % of snow and glaciated areas respectively. Such changes are likely to contribute to the faster development of glacier lakes leading consequently to the increase in potential of glacier-lake outburst flood hazards. Also, increase in precipitation by more than 20 % is likely to cause significant increase in sediment delivery, and more than 20 % increase in annual sediment deposit could be expected in a scenario of 50 % increase in annual precipitation.

Natural Forest Sector

Forests are the most important natural resources after water in Nepal. Majority of people use forest products as firewood, food, fodder, timber and medicines. Extensive utilization of and increasing demands for forest products have led to its dwindling both in area and quality. Further, Global Warming may cause forest damage through migration towards the polar region, changes in their composition, extinction of species etc. The consequence of this situation could affect directly not only the environment of Nepal but also lives of majority of the people.

Out of 39 vegetation zones categorized by Holdridge model, Nepal has 15 types under the existing (CO_2) condition. There would be only 12 types under 2x CO_2 climatic condition as depicted by the model. Similarly tropical wet forest and warm temperate rain forest would disappear, and cool temperate vegetation would turn into warm temperate vegetation under double CO_2 condition. Furthermore, vegetation pattern would be different from the existing under the incremental scenario (i.e. at 2^o C rise of temperature and 20 % rise of rainfall). All adaptive measures to reduce vulnerability of vegetation should be focussed on efforts to increase and conserve vegetative coverage and minimize impact of climatic change. On other words adaptation measures for bio-diversity sector should be developed for extensive planting of trees to capture Carbon dioxide as well as to identify/prioritize species that are not vulnerable to Climate Change. Besides, we need to reforest sensitive areas with drought, heat and flood tolerant species, enlarge and add protected areas, develop regional plans for non-reserve habitats to conserve wild-life populations and resources lying outside protected areas, and emphasize on ecological research and monitoring.

Health Sector

Present analysis emphasized potential impacts of Climate Change on Health especially on growing risk of Malaria, Kalaazar and Japanese Encephalitis outbreak. Particularly subtropical and warm temperate regions of Nepal would be more vulnerable to Malaria and Kalaazar. Increase of temperature would make the Subtropical region of Nepal more vulnerable to Japanese Encephalitis as well. Adaptation options in this sector could be considered and drawn out from historical perspective and experiences. Though chemical

control of the potential outbreak of disease may not be appropriate due to development of growing chemical resistance mosquitoes and ecological effects. Therefore more research and development of alternative approaches are required to control possible disease outbreak

Policy and Measures

Since 1957 His Majesty's Government of Nepal has been implementing National Economic and Social Development Plans to guide the social and economic development in the country. Increasing deterioration of natural resources and environment, since past few decades, have prompted the government to seriously act on resource and environmental conservation. Sustainable development efforts were intensified in the 1980s and early 1990s. Balance between economic/social development and conservation of natural resources and environment have been the basis for sustainable development policies of Nepal.

HMG has implemented a separate Environment Protection Act (EPA), 1996, and Environment Protection Rules (EPR), 1997, with an objective of maintaining a clean and healthy environment by minimizing adverse impacts and taking into consideration factors for sustainable development which could be achieved through economic development and environmental protection.

Public Education and Awareness

Nepal has promoted education and public awareness on Climate Change issues through various means. At the very basic level, a primer to increase understanding of Climate Change issues is being translated into Nepali and disseminated to public schools, libraries and government agencies. In the mean time, information materials related to Climate Change problem have been distributed on special occasions or events. Workshops and seminars, to present and discuss key issues, have been organized. Public education and awareness as well as public participation in environmental protection activities have also been promoted regularly.

To promote public awareness of the deteriorating environment, various government agencies stage campaigns through different media. A bottom up approach to resources management has stimulated more local participation and awareness of environmental programs. Public awareness is strongly linked to public participation in activities that address environmental issues. Promoting the role of local community, NGOs and the private sectors in pursuit of sustainable development, Nepal has contributed greatly to raise public awareness of environmental problems and issues such as Climate Change. Nepal is resolved to continue its active support and efforts to promote education and public awareness on Climate Change issues.

Recommended Research/Studies

A coherent scientific approach of study as opposed to individual agency initiative is needed for improved understanding of Climate Change impacts; this will promote and provide quality information data to the decision makers for developing suitable plans and polices on Climate Change.

Studies and assessments of measures on adequate adaptation to Climate Change also need to be continued. In the present perspective, adapting measures are recognized to be as important as mitigation measures in an effort to combat Climate Change. Hence, research and studies should be carried out on a constant basis in all sectors of the economy, including energy, transport, industry, agriculture, forestry, health and waste management. Although there are many uncertainties about the timing, magnitude and regional pattern of the changes on these sectors, there is strong evidence that they will pose significant risks to our economy, environment, and human health.

CHAPTER -1

Introduction

Nepal signed the United Nations Framework Convention on Climate Change (UNFCCC) on 12th June 1992, and ratified it on 2nd May 1994, making it effective in Nepal three months later on 31st July 1994. As a Party to the Convention, Nepal has been actively participating in the Convention processes since then. The Initial National Communication is one of the obligations the Convention requires from all Parties including the developing countries like Nepal. In this connection the Ministry of Population and Environment (MOPE) with mandates for implementing the UNFCCC provisions is coordinating the activities related to the obligations.

The Scope of Work of MOPE on environment is based upon the fact that the Ministry is made responsible to address the environmental problems and their probable solutions. In this regard, the Scope has been divided into two domains: primary functions to be carried by MOPE at its own initiatives, and the supportive functions to help other institutions. The Ministry performs all this in accordance with the Allocation of Business Rules of HMG, Nepal. It provides MOPE with mandates for, inter alia, acting as a national and international focal point in the domain of 'Population' and 'Environment'. The MOPE, therefore, has to fulfil the obligations taking all the initiatives in dealing with the commitments.

Preparation of this Initial National Communication report is based upon the COP2 guidelines for Non-Annex-I countries. Global Environmental Facility (GEF) made available a grant of three hundred and ten thousands US dollars through UNEP to prepare this Communication. Under this program a high level project Steering Committee (SC) was established (Appendix -I). The government also set up a National Climate Change Committee (NCCC) and four separate National Study Teams (NSTs) to prepare the country's response to Climate Change (Appendix-II and Appendix-III). The NCCC is chaired by the Director General of the Department of Hydrology & Meteorology of the Ministry of Science & Technology (MOST) while the SC is headed by the Secretary of the Ministry of Population and Environment (MOPE), which is the agency serving as Nepal's focal point for Climate Change Convention.

The Enabling Activity project, as this program is called, commenced its activities in 2001 under the Department of Hydrology and Meteorology (DHM).

The Initial National Communication deals on four major subjects: these are i) National Circumstances, ii) National Greenhouse Gas Emissions Inventory, iii) GHG Mitigation Options and iv) Vulnerability/Impact and Adaptations. Though the Decision 10 of COP2 requires Non-Annex-I Parties to use 1994 as the base year, the National Greenhouse Gas Emission of Nepal had to be estimated for the period July 1994 to June 1995 taken as the reference/base year (designated as 1994/95) using the Revised 1996 Guidelines of IPCC simply because Nepal's fiscal year starts from July annually and ends in June the next year; therefore all studies/ assessments in this report including the GHG Inventory estimate have been carried out using data and information accordingly; similar way of using other data/information for other years as well has also been followed in this report unless mentioned otherwise. It is to be noted in this context that the DHM supplied data used throughout in this study are not based on the above system however; they follow the normal calendar year January –December for every record keeping. In the entire work of preparing this Initial National Communication, experts from different fields were appointed to provide necessary technical guidance and direction to the project where Central Department of Hydrology and Meteorology, Tribhuvan University, took the lead role.

This Communication report begins with an Executive Summary followed by a brief Introductory Chapter-1 and a Chapter-2 on National Circumstances that provides an overview of Nepal's sustainable development processes. Based on sources and sinks, Chapter-3 presents a Summary of National Inventory of Greenhouse Gases for 1994/95. Chapter-4 discusses projections of Greenhouse Gases and Mitigation Options potentially applicable in Nepal. In Chapter-5, the results of study to evaluate Vulnerability/Impact and Adaptation aspects in major sectors like Forestry, Agriculture, Water Resources and Health are presented. National Policies and Measures to pursue sustainable development objectives are described in Chapter- 6. Chapter-7 provides information on Public Education and Awareness programs for natural resource conservation and environmental protection. Recommended Research/Studies are highlighted in Chapter-8. Finally, Chapter-9 concludes the reports dealing briefly on all aspects of the Initial National Communications of Nepal.

CHAPTER-2
National Circumstances

Most of the Nepal's territories are hills and mountains, which are considerably vulnerable to Climate Change. As a result of air temperature increase and change in precipitation pattern, increase in natural calamities is anticipated, the effect of which will be considerable in terms of agricultural productivity, water resource management and human health etc. Because of these and many other reasons, Climate Change is considered to be one of the important issues in the present world. However, in Nepal, as in any other least developed country, Climate Change issue is a priority only to the extent that it is reflected in the national development objectives in relation to protection of the environment and sustainable development. Therefore, unless the context of Climate Change is integrated and linked to the national development goals, priority cannot be attached to it, and hence programs related to Climate Change will not attract adequate attention. It is necessary to link Climate Change issues to Nepal's long-term development goals - poverty reduction, economic growth and employment, increased self-reliance, promotion of rural development, and preserving the environment. Table 2.1 presents information on the National Circumstances of Nepal for 1994/95. The sources of information are the official reports of government agencies. In one or two cases, where official data are missing, the expert estimations are used.

2.1 Topography

Nepal is a small landlocked country located between world's two most populous countries China to the north and India to the east, west and south with a total land area of 147,181 sq km. Nepal stretches from 26º 22' to 30º 27' North latitude and from 80º 04' to 88 º 12' East longitudes. The country looks roughly rectangular in shape with the length from east to west of about 885 km and width ranging from 130 to 260 km. The elevation of the country increases from about 60 m above mean sea level in the south to more than 8800 m above mean sea level in the north. The highest peak Mt. Everest, known as Sagarmatha to the Nepalese, rises to 8848 m and lies at the northern part of east Nepal . The country is divided into three broad ecological regions, i) the mighty Himalayas in the north, ii) Hills and Valleys in the middle, and iii) Terai, an extension of Indo-Gangetic plain, in the south. Mountains, Hills and the Terai regions are homes to 7 %, 46 % and

47 % of Nepal's population respectively. Terai is a low-lying plain, highly vulnerable to floods during the monsoon. Northwards, a series of complex valleys breaks up the simple pattern of parallel east-west mountain ranges, and one of these, the valley of Kathmandu, contains the capital of Nepal. Further to the north rises the Himalayas, the world's greatest mountain range.

Table 2.1: National Circumstances

Criteria	**1994/95**
Population in million	20.2
Relevant areas (km^2)	
Cultivated	34,416
Non-Cultivated	9,703
Grazing	17,659
Forest and shrubs	58,280
Plantation	990
Other	26,133
GDP (1994/95 million US$)	4,276
GDP per capita (1994/95 US$)	211
Estimated share of the informal sector in the economy in GDP (%)	9.0
Share of industry in GDP (%)	9.9
Share of agriculture in GDP (%)	40.8
Land area used for agricultural purposes (km^2)	29,680
Urban population as percentage of total population	9.2
Livestock population ('000)	
Cattle	7,444
Buffaloes	4,024
Pigs, Sheep and goat	7,126
Others	19,292
Forest Area (km^2)	
Shorea Robusta (SAL)	5,761
Tropical Mixed Hardwood	12,554
Lower Mixed Hardwood	7,679
Conifer	2,567
Upper Mixed Hardwood	13,135
Other Forest	992
Shrub	15,592
Population in absolute poverty (%)	42
Life expectancy at birth (years)	55
Literacy rate (%)	40

2.2 Climate

Nepal has a great deal of variations in climate. Although Nepal lies near the northern limit of the Tropics, a very wide range of climates from Subtropical in the southern Terai to Arctic in the northern high Himalayas exists here. The remarkable differences in climatic conditions are primarily related to the enormous range of elevation within a short north-south distance. The presence of the east-west extending Himalayan massifs to the north and the monsoonal alteration of wet and dry seasons also greatly contribute to local variations in climate.

Nepal experiences the seasonal summer monsoon rainfall from June to September. Most of the days during June to September are cloudy and rainy. Heavy incessant rains and periods of dry spells are not uncommon during these months. About 80 % of the annual precipitation in the country falls between June and September under the influence of the summer monsoon circulation system. The amount of precipitation varies considerably from place to place because of the non-uniform rugged terrain. However, the amount of summer monsoon rains generally declines from southeast to northwest. Although the success of farming or crop harvest is almost fully dependent on the timely arrival of the summer monsoon, it periodically causes problems such as landslides, subsequent losses of human lives and farmlands, loss of other infrastructures (not to mention great difficulty in the movement of goods and people) and large scale flooding in the plains. Conversely, when prolonged breaks in the summer monsoon occur, severe drought and famine often result.

The winter months December to February are relatively dry with clear skies. However, few spells of rain do occur during these months. The winter rain decreases in amount from northwest to both southward and eastward direction. During April to May the country experiences pre-monsoon thundershower activities. The pre-monsoon rainfall activities are more frequent in the hilly regions than in the southern plains. The period of October and November is considered as a post monsoon season and a transition from summer to winter. During October the country receives a few spells of post-monsoon thundershowers, similar in character to the pre-monsoon ones. The annual mean precipitation is around 1800 mm in Nepal. But owing to the great variations in the topography, it ranges from more than 5000

mm along the southern slopes of the Annapurna range in the central Nepal to less than 250 mm in the north central portion near the Tibetan plateau.

The onset of the monsoon in early June checks the increase in daily temperature over the country. Therefore, the maximum temperature of the year occurs in May or early June. Temperature starts decreasing rapidly from October and reaches the minimum of the year in December or January. Although normally the temperature decreases with height, there are also spatial variations in temperature in Nepal influenced by topography. Terai belt is the hottest part of the country, where the extreme maximum temperature reaches more than 45º C. The highest temperature ever recorded in the kingdom was 46.4º C observed in Dhangadhi, a town in far western Terai, in June 1995.

2.3 Social and Economic Conditions

Population

Nepal is one among the least developed countries in the world with large areas in the north virtually uninhabited. Preliminary findings of Population Census 2001 put population of Nepal at 23.2 million with growth rate of 2.24 % (Table 2.2). Of this total population, 85.8 % lives in the rural areas. Based on the Population Census of 2001, the population density of Nepal is about 158 people per square kilometer. Nepal has one of the highest population densities in the world with respect to cultivable land (MOPE, 2000). Sixty different caste/ethnic groups inhabit Nepal having their own culture and languages. Most of the Nepalese are Hindus, followed by Buddhists, Muslims and others. Nepal, the birthplace of Lord Buddha, is famed all over the world for its communal and religious harmony. Life expectancy at birth is 57 years, the lowest in South Asia; infant mortality per 1,000 live births is 83; and illiteracy among the population above the age of 15 is 62 %, the highest in South Asia (World Bank, 1999).

Table 2.2: Population and Growth Rate

Year	1961	1971	1981	1991	2001
Population (millions)	9.4	11.6	15.0	18.5	23.2
Annual Growth Rate (%)	1.65	2.07	2.66	2.09	2.24

Source: NPC, 1997; CBS, 2002

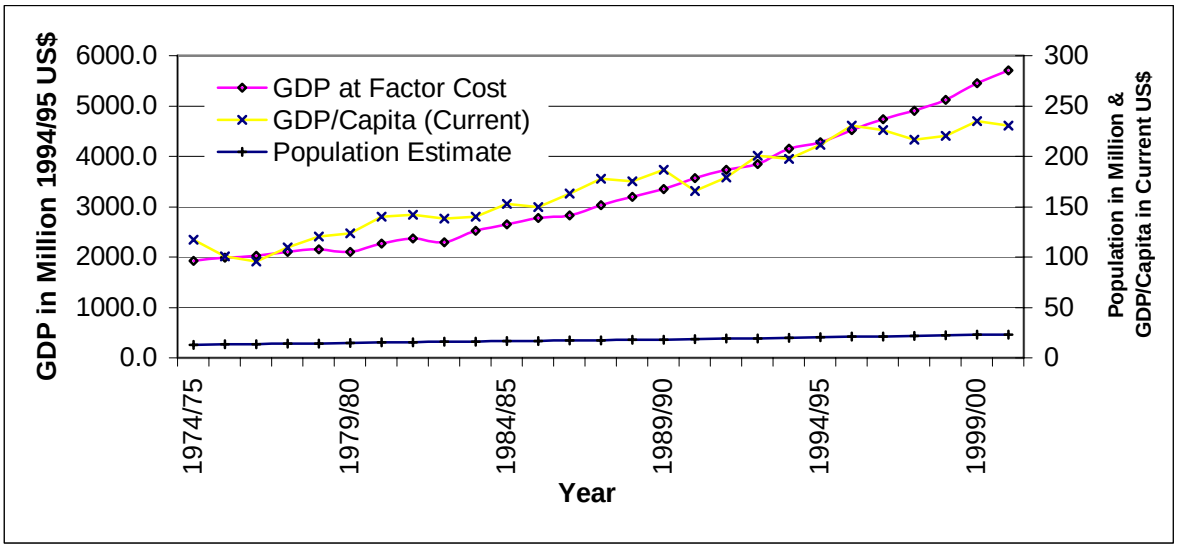
Economy

GDP of Nepal at factor cost for the year 2001/02 is estimated at US$ 5283 million and annual per capita GDP is estimated at US$ 224 (MOF, 2002) which is one among the lowest in the world because of lack of natural resources and industries. Agriculture is the mainstay of the economy, providing a livelihood for over 80 % of the population. In the fiscal year 2001/02, the share of agriculture in GDP was 37.9 %. The total land used for agricultural operation was 20.2 % of the total area of Nepal. Industrial activity mainly involves the processing of agricultural product including sugarcane, tobacco, jute and grain. Apart from agricultural land and forests, exploitable natural resources are hydropower and tourism. Table 2.3 presents the GDP (at factor cost), Population, Exchange rate and per capita GDP while Figure 2.1 shows the trend for GDP, Population and per capita GDP. Past data demonstrates that there have been improvements in per capita GDP (current price) in the last one-decade by over 40 %.

Table 2.3: GDP, Population, Exchange Rate and per Capita GDP

	1985/86	1990/91	1994/95	1995/96	2000/01
GDP (Current million US$)	2,498	3,063	4,276	4,773	5,354
Population (Million)	16.7	18.5	20.2	20.7	23.2
Exchange rate (NRs/US$)	21.3	37.9	49.1	50.45	74.0
GDP per capita (Current US$)	150	166	211	230	231

Source: MOF, 2002



Source: MOF, 2002 and CBS, 2001

Figure 2.1: GDP, Population and Per Capita GDP Trend

Major economic indicators (Table 2.4) show some degree of stability in terms of investment, saving and consumption with respect to GDP, which can also be interpreted as stagnant economy. Therefore, the economy of Nepal has not really been vibrant and growing.

Table 2.4: Major Economic Indicators of Nepal

(in Million NRs)

	1985/86	1990/91	1994/95	1995/96	2000/01
Real GDP at Factor Cost (1984/85 price)	46,512	59,767	71,686	75,744	95,678
Agriculture	23,393	28,394	29,919	31,054	36,802
Non-agriculture	23,061	31,319	41,747	44,439	58,757
Total Investment/GDP	19.9	21.6	26.3	28.4	18.1
Gross Fixed Capital Formation/GDP	43.3	27.0	19.9	18.6	9.5
Total Consumption/GDP	93.7	93.7	88.9	89.6	61.3
Gross Domestic saving/GDP	11.1	9.9	15.5	14.4	10.0
Gross National Saving/GDP	12.7	12.0	18.1	16.2	11.4
National Urban Consumer Price index	36.5	59.8	92.5	100	138.1

Source: MOF, 2002

The government expenditure also exceeds the revenues every year and this deficit in budget is covered up by external and internal loans (Table 2.5). In external trade also Nepal has deficit every year i.e. imports have exceeded exports every year, which is the main cause of imbalance of international payments.

Table 2.5: Trade and Government Budget

(in Million NRs)

	1985/86	1990/91	1994/95	1995/96	2000/01
Trade Balance	(4,712)	(13,559)	(22,766)	(33,591)	(39,582)
Export and Non Factor Services	6,506	14,226	53,084	55,405	91,821
Import and Non Factor Services	11,218	27,785	75,850	88,996	131,403
Budget Deficit	(4,045)	(10,591)	(10,204)	(13,671)	(24,188)
Revenue	5,818	12,895	28,512	32,718	55,647
Internal Revenue	4,645	10,730	24,575	27,893	48,894
Foreign Grant	1,173	2,165	3,937	4,825	6,753
Expenditure	9,863	23,486	38,716	46,389	79,835
Regular	3,584	7,574	19,264	21,562	42,769
Development	6,280	15,912	19,452	24,827	37,066

Source: MOF, 2001

With a Human Resource Development Index of 0.332, Nepal ranks 151 among 174 countries (HRD, 2001). However, Nepal has considerable scope for accelerating economic growth by exploiting its potential in hydropower and tourism; these are the areas of recent foreign investment interest. However, there are still some difficulties in these sectors because of the

small size of Nepal's economy, its technological backwardness, remoteness, landlocked geographic location, and its susceptibility to natural disasters.

Poverty in Nepal is widespread with about 38 % of the population living below the nationally defined poverty line in 1999. However, if the definition of 'US dollar a day' poverty line is applied, which is often used for the purpose of making international comparison of poverty, then the incidence of poverty in Nepal turns out to be 37 %. Nepal Living Standard Survey, 1996, conducted by the Central Bureau of Statistics, however, estimated the incidence of poverty in Nepal to be about 42 % (World Bank 1999). Large segments of the poor are hardcore poor barely keeping themselves alive and living on fragile and vulnerable ecosystems, and large areas of the country lack even the most basic infrastructure. There are wide variations based on rural-urban divide, geography, ethnic group and occupational caste (Table 2.6).

Table 2.6: Poverty Measures for Nepal (1995/96 Survey)

Ecological Zone	Head-count Index (Population below the poverty line*)	Poverty-gap Index
Mountain	0.56 (0.059)	0.185 (0.027)
Hills	0.41 (0.031)	0.136 (0.014)
Terai	0.42 (0.025)	0.099 (0.009)
Sector		
Urban	0.23 (0.058)	0.070 (0.025)
Rural	0.44 (0.020)	0.125 (0.008)
National Average	0.42 (0.019)	0.121 (0.008)

* Poverty line of NRs. 4,404 per person per annum.
Source : Concept Paper on PRSP/10th Plan, National Planning Commission, Nepal, February 2002.
Note : Figures in the parentheses are standard errors adjusted for stratification and clustering in the sample

2.4 Forest and Land use

About 80 % of the population of Nepal depends on the forests for daily fuel wood supply and 42 % on the fodder for livestock as these are extracted from the forest (WECS, 1997). Therefore, forest stands as one of the most important natural resources to meet three basic needs of the people in Nepal, namely firewood, fodder and timber.

In Nepal, major land use categories are: forest including shrub 39.6 %; agriculture including non- cultivated land 27 %; grassland 11.8 %; and others 21.6 % (Table 2.7). Land categorized as forest also includes shrub-land with less than 10 % crown cover. Of the total forestland, 35 % is in the hills and one-third in the mountain region. The land-use

data show 2.97 million ha as cultivated agricultural land, 0.99 million ha as non-cultivated agricultural land, 5.8 million ha as forests (including shrubs), 1.7 million ha as pasture land, and 3.1 million ha of other category (UNEP, 2001).

Table 2.7: Land Use Pattern of Nepal

Land-use type	Area ('000 ha)	(Percent of total area)
Cultivated land	2,968	20.2
Non cultivated land	998	6.8
Forest	4,269	29.0
Shrubs lands/degraded forest	1,559	10.6
Grass land	1,745	11.8
Others	3,179	21.6
Total	14,718	100

Source: UNEP, 2001

On the average, about 65 % of the total cultivated land is rain-fed. The Terai plains constitute 43 % of the total cultivated land. Up to 1999/00, the total irrigated area was 0.992 million ha. The land distribution is also very uneven. About 62.8 % of the land is owned by 16.1 % of the farmers. The per capita agricultural land declined from 0.16 ha in 1980 to 0.13 ha in 1999.

Forest constitutes Nepal's largest natural resource in terms of coverage. However, the forest area, which was 45 % in 1966, has declined considerably and the shrub land area has doubled from 4.8 % in mid 1980s to 10.6 % in mid 1990s. The annual deforestation rate in average is estimated to be 1.7 % with 2.3 % in the hills and 1.3 % in the Terai (FRIS, 1999). Similarly, the growing stocks of forest have declined from 522 million m^3 in mid-1980s to 387.5 million m^3 in 1999.

The annual per capita fuel wood consumption in the hills is about 640 kg whereas it is 479 kg per person per year for the Terai. The per capita timber consumption was estimated at 0.07 m^3 per year in 1985 and found to have increased to 0.11 m^3 per year by the year 2000. Based on this, national timber demand is estimated to be about 2.5 million m^3/year.

2.5 Bio-diversity

Although Nepal occupies only 0.03 % of the total surface of the earth, it has nearly 4.5 % and over 9 % of mammalian and bird species of the world total respectively (MOPE, 2001). The immense bio-climatic diversity in Nepal supports more than 35 forest types (Stainton, 1972). They are home to 5833 species of flowering plants, including about 248 species of endemic plant and 700 species of medicinal plants. Nepal's landmass is also home to 185 species of mammals, 847 species of birds, 645 species of butterflies, 170 species of fishes and other animals. Presently, 26 species of mammals, 9 species of birds and 3 species of reptiles are declared endangered and are being protected by Nepalese laws (MOPE, 2001).

Floral species and faunal species are conserved within and outside the protected areas. So far, 18.32 % of the total land area of Nepal have been designated as protected areas (National Park, Wildlife Reserve, Conservation Areas, and Hunting reserve including Buffer Zones). Therefore, Nepal is one of the richest countries in the world in terms of bio-diversity due to its unique geographical position and altitudinal variation from 60 m to 8848 m, all within a short distance of 193 km in average.

2.6 Water resources

Nepal is one of the richest countries in terms of water resources with the monsoon contributing a significant proportion in water regime. As a result, several sources of water in the form of glaciers, snow pack, groundwater, and river networks exist in Nepal. The country is drained by about 6000 rivers and streams including 3 major river basins: Sapta Kosi in the east, Karnali in the west and Sapta Gandaki in the central part the country (Upadhyay, 2000). The annual run-off from the total drained areas is estimated to be 202 billion m^3 (HMG, 1992). The contribution from the Nepalese territory accounts to an annual run-off of 170 billion m^3 (HMG 1992). About 4063 sq km is estimated to be covered by surface water, of which 97.3 % is under the large rivers followed by natural lakes (1.2 %), ponds (1.2 %) and reservoirs (0.3 %) (HMG, 1992). The area under snow & ice is 17,920 km^2which represents about 13 % of the country's total area (WECS, 1988). There are 3,252 glaciers and, 2,323 glacial lakes so far identified in Nepalese Himalayas. Among them, 20 glacial lakes are reported to have the possibility of bursting their banks in five to ten years time with catastrophic results unless urgent action is taken (Mool, 2001). Nepal's Terai belt has rechargeable ground water potential, which occurs in both artesian and non-artesian aquifers. Studies show that ground water table occurs at a depth of 5 m in

the plains. while artesian aquifers yields about 100 cu. m. /hr. Ground water is used for irrigation and for meeting drinking water needs through shallow tube wells at individual levels (Sharma, 1983). Deep tube wells at several district headquarters are supplying drinking water requirements. In the inner valleys and hills, ground water is limited, and wherever it occurs, the recharging characteristics are not clearly understood but its recharging capability is generally low. In Kathmandu, the use of ground water at its current rate appears to be unsustainable, as the total annual extraction is presently estimated at 23.4 million cubic meters, which is greater than the maximum recharge estimate of 14.6 million cubic meters. The effect of groundwater mining and pollution in the Kathmandu Valley is alarming and needs urgent attention (WECS, 2002).

The steep topography and high run-off offer opportunities for generating hydropower in the corridors of Nepal Himalayas. The theoretical potential on the basis of average flow is estimated to be 83000 MW electricity (Shrestha, 1968), out of which 44,600 MW has been assessed to be technically feasible, while 42,130 MW (50.6 %) could be economically harnessed (Sharma/Adhikari, 1990). Several sites to generate hydropower through large and medium schemes have been identified. Similarly, several sites for developing surface water irrigation through run-off river schemes have been identified in the Terai. Besides, the southern stretches of the three big rivers could be developed for some form of inland navigation.

2.7 Mineral Resources

In the past, Nepal was known as a mineral producing country and the metals such as iron and copper were exported to Tibet. But on the present day perspectives, most of existing mineral deposits are known to be small and unprofitable. Exploitation of these deposits on the basis of their known grade and extent is not encouraging. However, during the tube well drillings for water, leakage of inflammable gas has been noted at different localities in Kathmandu Valley. The total reserve of natural gas from whole of the prospective area is expected to be around 300 million m^3. Gas leakage is also noted near the shrine of Muktinath in Thakkhola region, and is also known to occur in Dailekh area. The exploration carried out so far has not revealed petroleum products that could be commercially exploited. However plans are in place to continue efforts to explore and establish commercially attractive petroleum product reserves.

Exploration has revealed large deposits of lime-stones in Chobar which is in the southern fringe of Kathmandu Valley with huge production potentials; about 15.3 million tons of limestone are estimated to exist there down to an average depth of 60 m. In addition, 10 million tons of proved cement grade limestones are known to exist in average down to a depth of 60 m in Bhaise Dovan in Makwanpur district. High-grade limestone reserve of 70 million tons is also known to occur in Udayapur. Further, 10 million tons of cement grade limestone in Dhankuta, 30 million tons in Surkhet, 18.74 million tons in Katari, 5.84 million tons in Panauti are the expected reserves waiting to be exploited in near future.

As for the coal, apart from the low quality lignite deposits of Kathmandu valley, commercial coal deposits of Dang supplies about 25 % of the total demand of coal in Nepal. (Sharma & Thapa, 2000).

CHAPTER - 3

National Greenhouse Gas Inventory

3.1 Introduction

This National Inventory of Greenhouse Gases (GHGs) stands as the second official inventory of GHG emissions in Nepal. The first inventory was undertaken for the base year 1990/91 and was prepared in 1997 (DHM, 1997). Department of Hydrology and Meteorology, HMG/N, had conducted the study with the financial assistance from USAID/Nepal. Besides presenting a 1990/91 inventory of GHGs then, the study had also evaluated some of the potential impacts of global warming in Nepal.

Nepal's present Inventory of Greenhouse Gases for the year 1994/95 is the result of recent studies conducted by various researchers in the country. In estimating the 1994/95 GHG emissions, the experts/researchers used the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997). To the extent possible, they have used published information on various GHG sources and sinks related activities, and completed the inventory using mostly the default emission factors recommended by the IPCC.

Still, many gaps in knowledge exist. The continued research as such would be invaluable in further quantification of GHG emissions and in generating additional scientific and technical information closer and more suitable to local conditions and circumstances. Further basic research, field observations and testing are needed to improve the quality of the data to reduce uncertainties and to enhance understanding of the relationship of the emissions with production activities. Obviously there is also a need for additional research or studies to derive local emission factors that realistically aid in working out the more refined Nepal's GHG emissions.

Table 3.1 shows detailed breakdown of Nepal's National Inventory of GHG emissions for 1994/95. Gross emissions of Carbon dioxide (CO_2), the main Greenhouse Gas, amounted to 24,525 Gg in 1994/95. However, due to carbon sequestration from reforestation activities and the re-growth of natural vegetation on abandoned lands net emissions of CO_2 were found to be 9747 Gg.

The total Methane (CH_4) emissions were estimated at 948 Gg in 1994/95. Most of the emissions were from Agriculture sector (867 Gg), out of which rice and enteric fermentation constituted 827 Gg. The crucial issue on CH_4 emission is that the bulk of CH_4 emissions came from activities that are closely linked to the livelihood of about 80% of the total population of Nepal. Any mitigation measures undertaken, therefore, could have serious implications for the local socio-economic and cultural environment. In 1994/95, Nepal also emitted about 31 Gg of Nitrous oxides (N_2O) to the atmosphere. Other than this, Nepal did not attempt any estimation of NO_x, CO and NMVOC.

Table 3.1: Nepal's National Greenhouse Gas Inventory in 1994/95 (Gg)

Greenhouse Gas (Source and Sink Categories)	CO_2 Emission	CO_2 Removal	CH_4 Emission	N_2O Emission
1. Energy	**1465**		**71**	**1**
A. Fuel Combustion	1465		71	1
Energy & Transformation Ind.	71			
Industry, Mining & Construction	320			
Transport	456			
Other sectors	618		71	1
B. Fugitive Emissions from fuels	0			
2. Industrial Processes	**165**			
A. Mineral Production	165			
Cement Production	163			
Lime Production	2			
3. Solvent and Other Product Use	**0**			
4. Agriculture			**867**	**29**
A. Enteric Fermentation			527	
B. Manure Management			34	2
C. Rice Cultivation			306	
D. Agricultural Soils				27
5. Land Use Change & Forestry	**22895**	**-14778**		
A. Changes in Forest & Other Woody Biomass Stocks	0	-14738		
B. Forest & Grassland Conversion	18547			
C. Abandonment of Managed Land		-40		
D. CO_2 Emission and Removals from Soil	4348			
6. Wastes			**10**	**1**
A. Solid Waste Disposal on Land			9	
B. Wastewater Handling			1	
C. Waste Incineration				
D. Other				1
Total Emission and Removal	**24525**	**-14778**	**948**	**31**
Net Emission	**9747**		**948**	**31**

Using the Global Warming Potential (GWP) factor, the total emission of the main GHGs of Nepal in 1994/95 has been calculated to be 39265 in Carbon dioxide equivalent. Of this total, CO_2, CH_4 and N_2O constituted 25, 51 and 24 percent respectively (Table 3.2).

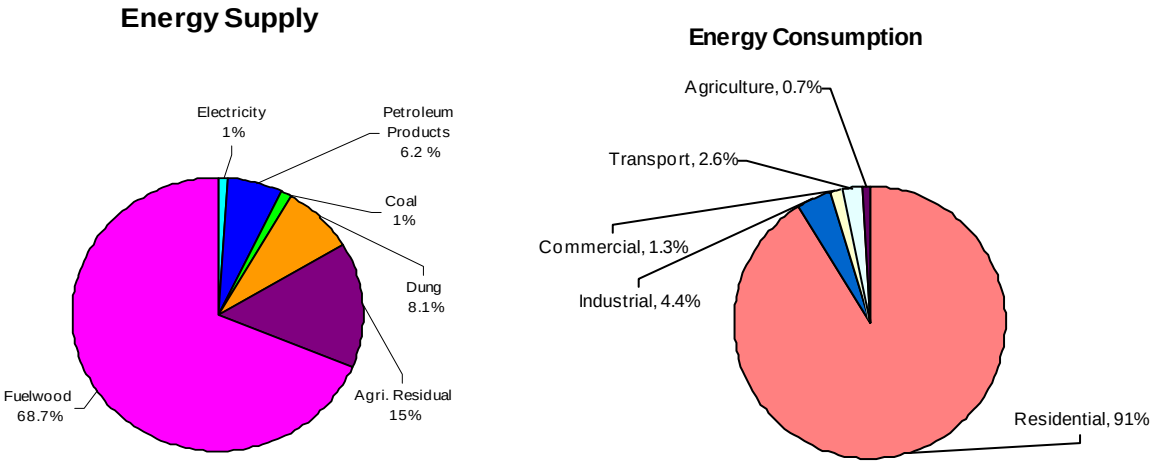
Table 3.2: Total CO_2 Equivalent Emissions of Nepal in 1994/95

	Emission (Gg)	Global Warming Potential (GWP)	CO_2 Equivalent	% of Total
CO_2	9,747	1	9,747	25
CH_4	948	21	19908	51
N_2O	31	310	9610	24
Total			39265	100

3.2 Energy

Nepal's energy resources consist of a combination of traditional and commercial sources. Traditional sources include fuel wood, agricultural residues, and animal wastes (dung) whereas commercial sources include hydropower and imported petroleum fuels. In addition, Nepal carries a diverge range of new and renewable energy sources like biogas, solar, wind and modern biomass energies. New and renewable sources of energy supply contribute to the country's overall energy in a modest proportion only.

The total energy consumption of Nepal in the year 1994/95 was estimated to be about 285 million GJ. About 92 percent of this energy consumption was met by traditional energy sources and the rest by commercial energy sources. Energy consumption estimates are segregated sector-wise into residential, industrial, commercial, transport, agriculture and others. Figure 3.1 depicts energy supply by fuel type and consumption by different sectors.



Total Consumption: 285 Million GJ

Source: WECS 1996

Figure 3.1: Energy Supply and Consumption of Nepal in 1994/95

As can be seen, a large amount of biomass (e.g., fuel wood, agricultural residue and animal dung) is still consumed as fuel for households, commercial establishments and industry. Some 12 million tones of fuel wood and 3.4 and 2.1 million tones of agricultural residue and animal dung respectively were estimated to have been burnt as fuel in 1994/95. To avoid double counting of emissions, the GHGs emitted from their use have been accounted for in the agricultural and forestry sector inventories.

Due to the increase in population in the country, both traditional as well as commercial fuel use are increasing rapidly resulting into more CO_2 emissions and other consequences including deforestation. This has made CO_2 emissions from energy sector the second largest contributor after land-use change and forestry. In fact GHG emission from land-use change and forestry also includes emission from use of fuel wood as energy. Other emissions, e.g. CH_4, N_2O, etc. from fuel wood consumption have not been estimated under the current inventory.

3.2.1 GHG Emissions from Fuel Combustion

The current inventory of GHG emissions from energy consumption takes into account all emissions from fossil fuel combustion. The estimates of GHG emissions from this sector carry least uncertainties; in other words, they are much reliable, being mainly the fossil fuels,

since consumption in this sector has been studied extensively and is well documented due to planned monetary transactions involved. The commercial nature of such transactions in this sector also makes it easy to assess GHG abatement options and their quantification as well, thus in turn making decisions and taking actions relatively easy.

Since there are no country specific emission factors in Nepal for emission assessment, default values suggested by IPCC guidelines are used whether in net calorific value estimation or in CO_2 emission studies or in fractions of carbon oxidization. Emissions from the use of fossil fuels from international bunkers are excluded in the current national GHG estimations. Therefore, CO_2 emissions from aviation fuel burning are not accounted for in the national inventory but are reported in memo-section, which amount to 69 Gg in the year 1994/95.

Thus the total CO_2 emissions from the combustion of fossil fuels amounted to 1,465 Gg in 1994/95 (Table 3.3). As the largest consumer of fossil fuels, transport sector emitted the largest share of CO_2 (31 %) followed by the industrial and the residential sectors (22 % each). When combined, these three sectors emitted more than 75 percent of CO_2 emissions. This CO_2 emission from consumption of fossil fuels in Nepal, compared to the world total, is highly insignificant.

The contribution of each sector to total GHGs may be misleading, however, because an economic sector that consumes large amounts of secondary forms of energy such as electricity, do not reflect the amount of emissions from the fuel's transformation. These emissions are accounted for in the energy supply sector. Thus, although consuming a large part (25 %) of total electricity produced in 1994/95, the commercial sector contributed 11 % to overall fossil fuel-derived CO_2 emissions.

Methane is also produced from energy related combustion activities, such as bio-mass burning, incomplete combustion of fossil fuel etc. Hence, Methane emissions are calculated from combustion of coal, gasoline, diesel and biomass. For the base year 1994/95, total Methane emissions from these sources were 71 Gg. Also, Nitrous oxide is produced from energy related combustion activities. The total Nitrous oxide emission from this activity was 1 Gg in base year 1994/95.

Methane emissions from very small-scale mining operation for lignite in Kathmandu and Dang valley and negligible activities of natural gas extraction in the country have not been accounted for and reported here.

Table 3.3: GHG Emissions from Fossil Fuel Combustion in Nepal in 1994/95 (Gg)

Sectors	Diesel	Kerosene	Coal	Gasoline	LPG	Fuel Oil	Total
Residential	-	291	2	-	24	-	317
Industrial	73	6	233	-	-	8	320
Transport	360	19	2	75	-	-	456
Agricultural	135	-	-	-	-	-	135
Commercial	4	113	26	-	15	8	166
Energy Conversion	-	-	-	-	-	71	71
Total	572	429	263	75	39	87	1,465

Sources: WECS 1996
Note: These exclude emissions from the burning of aviation fuel.

3.3 CO_2 Emissions from Industrial Processes

Industrial production processes produce various types of Greenhouse Gases apart from energy combustion in industries. These processes involve the chemical or physical transformation of raw materials into intermediate or final products. The amounts and types of GHG emitted by industrial processes depend on the quantities of raw materials used as well as the nature of conversions and their efficiencies.

The mass balance approach has been used in current estimation for different types of manufacturing processes. GHG emissions were worked out for two major industries, namely, cement and lime. GHG emissions from industrial processes in pulp and paper and food and beverage industries also might be of a comparable quantity but due to paucity of data and their non reliability they have not been estimated and accounted in the current GHG inventory. A total of 165 Gg of CO_2 is estimated to have been emitted during the year 1994/95 from the cement and lime industrial processes. Between these two, the cement industry is estimated to have accounted for nearly all CO_2 emissions (163 Gg) and only about 2 Gg of CO_2 was released from lime production.

3.4 Agriculture

Agriculture sector, being the main source of livelihood for about 80 % of the population, plays an important role in the economy and society of Nepal. Besides, this remains as an important source of labor, especially during the non-rainy season when labour requirement for agricultural activities is less, for example, in post harvest and pre harvest seasons. A number of agricultural practices and activities such as manure composting, flood irrigation for rice cultivation, etc. are known to produce adverse environmental consequences including GHG emissions. Despite the gradual reduction in its contribution to the country's total economic output, the agriculture sector continues to provide the basis for an agro-based manufacturing sector.

Agriculture sector is also one of the major sources of GHG (Methane and Nitrous oxide) emissions in Nepal. The three major sources of GHGs in this sector are domestic livestock, rice cultivation and agricultural soils. The estimate for these emissions in the current study is based on following agricultural activities:

1. Methane (CH_4) emission from cultivation of rice
2. Methane (CH_4) and Nitrous oxide (N_2O) emission from domestic livestock due to the process of enteric fermentation and from manure and animal waste managements, categorized as follows:
    a. CH_4 emissions from enteric fermentation in domestic livestock
    b. CH_4 emissions from manure management
    c. N_2O emissions from manure management
    d. N_2O emissions from agricultural soils

In addition to above, agricultural crop waste burning and other activities are also a source of Nitrous oxide, Carbon monoxide, and Nitrogen oxides release to the atmosphere but are considered to be insignificant in Nepal (DHM, 1997) and has been excluded in the present study. Other sources e.g. prescribed burning of savannas and field burning of agricultural residues are also insignificant in Nepal.

The total Methane emissions from agricultural sector in Nepal for the year 1994/95 was estimated to be 867 Gg. Emission from enteric fermentation in livestock covers 61 % of this emission total; rice cultivation covers 35 % and the remaining 4 % was covered by livestock manure management. The trend of total Methane emission from livestock (enteric

fermentation and manure management) shows the growth rate of about 7.23 Gg per year. Likewise the total Methane emission from rice cultivation is also found to be increasing at the rate of 2.59 Gg per year.

In the base year 1994/95, total Nitrous oxide emission from agricultural sector was estimated to be 29 Gg in which 27 Gg was contributed by agriculture soils and 2 Gg by animal waste management system (Table 3.1).

3.4.1 Methane Emissions from Cultivation of Rice

Anaerobic decomposition of organic material by methanogenic bacteria in flooded rice fields produces Methane, which escapes to the atmosphere primarily by diffusive transport through the rice plants during the growing season. The amount of Methane that gets released to atmosphere will be as much as 10 to 40 percent of the produced Methane and rest of it will be oxidized by aerobic methanotrophic bacteria in the soils (Holzapfel-Pschorn et al., 1985; Sass et al., 1990). Some of the Methane are also leached away as dissolved Methane in floodwaters that percolate down the field. Some Methane also escapes from the soil via diffusion and bubbling through the floodwaters.

The water management system and the duration and depth of flooding, under which rice is grown, are some of the most important factors affecting Methane emissions. Upland rice fields are not flooded, and therefore, are not subjected to produce Methane. Other factors that influence Methane emission from flooded rice fields are soil temperature, soil type, and fertilizer-use and cultivation practices. However, the extent of the influence of these factors in combination has not been well quantified.

Table 3.4 shows Rice cultivation area under different water management regimes in Nepal for the year 1994/95. Areas of upland rice cultivation are negligible in Nepal and hence not counted for in this study. Similarly, deep-water management system is not applicable in Nepal. Further, farmers have the tendency to make the field continuously flooded and, hence, single and multiple aeration are also not applicable. The total Methane emission from paddy fields in Nepal for 1994/95 was calculated to be 306 Gg which was 35 % of the total Methane emissions in Nepal from agricultural sector. Methane emission from irrigated and continuously flooded rice fields accounted for 41 % of the total Methane emissions from paddy fields in Nepal. Drought prone rain-fed rice cultivation emitted 48 % of the total

Methane emission from paddy fields, and the remaining 11 % Methane was contributed by flood prone rain-fed rice cultivation.

Table 3.4: Rice Cultivation Area under Different Water Management Regimes in Nepal in 1994/95

Water Management Regime	Harvested Area		Scaling Factor for CH_4 Emission	Organic Amendment Correction Factor	Other Correction Factor * (g/m^2)	CH_4 Emission	
	Area in (m^2x10^9)	%				Gg	%
Irrigated Continuously Flooded	3.1474	24	1	2	20	126	41
Rainfed Flood Prone	1.0947	8	0.8	2	20	34	11
Rainfed Drought Prone	9.0316	68	0.4	2	20	146	48
Total	13.2738	100				306	100

* Seasonally Integrated Emission Factor for Continuously Flooded Rice without Organic Amendment

3.4.2 Methane Emissions from Domestic Livestock

a) Enteric Fermentation

Methane emissions from the ruminant animals are more important than the non-ruminant animals. The major livestock in Nepal includes both ruminants and non-ruminants and they are cattle, buffalo, sheep, goat, swine and poultry. Emission calculations are derived based on the published animal population data (MOA, 2000) and default emission factors from IPCC Guidelines.

Livestock population and Methane emissions from enteric fermentation for different animal types are shown graphically in Figure 3.2. The total Methane emission for 1994/95 from domestic livestock enteric fermentation has been estimated to be about 527 Gg. Non-diary cattle contributes the highest emission, which amounts to 280 Gg, i.e. about 53 % of the total emission from livestock enteric fermentation. Next to this, buffaloes are also found to be the significant source of Methane through their enteric fermentation contributing about 32 % because of their high numbers, large sizes and ruminant digestive systems. Remaining animals contributed the rest of the Methane emission total. Diary-cattle and goats contributed approximately 8 % and 5 % respectively to the total Methane emission by enteric fermentation. Other animals e.g. sheep and swine, contribute less than 1 %. It is clear from the figure that the emission was dependent on the animal population except in the case of

goats, where despite their large numbers, Methane emission from this enteric fermentation was only 27 Gg.

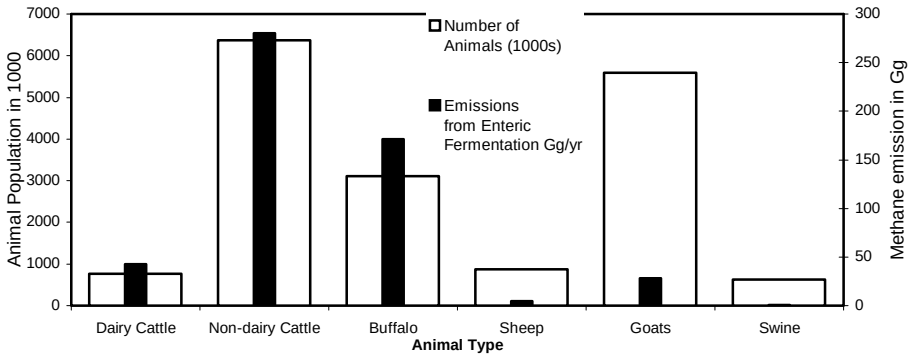


Figure 3.2: Methane Emission from Livestock Enteric Fermentation in 1994/95

b) Manure Management

Methane is also produced from organic material in the animal waste manures when they decompose in an anaerobic environment. Liquid system manure management produces a significant amount of Methane and is affected by the climatic environment in which the manures decompose. The composition of the manures, which depends on the consumption and digestibility of the animal, also affects the amount of Methane produced. The emission amount increases with the increase in energy content and digestibility of the feed.

Estimate of Methane emissions from manure management is also based on livestock population and emission factors supplied by IPCC Guidelines. Average emission factor suitable for Nepal is calculated by using animal population weighted average over various physiographic regions, namely Terai, hills and the mountain regions. The IPCC Guidelines provide emission factors for most livestock types with different values for developed and developing countries to reflect their different conditions and typical practices. Factors are also provided for three different climatic zones, e.g. cool, temperate and warm.

The livestock population and Methane emissions from manure management for different animal types are shown graphically in Figure 3.3. Total Methane emission from domestic livestock manure management system has been estimated to be 34 Gg for the year 1994/95. Diary cattle contributed the highest emission amounting to 15 Gg, i.e. 44 % of the total emission from livestock manure management. Next to this, non-diary cattle

contributed 26 % of the total. Likewise, buffalo and swine shared 21 % and 9 % of the total emissions respectively. Diary and non-diary cattle were found to be the most notable sources of Methane in manure management. Rest of the animals (sheep, goats and poultry) was the least contributor to the Methane emission total as can be seen in the Figure 3.3.

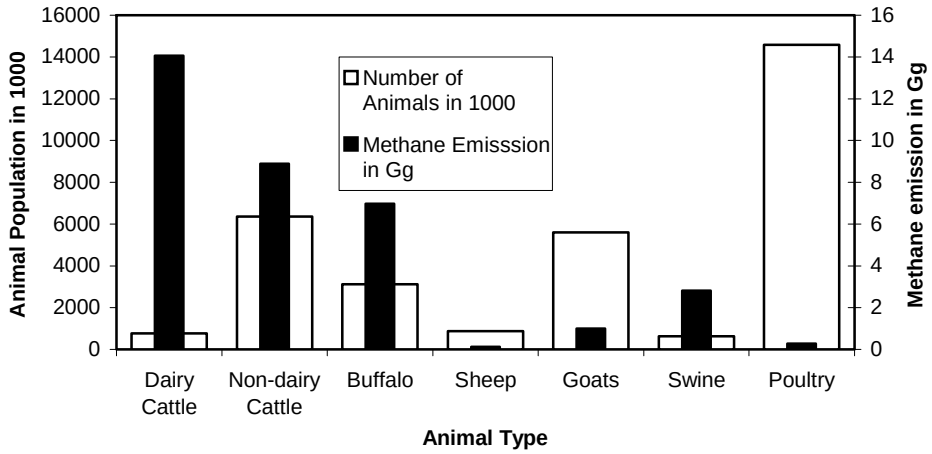


Figure 3.3: Methane Emission from Livestock Manure Management in 1994/95

3.4.3 Nitrous Oxide Emissions from Livestock and Agricultural Soil

a) Animal Waste Management System

Some manure nitrogens are converted to N_2O while managing the animal wastes. N_2O emission estimates include the gas produced this way in the manure handling before the artificial fertilizer is added to the soil. The Animal Waste Management System (AWMS) is divided into six different types in IPCC Guidelines -- anaerobic lagoons, liquid systems, daily spread, solid storage and dry-lot, pasture range and paddock, and "other systems". In this study, N_2O emissions from daily spread and pasture range have been reported following this classification. These emissions are reported here under agricultural soils. Default emission factor provided by IPCC guidelines for manure management has been used to work out the total annual emissions of N_2O for each type of waste management system. The total Nitrous oxide emission from different animal waste management systems were estimated to be about 2 Gg for 1994/95.

The majority of the emissions was contributed by solid storage and dry-lot, which was about 94 % of the total under AWMS. Liquid system, anaerobic lagoons and ‘others’ contributed

the remaining 6 %. The distribution of emissions of total N_2O among various animal waste management systems is shown in the Figure 3.4.

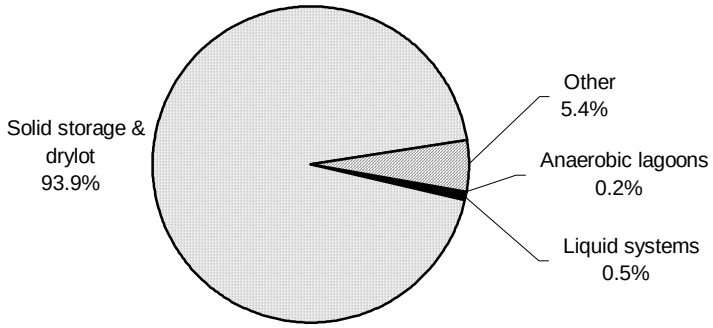


Figure 3.4: N_2O Emission from Animal Waste Management System in 1994/95

b) Agricultural Soil Management

A number of human activities adds nitrogen to the soil. These additional nitrogen increase nitrification and denitrification processes due to microbial activities in soils that contribute to the increased amounts of Nitrous oxide emissions. Number of researches have pointed out that factors like water content, temperature, nitrogen concentration, availability of organic carbon for microbial activity and pH of soil are responsible for the amount of Nitrous oxide emissions. However, the exact interaction of these conditions and their combined effect on the processes leading to Nitrous oxide emissions are not fully understood (U. S. Country Report, 1995). This study also reports Nitrous oxide emission from the anthropogenic use of fertilizers. Synthetic nitrogen fertilizers, synthetic multi-nutrient fertilizers, and organic fertilizers are included in the emission estimate calculation.

Total Nitrous oxide emission from agricultural soil management system in Nepal was 27 Gg in 1994/95. Among the various processes, the indirect Nitrous oxide emissions from grazing pasture range and paddock contributed about 41 % of this total. Direct Nitrous oxide emissions from agriculture fields, excluding cultivation of histosols, amounted to 31 % and the least contribution (28 %) was by indirect Nitrous oxide emissions from atmospheric decomposition of Ammonia (NH_3) and NO_x as well as leaching. These distributions are depicted in the Figure 3.5.

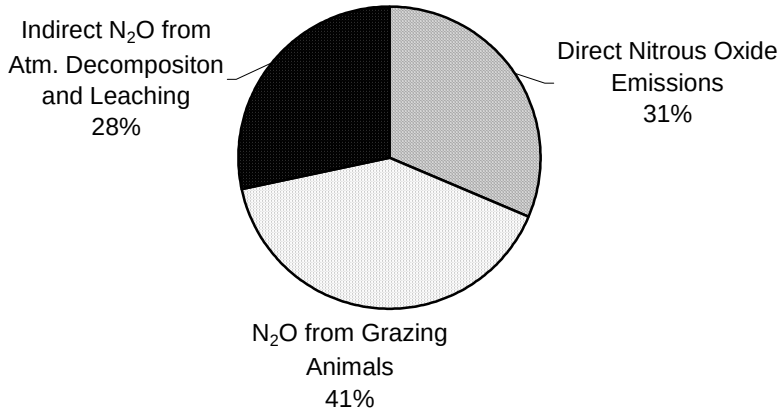


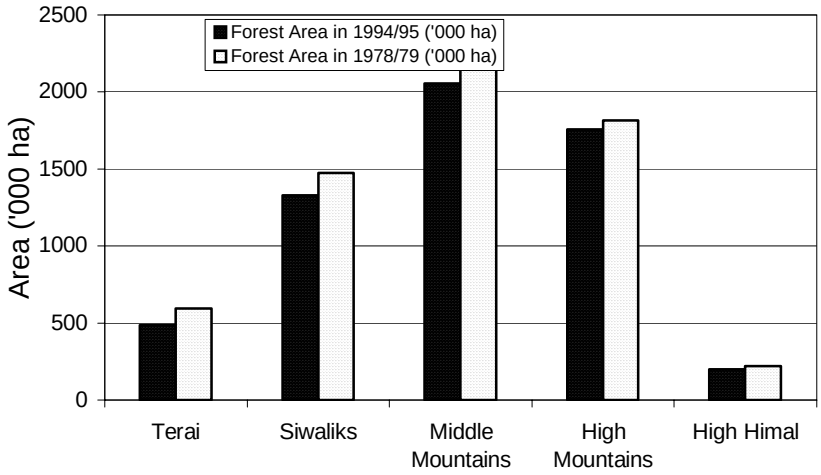
Figure 3.5: N_2O Emission Distribution from Agricultural Soil Management in 1994/95

3.5 Forests and Land-Use

Forests act both as a source and a sink for CO_2. Carbon dioxide is produced when forestland is cleared for non-forest uses such as agriculture and settlements. Forests absorb CO_2 from the atmosphere through the process of photosynthesis during the period of growth. The amounts of CO_2 emitted and sequestered by forests are very difficult to be estimated because of complex biological factors and the lack of reliable data, especially with regard to the rate of change of land-use, the use of converted forestland, and the biomass density of forests. In some cases where published data are not compatible or not detailed enough as required by the IPCC Guidelines, assumptions or generalizations have been made for preparing this inventory. A few cases of forest fire in the dry season is a common phenomenon in Nepal but due to the lack of data, GHG emissions from them has been ignored. All relevant land-use management practices where data are available have been included in this inventory.

According to the latest published report of the Department of Forest Research and Survey (DFRS, 1999) the forest area in 1994/95 has been estimated at 4,268.8 thousand ha, which is about 29 % of the total territory of the country. The forest cover in 1978/79 was about 5,616.8 thousand ha, covering around 38 % of total territory of Nepal (LRMP, Land Utilization Report, 1986). The difference has been cited for deforestation or depletion rate of forests, which amounts to 1.7 % between the periods of 1978/79 and 1994/95 (Figure 3.6). In total 1,348 thousand ha of forest land i.e. more than 9 percent of the total forest covers had been converted to the other land-use/land cover categories. During that period, shrub land doubled from 689.9 thousand ha (4.7 %) to 1,559.2 thousand ha (10.6 %). Combining the forests and shrub lands (woody vegetation) together, annually about 29 thousand ha of woody vegetation areas can be

found converted to non-woody vegetation areas (Table 3.5). This is a clear indication that forest resources were subjected to exploitation beyond its sustainable growth.



Source DFRS 1999; LRMP,1986

Figure 3.6: Deforestation in Different Physiographic Zones of Nepal from 1978/79 to 1994/95

Table 3.5: Changes in Forest Areas 1978/79-1994/95

Vegetation Types	Area in 1978/79 ('000 ha)	Area in 1994/95 ('000 ha)	Rate of Change
Forest	5616.8	4268.8	-1.7 %
Shrub	689.9	1559.2	5.2 %
Total	**6306.7**	**5828**	**-0.5 %**

Source: Forest Resources of Nepal (1987–1998), Publication No. 74, 1999, Department of Forest Research and Survey, Kathmandu, Nepal

In this sectorial study/assessment, total CO_2 emissions from forest and land management in Nepal in the year 1994/95 has been estimated at 22,895 Gg. The estimates are based on following activities:

1. Emission and removal of CO_2 from changes in woody biomass;
2. CO_2 emission from forests and grassland conversions;
3. Removal of CO_2 from abandonment of managed lands;
4. CO_2 emission and removal from soils;

More refinements will be needed to improve the quality of the inventory as follow-up in the future. There are varying degrees of uncertainty in data sources as well as coefficients, specifically in the area of estimation of loss of soil carbon.

3.5.1 Emission and Removal of CO_2 from Changes in Woody Biomass

About 80 % of total energy consumption in Nepal is obtained from fuel wood, of which about 63 % comes from forestland (WECS, 2001). Of the total fuel wood consumption, only 27 % is estimated to have been extracted on a sustainable basis, and the remaining from over-cutting. Some parts of the country have surplus fuel wood on a sustainable yield basis whereas most parts are in deficit. Due to very high transportation costs and lack of transport infrastructures, fuel wood from the surplus region cannot be transported to the deficit part of the country. Nepal's forests also suffer from open grazing, lopping and illegal cutting. The actual annual growth rate is below the normal growth rate and varies from 0.59 to 2.34 tons dry matter per hectare per year (WECS, 2001). Therefore this growth rate used in this inventory is lower than the IPCC supplied values. Using the normal growth rate of WECS, 2001, biomass increments and carbon uptake have been estimated in the Table 3.6.

Agro-forestry, an indigenous practice in the hilly region of Nepal, and private plantations in Terai and community forest management have resulted in positive impact on tree-stock. Especially the fodder species and plantation for timber in the farmlands and in the non-cultivated land are prevalent. Agriculture Census of Nepal (1991) has revealed that the woodlands and forest have increased from 15 thousand hectares in 1981 to 109 thousand hectares in 1991 (Environment Statistics, 1998) in private lands. Considering the average number of 408 trees per hectare from National Forest Inventory (NFI), it is estimated that 300 million trees exist outside the forest area in Nepal.

The six IPCC vegetation zones defined for tropical countries have been considered here with some modification to interlink with physiographic regions of Nepal. As per the IPCC Guidelines, though Nepal lies among the tropical countries with six forest categories/zones namely wet lands, moist with short dry season, moist with long dry season, dry, montane moist, and montane dry, the study has found only three of them as relevant to Nepal. The correlation between the IPCC defined zones, physiographic zones of Nepal's forest areas and its growth rate along with annual CO_2 uptake is also shown in the Table 3.6.

Table 3.6: Forest Areas, Growth Rate, Annual Bio-mass Increment and Carbon Uptake (1994/95)

IPCC Defined Categories	Corresponding Physiographic Zones.	Area (k ha)	Annual Growth Rate[1] (t dm/ha)	Annual Woody Biomass Increment (kt dm)	Total Carbon Uptake (kt C)
Moist with Long Dry Season	Terai and Siwaliks	1,716.1	2.34	4,032.84	2,016.42
Montane Moist	Middle Mountain and High Mountain	2,434.5	1.64	3,992.58	1,996.29
Montane Dry	High Himal	118.1	1.75	206.68	103.34
Shrub		1,559.2	0.59	919.93	459.96
Grass		1,765.9	0.085	150.10	75.05
Plantation (1985/86-1994/95)		99	2.71	268.29	34.15
Trees Outside Forest (Estimated figure)		300 Million trees	0.0057/ 1000 trees	1,710.00	855.00
Total				11,280.42	5,640.21

Source: [1] Wood Energy Planning: Nepal, Water and Energy commission Secretariat, Kathmandu, 2001, Nepal

Note: kt = kilo ton dm = dry matter ha = hectare C= carbon t= ton

Carbon Uptake = Half of Woody Biomass

Master Plan for the Forestry Sector Project in 1988 (MPFSP 1988) had evaluated country's estimated other wood requirements too (timber, poles, furniture and processed wood). According to this plan, other wood requirement for the year 1994/95 was about 2 million m^3 which is equivalent to about 1.3 million tons. The total biomass consumption, therefore, was about 14.5 million tons, out of which 11 million tons were obtained from the sustainable yield. Net biomass consumption after subtracting biomass obtained from cleared forest is shown in Table 3.7. Total CO_2 emissions due to change in bio-mass stocks came out to be around 14,737 Gg for the same year (Table 3.8).

Table 3.7: Total Biomass Consumption for the Base Year 1994/95

Total Fuel Wood Consumed[1] (kt dm)	Total Other Wood Use [2] (kt dm)	Total Biomass Consumption (kt dm)	Wood Removed from Forest Clearing (kt dm)	Consumption from Stock (kt dm)
13,167.35	**1,315.00**	**14,482.35**	**11,240.66**	**3,241.69**

Source : [1]Wood Energy Planning: Nepal, WECS, Kathmandu, 2001, Nepal.

[2] MPFSP, 1988, Ministry of Forest and Soil Conservation, Kathmandu, Nepal

Table 3.8: Annual CO_2 Emission/Removal from Change in Biomass Stock

Biomass Consumption from Stock (kt dm) *A*	Total carbon Release from stock *B(=0.5 x A)*	Annual Carbon uptake from Biomass Growth (from Table 3.6) (ktC) *C*	Net Carbon Uptake (+) or Release (-) (kt C) *D (=C- B)*	Emission (-) or Removal (+) of CO_2 ($Gg\ CO_2$) *E (=44/12x0.5xD)*
3241.69	**1620.85**	**5640.21**	**4,019.36**	**14,737.67**

Annual carbon removal due to the growing stock is obtained by multiplying the carbon content factor by net biomass growth. Calculation shows that about 14,737 Gg of CO_2 was removed (Table 3.8) from the atmosphere due to the growing stock in Nepal's forest.

3.5.2 CO_2 Emission from Forest and Grass Land Conversion

Biomass stock per hectare in Nepal's forestland varies from 115 to 178 tons (WECS 2001). In total, about 14,006 kilo tons of biomass are removed from the different forestlands and other lands by cutting the trees. In Nepal, commercial harvest is not in practice. Forestland, in general, is changed in two-step process, the first from forestland to shrub land and the second from shrub to cultivation. The biomass in shrub land after conversion is assumed to be 16.1 tons per ha (WECS, 2001) whereas average biomass in the cultivation land is assumed to be 10 tons per ha (IPCC, 1996).

Not all the biomass removed from the forest is consumed as fuel wood. Timber requirement and other factors (e.g. construction needs for settlement and development activities, and

illegal cross-boarder trading of wood) also play an important role. Out of the total biomass loss from the forest clearing, 20 % is estimated for the purpose of using them for timbers (DFRS, 1993) that last up to few decades. During the period of 1978/79 to 1994/95, altogether 1.3 million hectare of forest was cleared (74 thousands hectare per year). In total 14 million tons of wood was removed from forest clearing releasing more than 18,547 Gg of CO_2 to the atmosphere (Table 3.9).

Table 3.9: Biomass Loss from Forest Clearing and Carbon Released by Off-site Burning

Vegetation Types	Annual Area Conversion[1] (k ha)	Biomass			Biomass Burned (t dm) *A*	Biomass Oxidized (t dm) *B* (= 0.9 x *A*)	Carbon Released (kt dm) *C* (=0.5 x *B*)
		Before [2] (t dm/ha)	After [3] (kt dm)	Annual Loss (kt dm)			
Moist with Long Dry Season	20	115	16.1	1,978	1,582.4	1,424.2	712.6
Montane Moist	61.75	171	16.1	9,565.1	7,652.06	6,886.85	3,443.4
Montane Dry	2.3	178	16.1	372.4	297.9	268.1	134.0
Shrub	29	16.1	10	176.9	176.9	159.2	79.6
Plantation[1]	3.25	137	10	412.7	330.2	297.2	148.6
Other	14.3	115	10	1,501.5	1,201.2	1,081.1	540.5
Total				14,006.6			5,058.3
Total CO_2 released (3.66 x *C*)							18,547.1

Source : [1] Forest and Shrub Cover of Nepal, Publication No. 72, Department of Forest Research and Survey, 1999, Kathmandu, Nepal.
[2, 3] Wood Energy Planning: Nepal, Water and Energy commission Secretariat, Kathmandu, 2001, Nepal.

3.5.3 Removal of CO_2 from Abandoned land

There are few areas where lands once cultivated especially in the hilly and mountainous area are abandoned due to lack of productivity and other opportunities e.g. labor, security condition etc. LRMP study has specified some abandoned lands playing role of carbon uptake as shown in Table 3.10, which also shows the estimate of the total CO_2 uptake that took place due to abandonment.

Table 3.10: Carbon Uptake by Abandoned Land

Vegetation Types	20-Year Total Abandoned Lands ('000 ha)	Annual Growth Rate (t dm/ha)	Annual above ground Biomass Growth (kt dm)	Annual Carbon Uptake (kt C)	Total CO_2 Uptake (Gg CO_2)
Montane Moist	13.3	1.64	21.81	10.91	39.99
Montane Dry	0.1	1.75	0.18	0.09	0.32
Total					40.31

Source: Land Utilization Map 1986

3.5.4 CO_2 Emission and Removal from Soils

Conversion of forestland to other land-use category also affects the soil carbon. Forest soils are rich in organic matter than the land used for other purposes. After deforestation, the soils gradually loose its carbon content over the time. Temperature also affects the process of decomposition. In the higher altitude area (cold climate) the decay process is slower than in the Terai and Siwaliks regions (tropical climate).

There is no intensive information of soil carbon content. Land system map prepared by LRMP has estimated organic matter content in the various lands and physiographic regions of Nepal. Carbon release has been estimated here as per IPCC Guidelines, and it is found that during the period from 1974 to 1994 (20 years), altogether 23.71 Tg (23.71 million tons) of soil carbon have been lost. This is due to change in land-use from high carbon content soils (e.g. forest/shrub soils) to low carbon content soils (cultivation). The detail of soil carbon loss from different land-use system is given in Table 3.11.

Table 3.11: Soil Carbon Loss from Change in Land-use

Land-use System	Carbon Content (t/ha)	Area in 1994 (mha)	Soil Carbon in 1994 (Tg)	Area in 1974 (mha)	Soil Carbon in 1974 (Tg)	Loss of Soil Carbon from 1974- 1994 (Tg)	Annual CO_2 Emission (Gg/yr)
Terai Forest	102	0.487	49.67	0.622	63.44	-13.77	
Terai Cultivation	45	1.340	60.30	1.205	54.23	+6.08	
Warm Temperate Forest	68	3.386	230.25	3.756	255.41	-25.16	
Warm Temperate Cultivation	34	1.780	60.52	1.410	47.94	+12.58	
Cold Temperate Forest	124	1.954	242.30	2.055	254.82	-12.52	
Cold Temperate Cultivation	90	0.334	30.06	0.233	20.97	+9.09	
Total			696.81		673.1	-23.71	4346.83

Note: mha = million hectare, Tg = Terra gram

In Nepal, limestone ($CaCO_3$) is used to improve the agricultural soil condition and Table 3.12 shows the carbon emission from this liming.

Table 3.12: Carbon Emission from Liming of Agricultural Soils

Type of Lime	Total Annual Amount of Lime (Mg)[1] *A*	Carbon Conversion Factor[2] *B*	Carbon Emission from Liming (Mg C) *C(= AxB)*	Unit Conversion Factor	Total Annual Carbon Emission (Gg)	Annual CO_2 Emission Gg/yr
Limestone (CaCO3)	2074	0.12	248.88	0.001	0.25	0.91
Total			248.88			0.91

Source: [1] Krishi Chun Udhoyg, 2002
[2] IPCC Supplied Value
Mg= Mega gram

3.6 Waste Handling

Nepal is one of the least developed countries and the problem of waste management is therefore an urban phenomenon. In Nepal, the waste management is basically related to the domestic and commercial solid waste management system as well as the domestic and industrial wastewater handling and treatment capabilities. Solid waste management primarily relates to disposing of wastes, and the waste combustion is hardly practiced in Nepal. Therefore, the Carbon dioxide and Nitrous oxide emissions from waste combustion are not considered and only the Methane generation from land filling of waste is taken into consideration in this assessment. Land filling of waste and treatment of wastewater contribute to the generation of the atmospheric Methane (CH_4), as a contributor to anthropogenic Greenhouse Gas emissions. In addition to this, the indirect Nitrous oxide emissions from human sewage are also estimated here considering the fact that they are also identified as one of the sources for Greenhouse effect.

Methane emissions from waste sector have been worked out here from three different sources- disposal of solid waste, treatment of domestic and commercial wastewater and treatment of industrial wastewater. For the base year 1994/95, a total Methane emission from these three sources was calculated as 10.47 Gg. In this total of 10.47 Gg. of Methane emission, the disposal of domestic and commercial waste contributed 9.33 Gg (89 %), domestic and commercial wastewater treatment contributed 0.71 Gg (7 %) and treatment of industrial wastewater 0.43 Gg (4 %) of Methane (Fig.3.7).

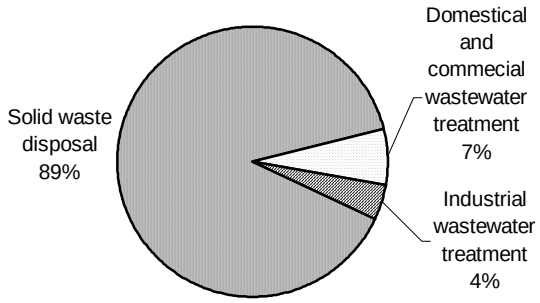


Figure 3.7: Methane Emission from Waste Management in 1994/95

3.6.1 Solid Waste

Urban infrastructural services and the wastes generated in the rural area also produce GHGs due to decomposition of organic materials. As the waste generated in the rural part is typically scattered in the agricultural fields rather than in solid waste disposal sites, they tend to decay aerobically generating extremely low CH_4 emissions. Hence, only the urban population is considered for the estimation of solid waste here. The urban population is growing very rapidly – average annual growth has been recorded at more than 12 % for the period 1981-2001 (CBS, 2001). Most municipalities report collection of only 50 to 60 percent of solid waste. Solid waste generation in urban areas ranges from 0.25 to 0.5 kg per capita per day. The proportion of non-biodegradable and hazardous waste is also reported to be rising. GHG emissions from Solid Waste Disposal Sites (SWDS) depend on several factors including waste disposal practices, waste composition and physical factors. In Nepal most of the wastes are dumped into open places and riverbanks with exception of Kathmandu Valley. However, for the purpose of this study, all sites have been assumed to fall in the category of uncategorized solid waste disposal sites. It is also assumed that only 50 % of total generated waste goes to SWDS.

Based on the composition of waste, from various studies, it is also assumed that Degradable Organic Carbon (DOC) in municipal waste for the base year 1994/95 is about 16%. Different studies indicate that the waste generation rate has varied from 0.25 kg/capita/day in 1978 (Lohani and Thanh), to 0.4 kg/capita/day in 1988 (GTZ) and 0.46 kg/capita/day in 1993 (Khanal, 1993). On the higher side, Rai (1990) estimated the rate to be 0.565 kg/capita/day. RESTUC (1999) estimated the average amount to be 0.48 kg/capita/day (SOE/NEPAL, 2001). Based on these studies, the average per capita waste generation rate is taken as 0.4 kg/day for the estimation of the solid waste generation in Nepal for the nineties. About 2/3 of the waste is reported to be organic matter. Following assumptions and default values have been used to estimate the Methane emissions from the solid waste.

- The MCF (Methane Correction Factor) is 0.6 (IPCC default value)
- Fraction of DOC which actually degrades is taken as 0.77 (default value)
- Fraction of Carbon released as Methane is 0.5 (default value)
- There are no Methane-recovering facilities in solid waste disposal sites in the country.

The Industrial Pollution Inventory of 1994/95 estimated that the contribution of industry sector in solid waste generation was 21,900 tons of waste per year. This has not been considered or treated separately, and it is assumed that this small portion comes within the above figures of per capita waste generation because no industries have separate waste disposal sites. Table 3.13 presents the solid waste generation and the CH_4 emissions for the year 1994/95.

Table 3.13: Urban Population and Waste Generation in 1994/95

Year	Population '000	WGR kg/day/person	Waste Produced '000 ton	CH_4 Emission Gg
1994/95	2,592.3	0.4	378.4	9.33

3.6.2 Wastewater

Organic contents, expressed in terms of Biological Oxygen Demand (BOD), determine the Methane producing potential of wastewater when handled anaerobically and also depend on the physical factors that influence the decomposition process as summarized below

a) Domestic and Commercial Waste Water Handling

As in case of solid waste, in determining the domestic sewage quantity, only the urban population is taken into account. The per capita water consumption in average is taken as 71 liters per day in the urban areas. Domestic and commercial wastewater are discharged into public sewers in urban Nepal, and of the total consumption of water, about 85 % results into wastewater (SOE 2001, MOPE/ICIMOD/UNEP/SACEP/NORAD). Out of the 58 municipalities, only Kathmandu valley has some wastewater treatment plants though, they are not operating properly. Therefore, most of them are as non-aerated lagoons, and it is assumed that 10 percent of wastewater generated is considered to be under anaerobic condition. Other assumptions are:

- The BOD value is taken as 0.04 kg/capita/day, or 14.6 kg/person/year (IPCC default value for Asia region)
- The Methane Conversion Factor (MCF) for the handling system is taken as 75 (default value taken from IPCC for Asia).

It is estimated that total of 0.71 Gg of Methane is emitted from wastewater generated from domestic and commercial sector.

b) Industrial Waste Water Handling

The industries that are primarily known for high BOD (Biological Oxygen Demand) or COD (Chemical Oxygen Demand) are – sugar, leather tanning, paper and pulp, beer, soft drinks and modern liquor, vegetable ghee and oil industries. The annual productions of these items are counted for determining wastewater generation and successively BOD and COD loads of the industries.

The emission factors used by Industrial Pollution Inventory Study, 1994/95, have been taken to estimate the wastewater volume and BOD load for the specified industrial products. Using the COD/BOD ratio of 1.7 (IPCC Guidelines), COD values are derived. Since Nepal introduced the effluent discharge standards only in 2001, 80 % of effluents were considered untreated in 1994/95. Industrial Production, wastewater and BOD, and COD loads for that year are presented in Table 3.14. It is estimated that a total of 0.43 Gg of Methane was emitted due to wastewater from industrial sector.

Table 3.14: Production Capacity and Annual Production of Major Waste Water Generating Industries in 1994/95

Introduction	Production	Unit	Wastewater Generation m^3/ton	BOD Wastewater kg/m^3	COD Wastewater kg/m^3
Sugar	34044	tons	22	3.8	6.46
Leather and Tanning	7950	'000 sqft	57	1.1	1.87
Soft Drinks	15784	'000 liters	4.3	0.5	0.85
Vegetable Oil	32313	tons	11	1.7	2.89
Beer	15761	'000 liters	61.3	0.50	0.85
Paper and Pulp	8494	tons	36	5.8	9.86
Liquor	2339	'000 liters	5	4.4	7.48

Source: Industrial Statistics, 2000/2001, Department of Industry, HMG/Nepal

c) Human Sewage

Nitrous oxide emissions from human sewage are resulted from nitrification and denitrification of the Nitrogens that are present in sewage. In general, temperature, pH, Biological Oxygen Demand (BOD) and Nitrogen concentration affect N_2O generation in human sewage. Fraction of Nitrogen in Protein $Frac_{NPR}$ (Kg N/Kg protein) has been taken as 0.16 (default value) in this assessment and the emission factor EF6 (Kg N_2O-N/Kg sewage-N produced) is taken as 0.01 (IPCC Guidelines default value).

Nitrous oxide emissions from human sewage have been estimated here for the total population of Nepal in 1994/95. Then using the IPCC methodology, the indirect Nitrous oxide emission for the base year 1994/95 came out to be 1.10 Gg.

CHAPTER- 4

GHG Emission Projections and Mitigation Options

In this section, the study looks specifically at the Greenhouse Gas projections along with emphasis on the main sources of emissions of two gases CO_2 and CH_4. Trend of emissions of these from three energy sub-sectors (residential, commercial, and industrial), from two agriculture sub-sectors (rice and livestock) and from forestry are projected to 2030/31. For livestock sub-sector, emissions of N_2O are also projected. In addition, to reduce the emissions GHGs, Mitigation options for these sectors are also discussed.

4.1 GHG Projections for Energy Sector

Carbon dioxide emissions depend on the type and amount of energy consumed, and energy consumption is closely linked to the socio-economic development of a country. Hence, projection of CO_2 emissions from the energy sector is based mainly on projections of the population and economic growth of a country over a specific period in the future. Besides, other Greenhouse Gases are also emitted from a number of activities that uses energy such as residential and commercial cooking, space heating, industrial processes, transportation and so on.

Like most developing countries, Nepal lacks an immaculate data collection and management system. As such, a vast array of data that becomes necessary to operate energy use forecast software like LEAP (Long Range Energy Alternate Planning) is often lacking. However, a combination of approaches has been adopted to utilise the available data, and LEAP has been applied in analyzing energy demands, energy use forecast, GHG emission, etc. for the residential and transport sector. But commercial sector's energy consumption analysis and projections have not been carried out here because of the fact that this particular sector contributes very little in terms of GHG emission. Furthermore, the data available for the industrial sector's energy consumption, especially the energy efficiency/intensity of the different technologies used by the industries are inadequate for running the LEAP program and the bottom up approach therein. Therefore, a simple process or method has been used for analysis in the case of industrial sector.

Of the total energy demand in the country, the residential sector consumes and is expected to consume the largest portion, estimated to be about 90 percent followed by the industrial, transport and commercial sectors. Agriculture remains the smallest user of total energy (Table 4.1). However, if biomass energy use is not counted or excluded, transport sector is seen to consume the largest amount of energy at 30 percent followed closely by residential and industrial sectors. Final energy consumption projections and the mitigation options have therefore been are analyzed and conducted here only for residential, industrial and transport sectors. Besides, analysis for residential and transport sectors have been carried out separately with highly desegregated approach using LEAP due to their varying reliance on the form of energy, e.g. biomass and fossil fuel.

Table 4.1: Sectoral Energy Consumption by Fuel Type in 1994/95 ('000 GJ)

Description	Residential	Commercial	Industry	Agriculture	Transport	Total
Biomass	**253,765**	**1,044**	**7,491**	**0**	**0**	**262,300**
Fuel Wood	188,062	987	7,182	0	0	196,231
Agriculture Residue	42,572	57	309	0	0	42,938
Animal Dung	23,131	0	0	0	0	23,131
Commercial	**5,691**	**2,732**	**4,952**	**2,034**	**7,583**	**22,992**
Coal /Coke	14	286	2,523	1,948	16	4,787
Petroleum	4,564	2,043	1,248	0	7,561	15,416
Electricity	1,113	403	1,181	86	6	2,789
Total Energy	**259,456**	**3,776**	**12,443**	**2,034**	**7,583**	**285,292**

Source : WECS,1996

Energy use in this country is increasing faster in the transportation sector than in any other sector. Increase in transportation energy use is a clear indication of a large amount of carbon emissions because virtually all energy requirements of this sector are in the form of petroleum products. Mitigation options to reduce GHG emission in transportation is one of the focal areas in the study. It is an emerging challenge for countries like Nepal to devise strategies that can take care of the increased mobility of the people and the goods required for meeting the developmental aspirations yet without environmental implications.

4.1.1 Residential Sector Energy Consumption and Projection of GHG Emissions

The analytical study of residential sector was done with bottom up approach using LEAP software. The sector was divided into various sub-sectors and end-uses in the analysis and the study has come out with projection of emissions based upon 1994/95 energy consumption base case. As can be seen from Table 4.2 below, residential sector's energy consumption is projected to almost double the figure in 2030/31 amounting to 428 TJ in the business-as-usual scenario compared to what it was in 1994/95. Fuel wood occupied a major portion of energy consumptions in this sector.

Table 4.2: Residential Sector Energy Consumption/Demand and Emission Projection Business-As-Usual Scenario

Year	Energy Consumption million GJ	GHG Emission Gg
1994/95	245.6	30210
2000/01	279.9	34420
2005/06	313.6	38570
2010/11	347.9	42790
2020/21	407.8	50150
2030/31	428.5	52720

4.1.2 Industrial Sector Energy Use and Projection of GHG Emissions

Industries in Nepal use mostly particular kinds of fuel such as light diesel oil, furnace oil, and high-speed diesel, etc. The industrial base in fact is very weak in Nepal, and its growth has been erratic and dependent on a lot of external factors. National Planning Commission of Nepal makes growth forecasts in terms of agricultural and non-agricultural GDP only. Since non-agricultural GDP is comprised of sectors such as service sector, remittance, etc. it is very difficult to be precise in the projection of energy use and GHG emissions in the industrial sector of Nepal. In order to make the desired projection of the GHG emissions from industries in this study, the Weighted Industrial Production Index (WIPI) published by His Majesty's Government (Economic Survey, fiscal year 2001/02) has been applied as a basis under business-as-usual scenario. The WIPI has the fiscal year 1986/87 as the base year with index 100, and is available up to the year 2001/02. The GHG emission on the basis of the

amount of finished industrial products using IPCC Guidelines as well would be the best estimation given the lack of appropriate information in the country (Figure 4.1).

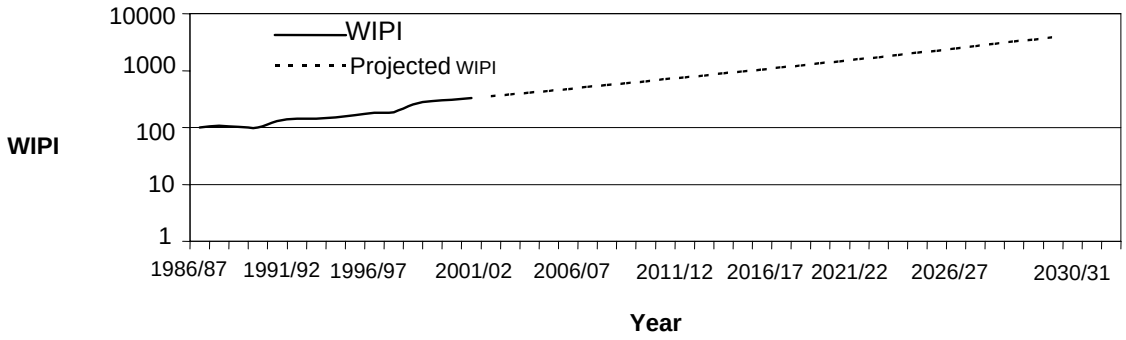


Figure 4.1: Weighted Industrial Production Index and Business-As-Usual Scenario

It is assumed that the structure of industrial matrix and energy consumption pattern will not alter substantially during the projected period. It is also assumed that the GHG emissions from industries will follow similar increasing trend as that of WIPI. Log-Log equation has been used to predict industrial WIPI in the future. Projected WIPI is then used for the GHG projection in the future under the business-as-usual (BAU) scenario. Table 4.3a shows the WIPI for different fiscal years. Figure 4.1 shows the actual and projected WIPI in logarithmic scale. Similarly, Table 4.3b shows the WIPI projection and CO_2, CH_4, and NO_x release projection up to 2030/31 under BAU Scenario. It shows that projected values of CO_2 is slightly lower but CH_4 and NO_x are slightly higher than that estimated by the Inventory Group. This might be due to assumption. However projected results indicate that GHG emission from industrial activities increases exponentially, and some mitigation measures have to be applied.

Table 4.3a: Historical Weighted Industrial Production Index (WIPI)

Year	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02
WIPI	100	107.4	102.0	100.6	129.7	141.7	143.7	150.3	164.1	178.0	185.4	255.1	290.7	308.6	328.1	352.9

Table 4.3b: Weighted Industrial Production Index (WIPI) Projection and Resulting Emission

Year	WIPI	CO_2- BAU Gg	CH_4-BAU Gg	NO_X-BAU Gg
1994/95	164.07	172.758	0.0	0.152
2000/01	328.06	349.544	0.14	0.308
2005/06	475.26	491.811	0.25	0.433
2010/11	699.19	719.043	0.32	0.511
2020/21	1588.81	1612.436	0.48	0.661
2030/31	3870.28	3871.826	0.66	0.800

4.1.3 Transport Sector Energy Consumption and Resulting GHG Emissions

One of the most desired personal service facilities in the urban areas of the developing countries including Nepal is ownership of a motorized vehicle because of the absence of an efficient mass-transit system in the cities, and the evidence is overwhelming. Personal vehicle ownership in Nepal is increasing rapidly in the form of small engined two wheelers and cars. The principle determinant of the personalized vehicle ownership is one's income. As economies grow and incomes rise, more people can afford to buy their own vehicles. The relationship between the income and vehicle ownership is however not a simple function and is found to be dependent on other factors too such as level of society, geophysical setting, and transport infrastructures, etc.

Transportation mode in Nepal can be broadly classified and sub-classified as indicated in the Table 4.4.

Table 4.4: Types of Transportation in Nepal

S.N.	Mode	Sub-mode
1	Surface transportation	Roadways, Railways, Trolley Bus
2	Air Transportation	Domestic International
3	Water Transportation	Ferries and boats
4	Cable Transportation	Rope-ways, Cable Car

4.1.4 GHG Projection for Transport Sector

In this aspect of this study involving LEAP program, population and GDP have been taken as important parameters for projecting energy demands in the country. Figure 4.2 shows the relationship between GDP and energy consumption in transport sector in the past as well as energy demand projection by CMST.

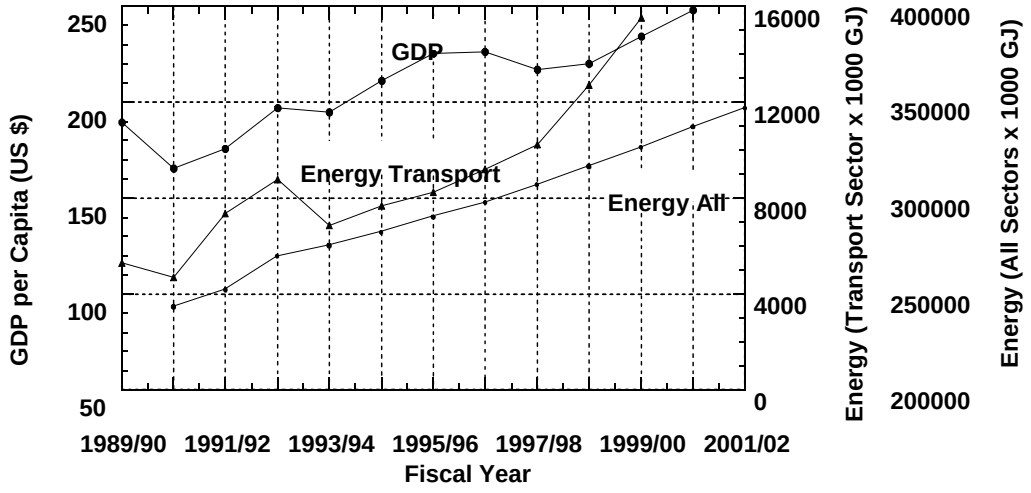


Figure 4.2: GDP and Energy Consumption

The analysis using LEAP software for transportation sector is based on per capita annual transportation usage (passenger-km and ton-km).The energy consumption per capita in the past was correlated with population and GDP.

The energy consumption and GHG emission projections are shown in Table 4.5. The energy consumption in comparison to the base year 1994/95 was found to have doubled in six years

from 7,850 thousand GJ to 15,900 thousand GJ in 2000/01. From the analysis, energy consumption is expected to reach 64,820 thousand GJ in 2030/31, and the GHG emission was 643.7 thousand tons carbon dioxide equivalent in the base year 1994/95 which included emissions from international flights as well, without which the emissions would be 515 thousand tons of carbon dioxide equivalents. The discrepancy between this value and that calculated under the GHG inventory is due to more detailed (bottom-up) nature of Mitigation Options Analysis. The GHG emission is expected to reach 5,063.2 thousand tons carbon dioxide equivalent in 2030/31. The passenger transportation is the main contributor to the GHG emission total in this sector.

Table 4.5: Business –As-Usual Energy Consumption and GHG Emission Projections in the transport sector

Years	Energy Consumption ('000 GJ)	GHG Emission in CO_2 Equivalent ('000 ton)
1994/95	7, 850	643.7
2000/01	15,900	1,304.7
2005/06	22,600	1,838.5
2010/11	30,270	2,442.1
2020/21	47,420	3,768.6
2030/31	64,820	5,063.2

4.2 Mitigation Options

Mitigation option performed in the present study relied mainly upon desegregated analysis or methods using emission coefficients which were dependent on a variety of parameters including the type of end use device, as against using overall emissions from each fuel type given in GHG inventory report.

4.2.1 Mitigation Options in Residential, Commercial and Industrial Sectors

The traditional source of energy consisting of fuel wood, agriculture residue, and animal dung in residential sector is not likely to change considerably in the foreseeable future.

The Mitigation options should, therefore, be concentrated on traditional sources of energy specifically in residential sector to have a meaningful impact in the national scene. The Mitigation tools selected in the present scenario analysis therefore include process modification as well in addition to efficiency enhancement, technology upgrading, and fuel-

replacement. Currently most appropriate approach of all seems to be technology upgrading such as from 3-stoves and wick lamps to improved stoves, biogas stoves and lanterns, etc. The commercial sector, on the other hand, uses electricity for cooking, heating, cooling and lighting; yet the electricity use is only about 3 %. The mitigation options in this regard is therefore to discourage use of fossil fuels for space heating, for example, in hotels and encourage use of solar thermal systems and also encourage incorporation of passive solar architectures in the design stage of the residential buildings and hotels etc.

The order of magnitude of the energy use by industrial sector compared to that of residential sector is very small. Mitigation options selected for industrial sector should not mean to stifle the already weak industrial base of the country. The efforts being made by His Majesty's Government to enhance the efficiency of energy production and use without affecting overall productivity of the industries is, therefore, very appropriate. Any GHG Mitigation option considered in this context should also provide encouragement in the use of energy efficient devices and technologies through appropriate schemes for new industries and also in the use of retrofit devices in the existing industries.

The energy demand and emission projection for business-as-usual and mitigation scenarios for residential sector are shown in Table 4.6 and Figure 4.3. Similarly Table 4.7 shows CO_2 projection for business-as-usual scenario and the applicable Mitigation option for industrial sector.

Table 4.6: Residential Sector Energy Demand and Emission Projection for Business – As- Usual and Mitigation Scenario

Year	Energy Demand Projection million GJ		Emission Projection Gg	
	Business-As-Usual Scenario	Mitigation Option	Business-As-Usual Scenario	Mitigation Option
1994/95	245.6	245.6	30210	30210
2000/01	279.9	231.3	34420	28450
2005/06	313.6	219.4	38570	26990
2010/11	347.9	207.5	42790	25520
2020/21	407.8	183.7	50150	22600
2030/31	428.6	159.8	52720	19660

Note: TJ= Terra-joule

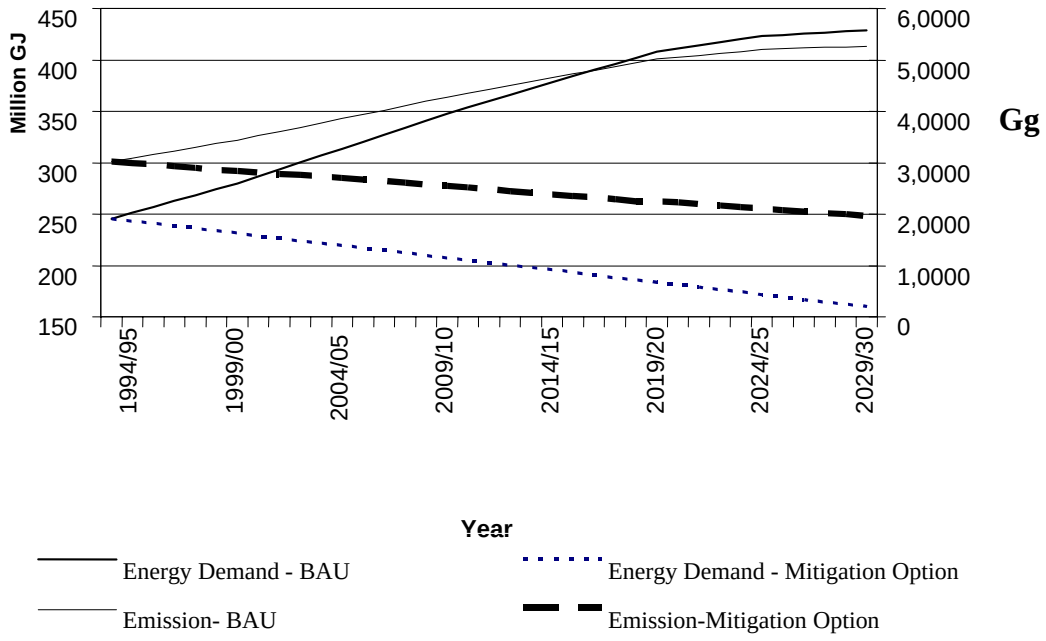


Figure 4.3: Energy Demand and Emission Projection and Mitigation under Business-As-Usual Scenario in Residential Sector

Table 4.7: Weighted Industrial Production Index (WIPI) Projection and Resulting Emission Business-As –Usual and Mitigation Scenario

Year	WIPI	CO_2- BAU Gg.	CH_4.BAU Gg.	NO_X-BAU Gg.	CO_2-MI Gg.
1994/95	164.07	172.758	0.0	0.152	172.758
2000/01	328.06	349.544	0.14	0.308	314.590
2005/06	475.26	491.811	0.25	0.433	442.630
2010/11	699.19	719.043	0.32	0.511	647.139
2020/21	1588.81	1612.436	0.48	0.661	1451.193
2030/31	3870.28	3871.826	0.66	0.800	3484.643

Note: MI = Mitigation

In order to reduce the growing amount of CO_2 emissions, a number of Mitigation options have been identified and evaluated on both the demand and supply sides.

In identifying technically feasible solutions and estimating their corresponding potentials for reducing CO_2 emissions, the following important Mitigation options are considered.

a. Demand-side Management

Managing the demands for energy becomes increasingly important to supplement the supply management sector. Options to curbing demand will be to improve energy efficiency through demand side management. In consideration of this aspect, Demand side management has proposed a couple of efficient steps given in Table 4.8 for various electricity end-users in the residential, commercial and industrial sectors.

Table 4.8: Efficient Appliances Considered for Power Reduction and Greenhouse Gas Emissions Mitigation

Sector	Existing appliance	Efficient appliance
Residential	Incandescent lamps	Compact fluorescent lamps (CFLs) 13 W-23 W and fluorescent lamps (FLs) 18 W-40 W
Commercial	Incandescent lamps	Compact fluorescent lamps (CFLs) 13 W-23 W and fluorescent lamps (FLs) 18 W-40 W
Industrial	Standard electric motors <3. 7 KW & >3.7 KW	Efficient electric motors <3. 7 KW & >3.7 KW

Source: ARRPEEC, 1995

b. Improving Supply and Efficiency

As far as Climate Change impact reduction is concerned, one of most desirable Mitigation options for Nepal will be the improvement in the supply or increase availability of low carbon fuels such as natural gas, as well as greater use of renewable energy sources and more efficient technologies for power generation. This mechanism of switching of fuels in the cement industry as well as in the transport sector for reducing emissions of CO_2 is also recommended.

Though higher amounts of CO_2 reduction are reported to be technically possible to achieve, the choice of Mitigation options and their implementation are difficult because the most effective option may not be consistent with national policy or may be uneconomic for Nepal. Table 4.8 shows, for example, the estimated CO_2 emission mitigation potentials of available efficient appliances in electricity during 1996-2010 periods from a technical perspective. If all incandescent lamps used by house holds in 1996 had been replaced by CFLs and if these CFL lamps were maintained at the 1996 level capacity till 2010, the entire thermal power generated for running these lamps during the period could have been avoided with subsequent cuts in the equivalent emissions of CO_2. If similar efficiency improvements were

brought about at commercial lighting and industrial electric motors then, over 70 % of emissions would not have occurred during the period.

Table 4.9: CO_2 Emission Mitigation Potential of Efficient Appliances during 1996-2010 Period

Efficient appliances used sectors	Reduction in CO_2 emission	
	('000 tons)	% of total emissions
Residential lightning	1013	100
Commercial lighting and Industrial motors	755	74

Source: ARRPEEC, 1995

Note: CFL= Compact Fluorescent Lamp

c. Renewable Energy

Renewable energy is an important source of energy for lighting and heating proposes at present in Nepal. In spite of increase in generation of electricity from hydropower in the country, biomass energy is increasingly becoming a potential source of domestic energy supply in the country-sides. In addition, other renewable sources of energy potential for Nepal include solar energy, wind power and burning of animal wastes.

To enhance tapping and use of renewable energies, Nepal has constituted an Alternative Energy Promotion Center, which plans and manages officially the development of renewable energy resources in the country; the sectors of its responsibility include:

- Solar energy
- Biomass energy
- Wind energy
- Others

Nepal has considered and identified these renewable energy resources as important response options to mitigate emissions of GHGs. They are emerging as a large source of untapped alternative energies with very high potentials for uplifting Nepal's socio-economy. Studies on cost implication for these options are supportive of their integration into the GHG Mitigation option policy of Nepal.

4.2.2 Mitigation Options in Transport Sector

As transport sector is the largest consumer of fossil fuels, and consumption in this sector is projected to increase more dramatically, Mitigation options in this sector are given due consideration. However, any Mitigation option should be based on the country specific situation and with due consideration to the development stage of the national economy. Five fundamental generic strategies are considered here to reduce GHG emissions in the country's transport sector; they are:

1. Increase in vehicle performance efficiency
2. Switch to less greenhouse gas-intensive fuels
3. Switch to less greenhouse gas-intensive transportation modes
4. Decrease travel distance
5. Increase occupancy of public vehicles.

Based on these fundamental strategies, three mitigation scenarios were investigated in the analysis:

Scenario 1: Energy efficiency is the primary action, which is anticipated to be achieved through improved vehicle quality, maintenance of vehicles, road condition improvements, and traffic management along with stringent emission control measures. This scenario considers increase in vehicle energy efficiency by 1 % to 2.5 % per annum. Larger efficiency can be anticipated for commercial vehicles through better maintenance. This scenario in effect can achieve significant amount of GHG emission reduction compared to baseline scenario. Thus GHG emission reduction by the year 2030 is expected to be 35 % from the baseline scenario (Figure 4.4a). This scenario also calls for a strong policy formulation, coordination and implementation. In addition, this option also looks at the need for involving a substantial volume of infrastructure development requiring a large capital investment.

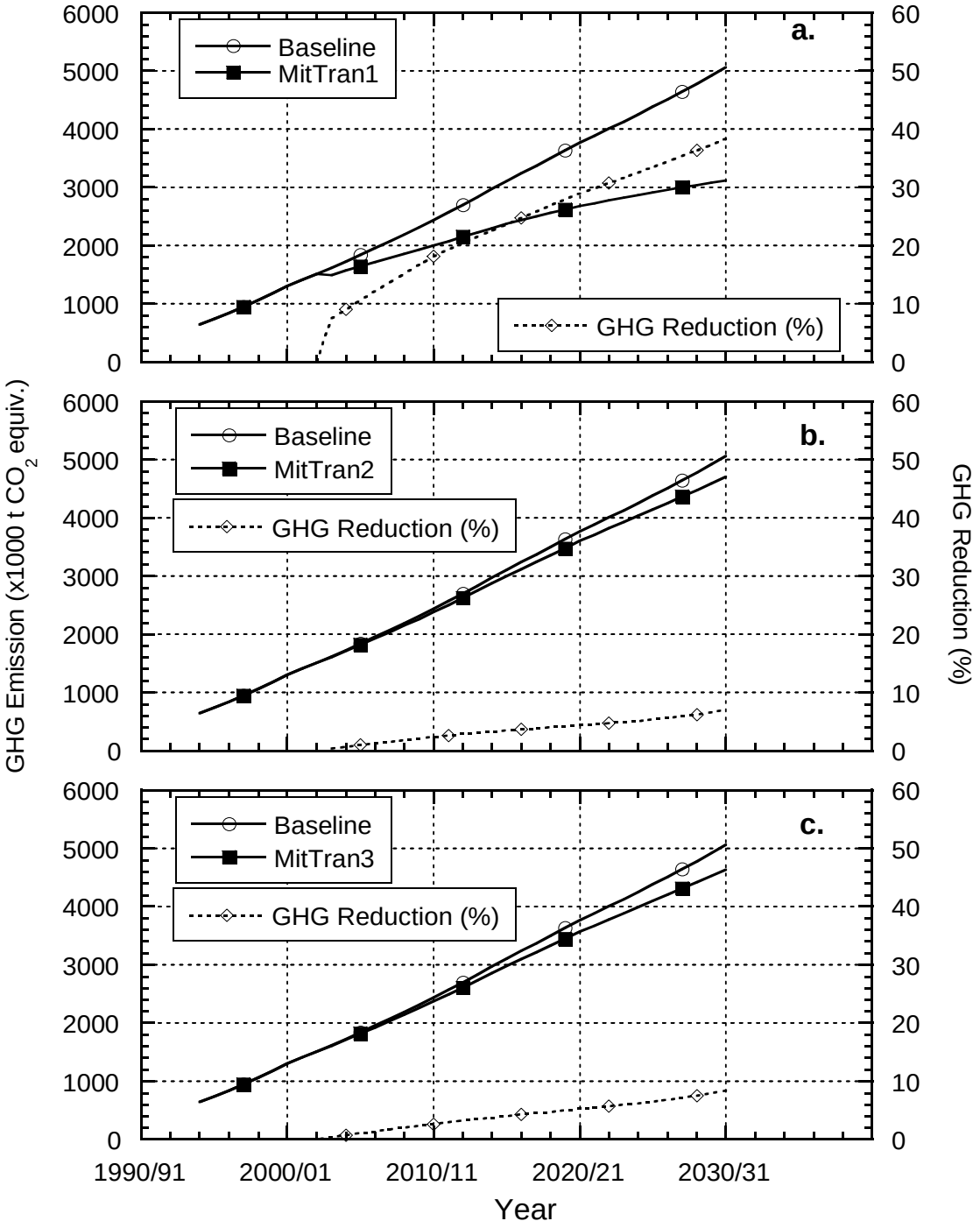


Figure 4.4 : GHG Emissions under the Three Mitigation Option Considered

Scenario 2: The tendency to own private vehicles has started growing in Nepal; this has clearly been accounted for in the baseline scenario projection. It has been established that mass transport has less emission per passenger per km. This scenario, in view of the above fact, focuses on improvement of mass-transit based transport to counteract the private ownership trend. Hence the share of public transport, which is lower than the private transport, will gradually increase after 2008/09 and reach 60 % of the total in 2030/31 (Figure 4.4b). Although this option can achieve only one third of the GHG emission reduction compared to the first option (scenario 1) it requires less infrastructure development. However, a strong policy is a must for the implementation of this option.

Scenario 3: This is an extension of scenario 2 (Figure 4.4c). In addition, for increasing volume of public transport, this option considers transport using less GHG emission intensive fuels. Because of the large hydropower potential of the country, gradual increase in electrical transportation such as trolley buses and electric trains for passenger service and rope-ways for goods has been proposed. Switching to LPG, CNG, or ethanol blend is not considered here. It can be seen that the increase in GHG emission reduction over scenario 2 is marginal. Expansion of electric vehicles is a much popular option in Nepal and is often suggested to address pollution problems or to reduce the imported fossil fuels.

In areas other than urban centers, electric transportation may not be a feasible option. In urban centers, this option has added benefit of local environmental protection, and proved feasible.

4.3 GHG Projection and Mitigation Options for Non-Energy Sector

4.3.1 Land-use, Land-use Change and Forestry

The Mitigation option analysis carried out in this sector has identified the status of reachable forests in Nepal as given in Table 4.9. About 51.5 % of the forest of Nepal are reachable. Non-reachable forests of Nepal (totaling 2.1 million-hectare) can be considered virtually as permanent carbon sinks. Reachable forests of Nepal are limited to about 2.2 million hectares and are potentially vulnerable to Climate Change induced socio-technical and other intervention. The reachable forest of Nepal will be the primary subject for all analysis and treatment in considering application of Climate Change induced mitigation measures in the years to come.

Table 4.10: Reachable Forest Area by Altitude Classes and Development Regions

('000 ha)

Altitude Class m	FWDR	MWDR	WDR	CDR	EDR	Nepal	Climate Zone
0-500	160.7	210.3	111.2	229.8	147.3	859.3	Sub-tropical
501-1000	54.4	114.0	31.9	88.3	76.1	364.8	Sub-tropical
1001-1500	56.6	54.0	37.4	47.1	102.9	298.0	Temperate
1501-2000	67.5	24.0	15.3	66.3	72.8	245.9	Temperate
2001-2500	19.6	24.0	24.9	38.5	70.2	177.1	Temperate
2501-3000	NA	18.0	33.1	52.2	73.6	176.9	Temperate
3001- above	NA	10.0	8.3	5.5	33.4	57.2	Arctic
Total	358.8	454.4	262.1	527.7	576.3	2179.3	

Source: FRISP/1999

Note: FWDR = Far-Western Development Region
MWDR = Mid-Western Development Region
WDR = Western Development Region

Forest resources in Nepal, as already mentioned, have been exploited beyond their sustainable ecological growth. Excessive dependency on forest to fulfill the needs of firewood, fodder, timber and habitat is the main cause for forest area depletion in Nepal. The total cultivated land area in Nepal has increased from 3.05 million hectares (20.7 %) to 3.44 million hectare (23.4 %) between the period of 1985/86 and 1994/95 (WECS, 2001) and was primarily achieved by forest clearing.

Thus the prime forces responsible for such depletion of the forest of Nepal are, i) unsustainable harvesting of wood for fuel and non-fuel forestry products, and ii) the periodically occurring authorized and non-authorized conversion of forest into agricultural lands for expansion of farming activities.

4.3.2 Projection of Carbon Storage and Release in Land-use, Land-use Change and Forestry

In the study of this sector, assessment of Land-use, Land-use Change and Forestry patterns for the base year (1994/95) in Nepal and their contribution to GHG accounting and budgeting

were carried out using COPATH 2002 software. Projection of GHG emission reduction and Carbon sequestration for short term (2010), mid term (2020) and long term (2030) was carried out using the same software. Results thus obtained from COPATH 2002 for the base year 1994/95 are not compatible with those of National GHG Inventory as given in Chapter - 3, due to more detailed nature of analysis of the former; therefore they have not been considered reliable here and are used primarily for mitigation analysis purposes only in this section.

These results obtained from the analysis have been given in Table 4.11 below showing the total carbon stored, total carbon released in base year 1994/95 and their projection till 2030/31 from decomposition of the forest in different climato-geographic zones and forest types of Nepal.

Table 4.11: Carbon Storage and Release for the Base Year 1994/95 and for 2010/11, 2020/21, 2030/31

S.N	Year	Dev. Regions	Forest Area (10^4 ha)	Total Carbon Release (10^6 tons)	Total Storage Carbon (10^7 tons)
1	1994/95	EDR	58.00(B.Y.)	23.33	11.07
	2010/11	EDR	60.9(+5%)	24.5	11.62
	2020/21	EDR	66.7(+10%)	26.8	12.72
	2030/31	EDR	72.5(+10%)	29.1	13.82
2	1994/95	CDR	53.00(B.Y.)	21.32	10.12
	2010/11	CDR	55.65(+5%)	22.39	10.63
	2020/21	CDR	60.95(+10%)	24.49	11.64
	2030/31	CDR	66.25(+10%)	26.59	12.65
3	1994/95	WDR	26.00(B.Y.)	10.46	49.66
	2010/11	WDR	27.30(+5%)	10.98	52.14
	2020/21	WDR	29.90(+10%)	11.98	57.10
	2030/31	WDR	32.50(+10%)	12.98	62.06
4	1994/95	MWDR	45.00(B.Y.)	18.10	85.95
	2010/11	MWDR	47.25(+5%)	19.01	90.24
	2020/21	MWDR	51.75(+10%)	20.81	98.83
	2030/31	MWDR	56.25(+10%)	22.61	107.43
5	1994/95	FWDR	35.00(B.Y.)	14.49	68.76
	2010/11	FWDR	37.80(+5%)	15.21	72.19
	2020/21	FWDR	41.40(+10%)	16.61	79.07
	2030/31	FWDR	45.00(+10%)	18.02	85.95

Note: EDR = Eastern Development Region
CDR = Central Development Region
MWDR = Mid-Western Development Region
WDR = Western Development Region
FWDR = Far-Western Development Region
BY = Base year

Aggressive leasehold and community forest conservation policies with priority to mid hills and Siwaliks will be one of the best forestry sector policies for sustainability in Nepal to achieve the set target in reforestation program which, in turn, also becomes the best mitigation measures for Nepalese forests today. Since large number of communities live very close to the forests and depend heavily on forest for various aspects of livelihood, centralized forest management policies of today need to be urgently liberalized with additional responsibility infusion to these individuals or communities along with increased awareness and other possible alternatives affordable for them. Government policies governing the terms of concessions for timber harvest and tax rebates as well as fuel wood and non fuel wood product dissemination policies are in existence though simply in legal codes, they have hardly any real value effect in forestry sector economy.

Reduction in fuel wood use, use of its substitutes, and use of recycled or more efficient wood products along with improved stoves can appreciably minimize the national total fuel wood demands. Hence, effective forest conservation legislations in Nepal which also protect wild animal habitats and plans particularly in buffer zones are urgently required in practice for adaptation to Climate Change in partial fulfillment of UNFCCC obligation and bio-diversity related international commitments of Nepal.

4.3.3 Mitigation Option for Forestry Sector

Afforestation, reforestation, enhanced regeneration of forests and agro-forestry in reachable forests as specified in mitigation targets can achieve expansion of carbon sinks. Carbon sequestration capacity of Nepalese forests in the middle mountains such as in Annapurna Conservation Project Area is estimated to be 77 tC/ha, and the cost per ton of carbon sequestrated is calculated to be between US$ 13.64 and US$ 16.14 at 1994 price (WRI, 1994). If this estimate is considered as a basis for the cost of carbon sequestration through forest plantation in particular through afforestation and reforestation in degraded lands in Nepal, the cost of carbon emission reduction by 10 percent would be several times lower compared to the mitigation measures by substitution of kerosene and LPG with hydroelectricity.

Agro-forestry practices have long been considered as ecologically sound farming practices and offer potential for regaining some of the lost carbons through changes in land uses patterns as much as 176 tC/ha after period of 10 years (estimated for tropical regions).

Improvement in land management practices such as protection of trees on the farm, contour felling and mound-based soil fertility management, etc. could help to regain about 44 tC/ha to 46 t C/ha (Tinker, 1997).

Studies performed in developed countries indicate that the cost of per ton of carbon sequestration could be in the range of US$10-26; in the context of Nepal, the cost could be much lower as these practices are more labor intensive. However, the current institutional mechanism lacks capacity to cope with Climate Change related forestry sector adaptation, and mitigation policy administration lacks the capacity for accounting framework to measure changes in biomass stocks and to promote sustainable forest management with concrete economic and environmental goals.

4.4 GHG Projection and Mitigation Options for Agriculture and Livestock Sector

4.4.1 Methane Projection from Rice Cultivation

As reported earlier, a major chunk of Methane emissions comes from the rice fields in Nepal. The variation of the Methane emission from rice cultivation assessed in this section is shown in Figure 4.5. This was analyzed using the last 33 years rice cultivation data of Nepal, and was extended unto 2029/30 in business-as-usual scenario. The increasing trend of Methane emission per year is found to be 2.59 Gg, and projection to 2009/10, 2019/20 and 2029/30 is estimated to be 375 Gg, 395 Gg and 430 Gg respectively using this linear trend.

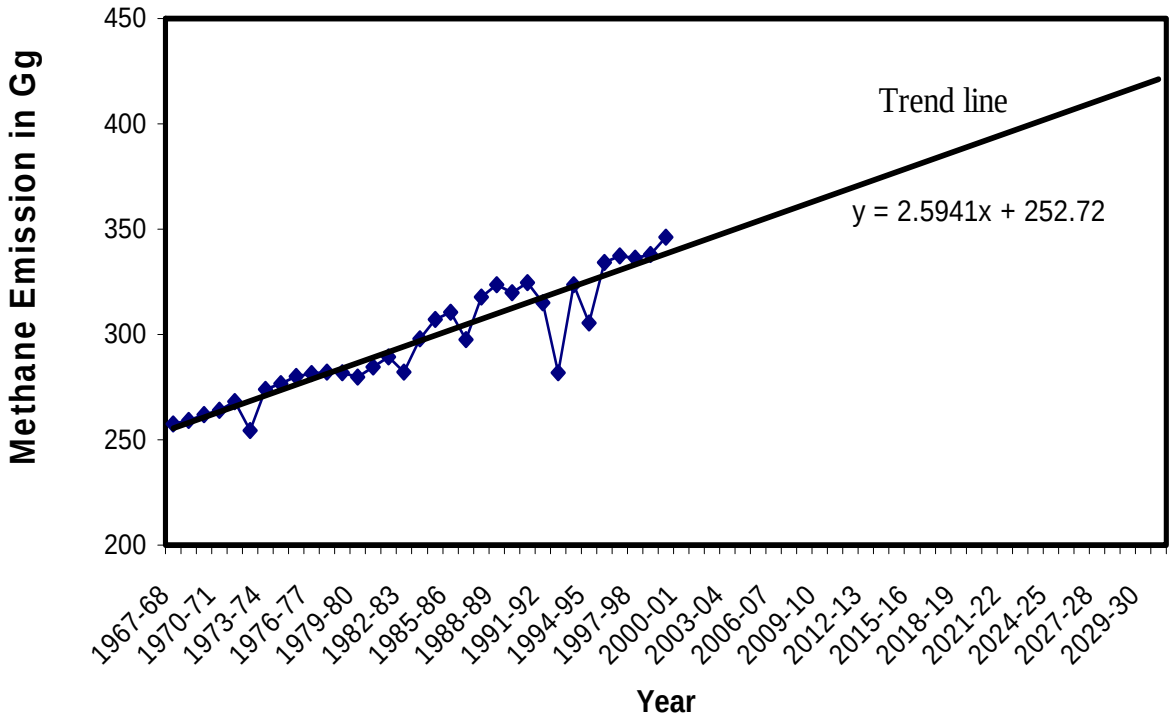


Figure 4.5: Methane Emission from Paddy Field (Gg/yr)

4.4.2 Mitigation Options for Agricultural Sector

Agricultural activities producing Greenhouse Gases like Methane, for example, from domestic livestock and cultivation of rice and Nitrous oxide from manure management and agricultural soil are prime sources of economy in Nepal. In addition to this, Methane emission is also reported from manure management. Besides, agricultural crop burning as a part of agriculture activities also produces Nitrous oxide, Carbon monoxide, and Nitrogen oxide in addition to Methane. In view of these emissions, following mitigation measures are considered as viable option for agriculture sector:

- Adoption of reduced tillage practice (zero till or no till or minimum till) in the rice-wheat system to reduce large amounts of carbon emissions.

- Adoption of agro-forestry practice to convert unproductive croplands and grassland into another form if agro-forestry sector where maximum atmospheric CO_2 build up is absorbed.

- Minimizing Methane and Nitrous oxide emission in rice field through improvement in the efficient use of fertilizers such as sulfur coated urea and slow releasing fertilizer, and improvement in irrigation management such as alternate flooding and drying the rice field. Selection of rainfed crop varieties would help to reduce Methane emission.

- Popularize Biogas plants amongst the rural communities since biogas has been proved as an efficient alternative technology for the rural area to supplement the energy and for environment protection. Biogas slurry is also a good source of fertilizer that may compensate chemical fertilizer requirement for crop production. Overall the biogas is a save technology to replace fuel wood and mitigate global warming.

- Improved water management through soil aeration and periodic drainage of paddy fields.

- Incorporation of pre-fermented farm residues in organic matter amendment.

- Proper selection of rice cultivators,

- Crop rotation; and

- Change in traditional planning practices.

Among these practices, the conservative tillage system helps retain at least 30 per cent or more crop residues; they remain to cover the soils at planting and can protect soil organic matters from decomposition by minimizing the chances of soil erosion. Improvements in the slash-and- burn agriculture could enhance an additional 2-3 tons of organic matter per ha per year. Agro-forestry practices have long been considered as ecologically sound farming practices, and offer some potentials for regaining lost carbons through changes in land use pattern as much as 176 tC/ha after a period of 10 years. Improvements in land management practices such as protection of trees on the farm, contour felling and mound-based soil fertility management, etc. could help regain from about 44 tC/ha to 46 tC/ha, with several combinations of these practices. Such improvements in agricultural practices alone could help in sequestering excess carbon by 10-20 per cent by 2030 in agricultural soils and biomass. The incremental costs of such measures, however, are difficult to note in the context of Nepal

as no exact studies have yet been carried out on these aspects. Studies performed in developed countries indicate that the cost per ton of carbon sequestration could be in the range of US $ 10 to 26, and in the context of Nepal, the cost could be much lower as these practices are more labor-intensive.

Experiments conducted in various countries indicate that up to 90 per cent of Methane emissions can be reduced by these options. However, some of the proposed measures require special application, while others are more costly or difficult to undertake. The effectiveness of some options also depends on soil characteristics as well as on the methods and conditions of application. Further studies and field-testing are needed to assess the impact of different soil types and water management regimes on Methane emissions in order to assess their suitability for local application.

4.4.3 Projection of Methane Emissions from Livestock Sector

Present study indicates that emissions of Methane in Nepal from livestock sector are very small though not negligible. The assessment has computed the emission of Methane from both enteric fermentation and manure management of livestock using last 14 years population data of livestock in Nepal (Figure 4.6). The increasing trend of Methane emission per year was found to be 7.23 Gg. The emission in 2010/11, 2020/21 and 2030/31 was calculated to be 665 Gg, 735 Gg and 805 Gg respectively using this linear trend. The growth of emission is depend not only on population size but also on various other factors like changing climatic conditions, food intake, manure management etc. The steep increase in the emission during 1992/93 to 1994/95 may be because of the sudden increase in population size of dairy and non-diary cattle as well as buffaloes.

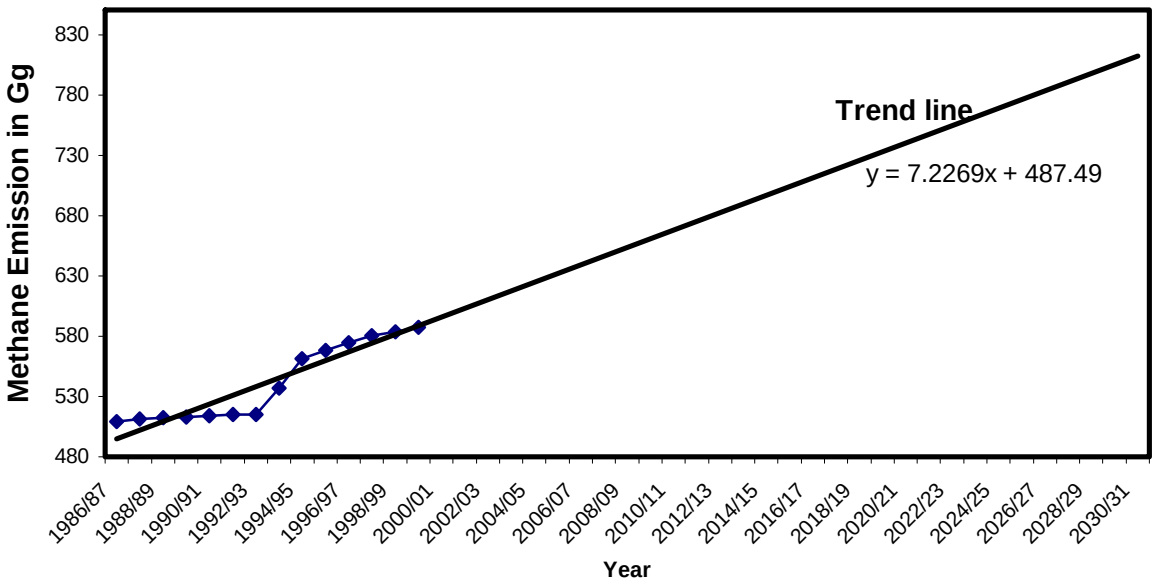


Fig 4.6: Methane Emission from Livestock (Gg/yr)

4.4.4 Mitigation Option for Livestock Sector

Experiments have shown that the increasing trend in fecal Methane emission arising out of the growth in population of dairy cattle and poultry can partly be offset by changing the herd composition having lower enteric emission.

Based on some of these experiments and studies conducted abroad, the following options to reduce Methane emissions in enteric fermentation are identified for consideration in the context of Nepalese livestock farming:

- Make use of mineral supplements to reduce the amount of feed having the minimum nutrient requirements;
- Supplement the poor quality roughage with urea-molasses, legume and/ or low cost agriculture by-products;
- Carry out chemical treatment of low-quality roughage particularly with urea solution in order to improve its digestibility and to increase the non-protein nitrogen contents of fibrous feed;

- Expand and conserve pasture forage for dry season feeding particularly for dairy cattle; and

- Improve ruminant's digestion through better feeding to minimize Methane emission. This also demands the discarding of unproductive livestock population.

4.5 GHG Projection and Mitigation Option for Solid Waste Sector

4.5.1 Solid Waste Sector

Since Methane is one of the principal Greenhouse gases, presently second only to Carbon dioxide presently in its contribution to global warming, and since the amount of this gas emitted to the atmosphere from solid waste depends on amount of waste disposed, its composition and the nature of the disposal mechanism, adapting mitigatory measures in Nepal is as urgent as in any other developing world. Nepal is no exception in the aspect of poor management practices in solid waste due to rapid urban growth, and this is leading the situation to greater volume of waste disposal resulting into increase in Methane emission

4.5.2 Methane Emission and Projection from Solid Waste Sector

Since solid waste disposal is specifically an urban problem, present study was concentrated only on the principal municipalities of Nepal. According to the analysis, the emission of Methane in Kathmandu Valley was estimated at 2.56 Gg in 1994/95, and the combined Methane emission from all other 58 municipalities of Nepal was estimated at 9.69 Gg/year for the same year; projection of the solid waste and Methane emission are shown in the Table 4.12. The table also indicates results of projection applying mitigation measures.

Table 4.12: Projection of Solid Waste and Methane Emission of 58 Municipalities of Nepal

Year	Annual Waste (Gg)	Methane Emission (Gg/yr)	Mitigated (Gg/yr)
2005/06	601.101	14.81	14.81
2010/11	758.719	18.69	16.82
2015/16	963.807	23.75	21.38
2020/21	1231.867	30.35	27.27
2025/26	1583.747	39.02	35.12
2030/31	2047.562	50.45	45.41

4.5.3 Mitigation Options for Solid Waste Sector

While considering the above situation of solid waste problem and emission of CH_4 in Nepal, the following options in these contexts are proposed for reducing the GHG gas emissions:

i) Recovery and use of landfill gas: The landfill Methane generated in the site should be extracted or collected and used for energy purposes. Possible options for using the gas include:

- Electric generation and co-generation;
- Use the gas for heating purposes including cooking, or steam generation for industrial processes and industrial boilers;
- Piped supply for using it as natural gas.

ii) Reduction of Methane generation: Encouraging minimization of solid waste and proper management en-masse of recycling, incineration and composting can reduce Methane production.

iii) Reduction of waste generation at source: Encourage reduction of waste disposal and the recycling of waste at the source itself.

4.6 Implementation Issues

Nepal is one among the many developing countries where reducing GHG emission is not a national development priority. It is however felt that the awareness about Climate Change issue is gaining ground in the pubic, and its importance is gradually being understood. It is realistic, therefore, to expect that the national policy will give due consideration to GHG emission issues in the future. Environment protection issues, albeit, are already gaining rapid acceptance in the policy level of Nepal though. But still environmental protection at present is viewed in a rather narrow sense and is limited to urban areas. The Tenth Five Year plan nevertheless has given due importance to environment protection.

In the Climate Change context, another policy matter serious enough to be focused on, relevant to GHG emission reduction, is development of hydropower in Nepal.The backbone of this policy is to harness the vast natural resource of the country, make the country self-sufficient in energy and get economic benefit of exporting the extra energy to other countries. This in return also implies large amounts of GHG emission reduction. Hydropower as a substitution to

fossil fuels has zero GHG emission. But the country has experienced substantial price increase in the past, and the electrical energy unit price is one of the costliest in the world (US$ 0.13♣/kWh). This has to be radically revised in the future to make hydropower attractive and an economically feasible alternative to fossil fuel. This issue is not dealt adequately in the policy documents of Nepal.

Article 12 of the Kyoto Protocol defines Clean Development Mechanism (CDM), which was designed for extending the co-operation between the developing countries and developed countries for reducing GHG emissions. Although approval of Kyoto Protocol is yet to take place, CDM has started materializing in different parts of the world. The mitigation options described, for example, in transport sector especially MitTran 1 and MitTran 3, require large investment and are beyond the possibility of the nation. CDM could in one way implement those mitigation options. However, implementation of CDM projects, as experience shows, will not be a straight forward approach. This requires consorted effort of both receiving country and donor country. Implementation of CDM, first of all, requires certain institutional development within the country to identify potential projects, to make accounts, monitor and verify the certification of CDM projects and most important of all to explore market for their implementations.

♣ The electricity tariff is for domestic user with monthly usage more than 250 KWh (http://www.nea.org.np/newtariffrate.htm)

CHAPTER-5

Vulnerability and Adaptation

5.1 Introduction

Working Group I of IPCC, in its report "*Climate Change 2001: The Scientific Basis"* concluded that the globally averaged surface air temperature has increased by 0.6º C over the 20th century. In the IPCC Third Assessment Report, the globally averaged surface air temperature is projected by models to rise 1.4 to 5.8º C by the year 2100 relative to 1990, and the globally averaged sea level is projected by models to increase 0.09 to 0.88 m by 2100 *(IPCC, Climate Change 2001: Impacts, Adaptation, and Vulnerability).* These changes will vary by regions and will be accompanied by increases or decreases in precipitation, as well as changes in the frequency and the intensity of some extreme climate phenomena. In this context, several Global Circulation Models (GCMs) were used worldwide to simulate Climate Change scenarios resulting from the accumulation of Greenhouse Gases in the atmosphere.

These days the GCMs and Regional Climate Model (RCM) derive shorter or even year-to-year Climate Change scenarios by using transient type of models. In Nepal, the process of understanding vulnerability to Climate Change and adaptation measures to reduce impacts of Climate Change started only recently. Studies were conducted involving the use of a couple of scientific/technical models. However, each model had its own limitation due to simplifying assumptions and data constraints. Therefore, various scenarios generated from different models carry considerable uncertainty in the outcomes. In spite of these facts, the study conducted also presents in the following chapters various aspects of vulnerability of agriculture, water resources, health as well as bio-diversity to Climate Change evaluated over a period of time. Also, potential adaptation measures are identified and assessed for minimizing the impacts of Climate Change.

Furthermore, in assessing these adaptation measures, flexibility and cost effectiveness were taken as the main criteria taking into account possibilities of wide range of potential changes in climate in the region as well as the possibilities of significant impacts of Climate Change to ecosystems and natural resources.

5.2 The Climate Change Scenarios

5.2.1 The Climate Models (GCMs and RCM)

As mentioned earlier the use of GCMs and RCM in Nepal is still in the beginning stage and hence, the most appropriate way to interpret the results is to appreciate the order of the magnitude of the issues keeping in view their qualitative outcome rather than the numerical values as such. Considering these facts, transient Climate Models were selectively used in the recent studies. In such models, CO_2 is assumed to increase annually by one percent, and the Climate Change scenario is derived accordingly for each year. In the Regional Climate Model developed by Hadley Centre (RCM-Had RM2), yearly transient increase of CO_2 for 20 years were carried out with two types of run for the period 2041-2060, giving 20 years mean projection of Climate Change corresponding to year 2050. In this respect, therefore, two types of model simulation data are available namely: CTL RUN - CO_2 fixed at 1990 level and GHG RUN- CO_2 at 1 % compound increase per year from 1990 level.

A brief description of these models is presented in Table 5.1.

Table 5.1: Model Description

Model	Model Resolution (Latitude x Longitude)	Vertical Level
CCCM	3.75° X 3.75°	10
GFD3	2.22° X 3.75°	9
Had RM2	0.4425° X 0.4425°	19

Note: CCCM = Canadian Climate Change Model
GFD3 = Geophysical Fluid Dynamics Laboratory R-30 Model
Had RM2 = Hadley Centre, Regional Climate Model

In the GCMs, local Climate Change scenarios are derived by interpolating the average monthly values of temperature, precipitation (mm/day) and solar radiation using the relevant software to each station location. The baseline climate scenario has been developed from the data series of 80 stations in Nepal for the period 1981 to 1998, utilizing the temporal and spatial distribution of available data series. The series include monthly data of maximum temperature, minimum temperature, solar radiation and precipitation.

Previous study on Climate Change (Shrestha, 1997) had confirmed that, for Nepalese condition, CCCM and GFD3 models performed better than others; hence, output of these

models are used in the present study. In the case of RCM, one grid point coordinate file and six separate files: three for GHG data and three for CTL data for each temperature, precipitation, and solar radiation were taken.

5.2.2 Solar Radiation Change

Since solar radiation is the source of all our energies, its variation results in creating differences in temperature, pressure, ocean currents, air masses and other major synoptic phenomena. Because of its relation to so many elements and phenomena, it is considered as the most decisive and important factor of all the climatic elements. Budyko has estimated that 1 % change in radiation would lead to 1.2-1.5º C change in the mean annual temperature of the earth.

In the study on solar radiation over Nepal using the GCM simulation models, it is found that there is mostly a decrease in solar radiation throughout Nepal (Table 5.2). Model GFD3 shows a negative balance -5 to-16 W/m^2 with SW-NE gradient over Nepal, and model CCCM also projects a negative balance for the whole Nepal with gradient 0 to -26 W/m^2. The RCM simulation model also estimates negative balance of solar radiation with lower values in the central belt of western Nepal with magnitude -2 to -22 W/m^2.

Table 5.2: Ranges of Variation in Solar Radiation (W/m^2) in Nepal

Model	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
RCM	-25 to 0	-50 to +30	-13 to +6	-8 to +2	-22 to +4
CCCM	-10 to +1	-65 to -2	-27 to -12	-5 to +8	-26 to +1
GFD3	-1 to +7	-39 to -11	-6 to -1	-11 to +2	-16 to -5

5.2.3 Temperature Change

Temperature undoubtedly is the most important climatic variable used in every impact analysis. In Nepal, the elevation generally increases from south to north with decreasing temperatures. The country's annual mean temperature field is presented in Figure 5.1.

In the study carried out with all these models (CCCM, GFD3 & RCM) and their projections, there is rise in average annual temperature in the range of 2 to 4^{o} C over Nepal, when CO_2 is doubled. Magnitude of temperature rise is greater in western Nepal than other regions.

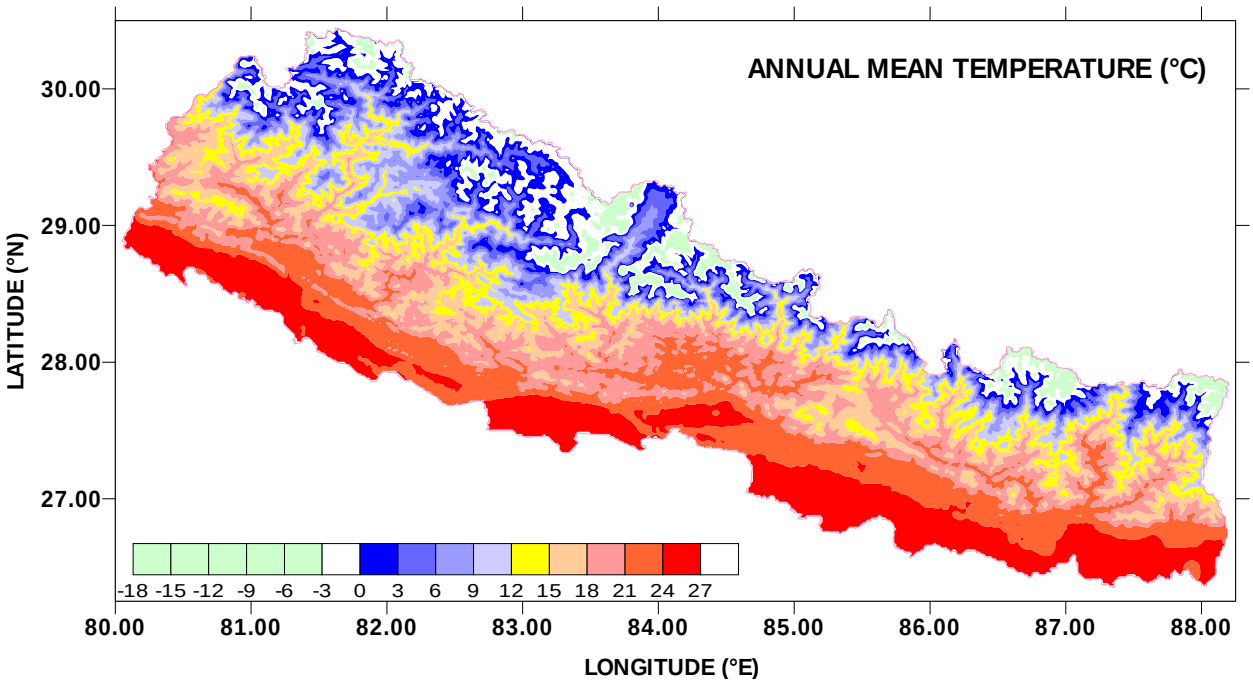


Figure 5.1: Annual Mean Temperature over Nepal

Season wise, winter shows greater increase (2.4^{o} C to 5.4^{o} C) in far-western region than any other seasons according to CCCM model, and for all seasons in general, the rising gradient is from east to west, whereas in GFD3 model it is from west to east during pre-monsoon and winter.

The range of variation in temperature rise, projected by models for different seasons, is presented in Table 5.3.

Table 5.3: Range of Variation in Temperature Rise (ºC) in Nepal

Model	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
CCCM	+2.0 to +4.0	+1.4 to +4.4	+3.7 to +4.7	+2.4to +5.4	+2.3 to +4.3
GFD3	+2.8 to +3.5	+1.8 to +3.3	+2.7 to +3.7	+3.2 to +3.8	+2.9 to +3.3
RCM	+ 1.0 to +15	+0.5 to +13.3	+1.0 to +12.5	+2.0 to +10.5	+1.0 to +12.4

The temperature trend analysis (Fig. 5.2a) shows that, except for small pockets in the eastern region and far western Terai, most of Nepal is depicted with a positive trend of 0 to 0.5° C per decade based upon the data of 80 stations for the period 1981-1998.

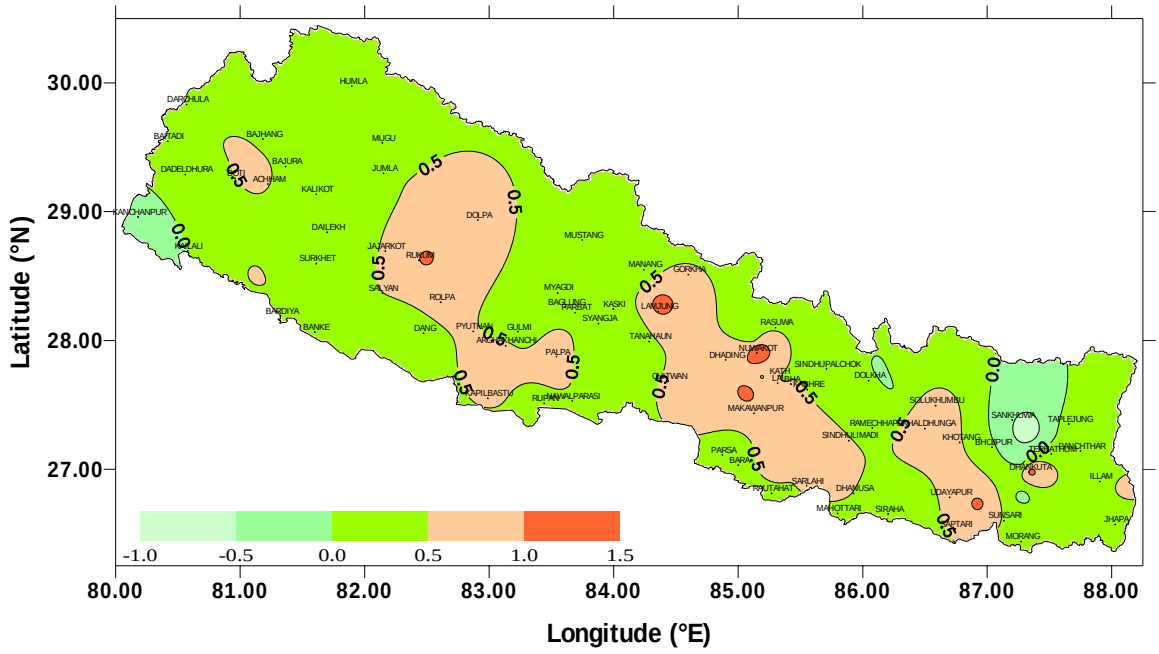
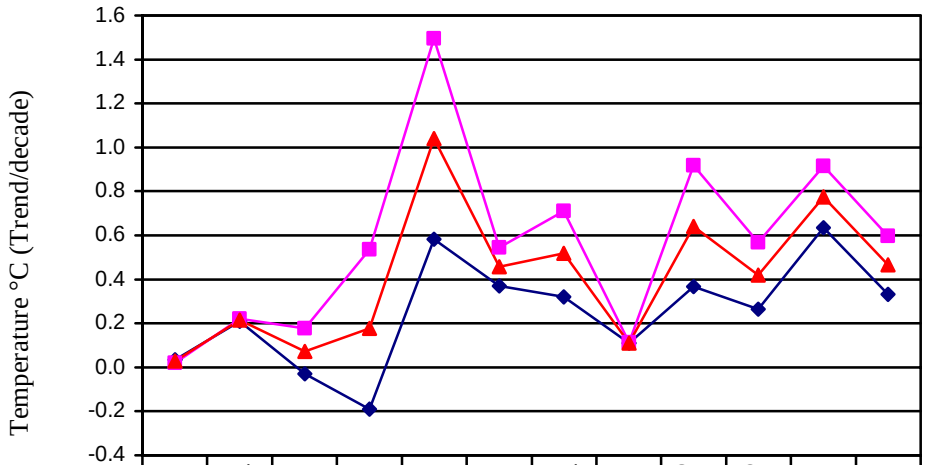


Figure 5.2a : Observed Mean Annual Temperature Trend (°C) per Decade for the Period [1981-1998]

But the overall temperature in the country is found to be rising at the rate of 0.41º C per decade, and this is shown in figure 5.2b together with monthly details of the average trend of maximum, minimum and their mean per decade.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmin. TREND	0.034	0.208	-0.03	-0.19	0.583	0.369	0.319	0.109	0.367	0.265	0.636	0.332
Tmax. TREND	0.021	0.221	0.178	0.537	1.496	0.546	0.711	0.114	0.918	0.569	0.916	0.598
Tmean TREND	0.028	0.215	0.072	0.177	1.04	0.458	0.518	0.109	0.641	0.418	0.775	0.465

	Annual	Monsoon	Pre-monsoon	Winter
T min. Trend /decade	0.25	0.29	0.12	0.30
T max. Trend /decade	0.57	0.57	0.74	0.44
T mean Trend /decade	0.41	0.43	0.43	0.37

Figure 5.2b: Trend of Maximum, Minimum and Average Temperatures for Nepal (1981-1998)

5.2.4 Precipitation Change

In the model output analysis, GFD3 model projects general increase in precipitation for whole of Nepal with gradient from south west to north east in the magnitude of 150 to 1050 mm at 2 x CO_2 level. CCCM model projects a decrease in precipitation from 0 to 400 mm in the eastern region, but increase in precipitation in other regions up to 1600 mm. On the other hand, the RCM indicates a change in precipitation by -1000 to +3000 mm. Range of precipitation change during various seasons projected by the models is given in Table 5.4.

Table 5.4: Range of Precipitation Change (mm) in Nepal

Model	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
CCCM	-70 to +20	-100 to +1600	+25 to +72	-200 to -18	-400 to +1600
GFD3	0 to +60	+100 to +900	+2 to +14	+24 to +59	+150 to +1050
RCM	0 to +900	-1500 to +2000	-100 to 100	-25 to +200	-1000 to +3000

Note: CCCM and GDF3 projections apply to the time period when CO_2 is doubled

:RCM projections apply to the year 1950 (mean between 1940 and 1960)

The GCM projection of precipitation scenario against observed precipitation values shows that rainy season in Nepal including pre and post monsoon seasons will be more intense. Highly noticeable increase is found especially during June and July, while slightly lower than observed precipitation amounts are estimated for August. Precipitation scenario also indicates that winter and spring will be drier than what it is now.

According to the precipitation trend analysis (Figure 5.3a) based upon 80 stations data, in general, most of Terai belt and western Nepal will observe negative trend (with maximum decrease of <300 mm per decade in the Terai belt of central Nepal) except in a few pockets of positive trend. While hills and mountains of west Nepal and northern belt of eastern Nepal will be having positive trend with a maximum of 1100 mm per decade, maximum negative trend will be observed in the eastern and central part of Nepal with the magnitude < 700 mm per decade.

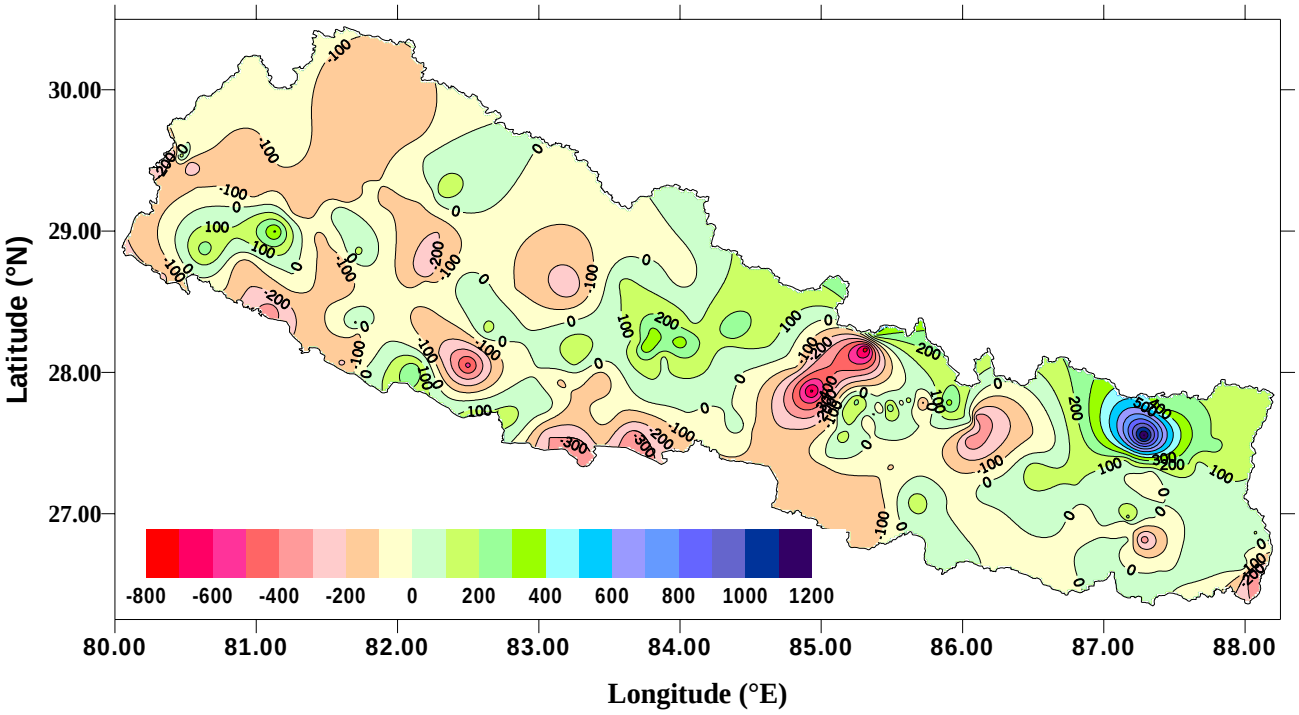


Figure 5.3a : Trend of Annual Precipitation (mm) per Decade for the period (1981-1998)

Overall average trend for Nepal (Figure 5.3b) indicates that the precipitation over Nepal is decreasing at the rate of 9.8 mm per decade on annual basis.

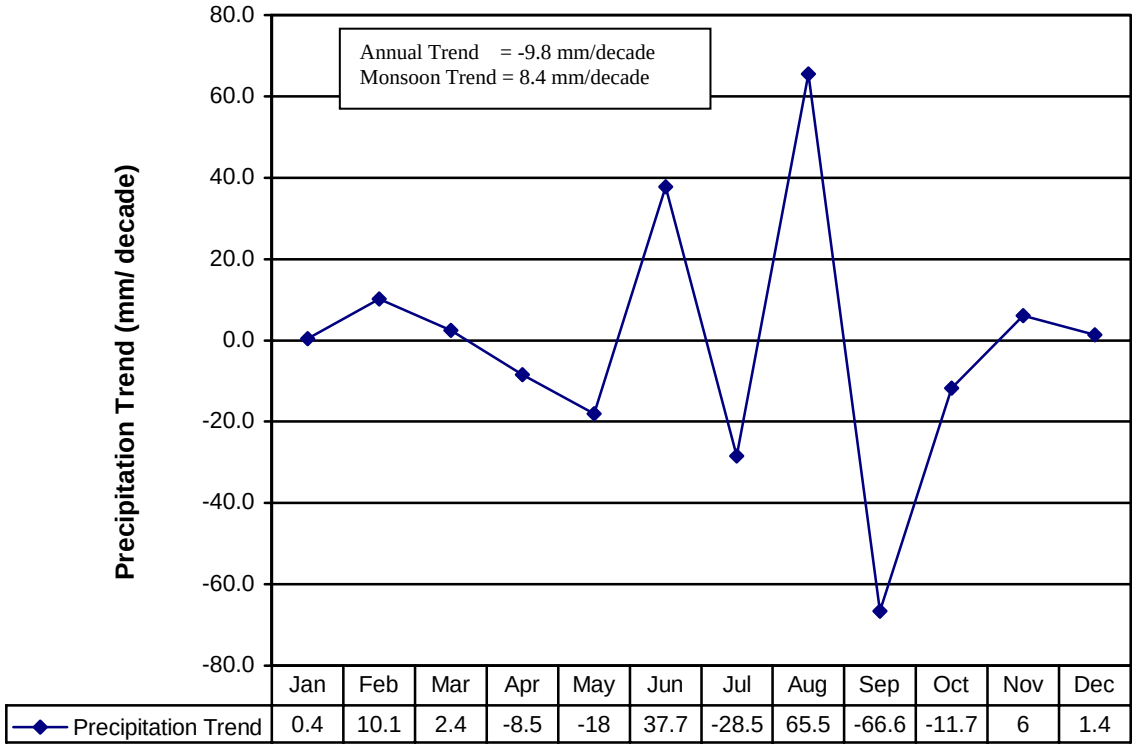


Figure 5.3b: Precipitation Trend for Nepal (1981-1998)

Average precipitation trend shows that increase in rainfall during monsoon season in Nepal is both by increase in number of rainy days and by increase in rainfall magnitudes.

Trend of monsoon onset and monsoon withdrawal (Figure 5.4 a and b) from 21 years of data show that monsoon season is elongating in both the ends, and onset has occurred earlier by 71 % of a day per annum and withdrawal is delaying by about 15%. Although this trend appears to elongate monsoon for long, it will not be possible to continue for ever due to changes in seasons. In the case of trend of withdrawal of monsoon it is not so distinct whereas the trend of monsoon onset is quite distinct. Hence before the trend terminates, monsoon may overtake some parts of pre-monsoon season.

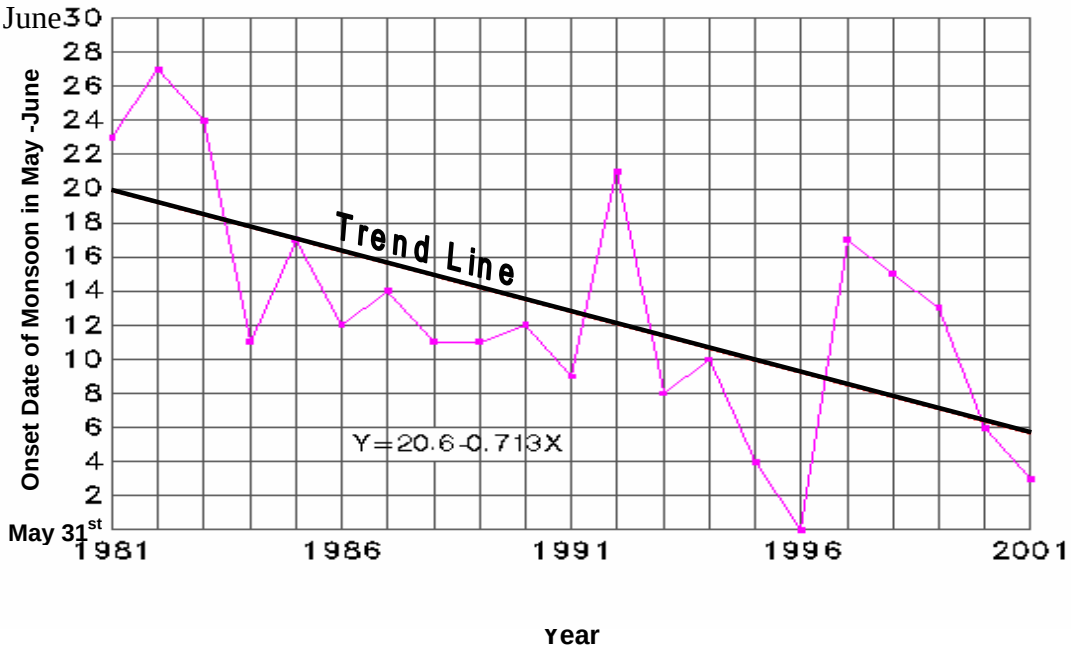


Figure 5.4a : Variation of Monsoon Onset dates (1981-2001)

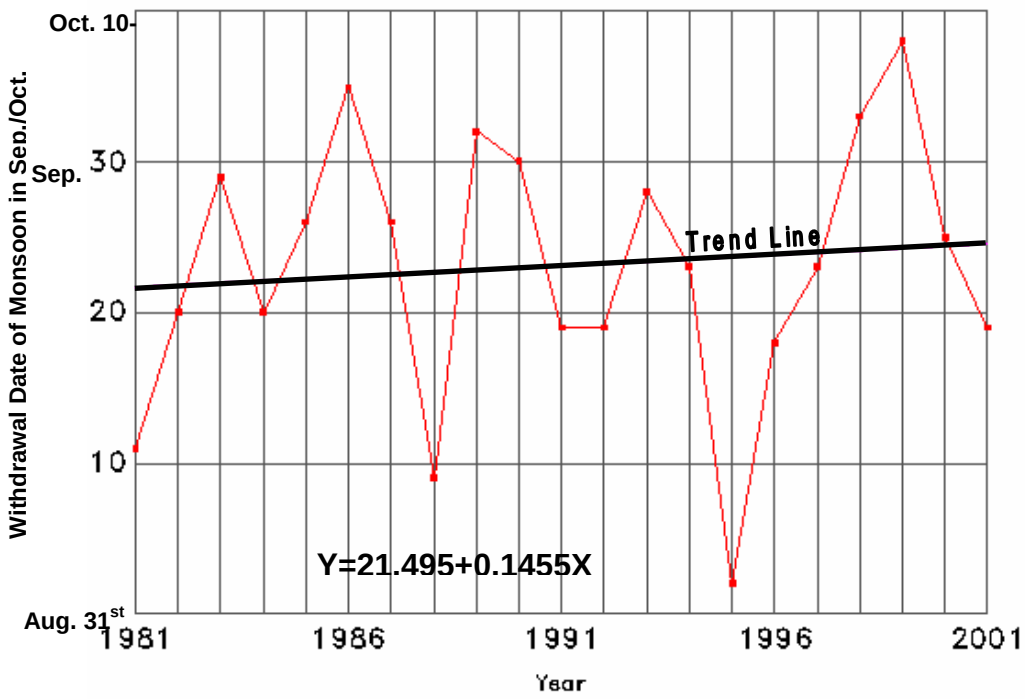


Figure 5.4b: Variation of Monsoon Withdrawal dates (1981-2001)

In the RCM model, it is found that solar radiation and temperature in the central and eastern region are quite compatible with the observed ones. Hence, RCM model may best fit in Nepal if the temperature projection in the western Nepal especially in the hilly and western Terai regions can be improved whenever refined model becomes available and can be run in the

country's microcomputers. However, in the case of precipitation, compatible base line scenario can not be achieved due to intense topographical variation.

5.3 Agriculture

Nepal is an agrarian country with nearly 80% population depending on agriculture. This surely implies that the issue of food balance here is very important. Due to terrain topography and inaccessibility, population and food supply remain the central concern in the economic planning although the current agriculture production is nearly sufficient to cater to the need of the country. The present production of rice, wheat, maize, millet, potato and other cereals together stands at about 6.99 million metric tons. In the past, cereal production was always towards the negative balance. In 1999/00, however, due to favorable weather conditions, edible cereal production was 4.45 million tons against the total requirement of 4.39 million tons then (ABP&SD/MOAC, 2000). But the serious negated consequences resulting from the shortage of edible oil and some pulses caused massive import of these commodities.

The impact of Climate Change on agriculture will eventually affect the economic well being of the population because it will have either a decreasing effect or an increasing effect on the production pattern of the agriculture sector affecting in turn the economy of the country in the similarly way. Impact of Climate Change on crop yields due to the GHGs particularly the CO_2 increase has been assessed using the model DSSAT3.5. The CO_2 has been set at 580 ppm by 2075 and the temperature rise has been set to 1^o C, 2^o C and 4^o C.

5.3.1 Climate and Agriculture

Due to diversity in topography, culture and climatic conditions, different cropping patterns are in use in Nepal. High Himalayas are not suitable for cultivation, except for pasture or grazing lands. In these high mountain areas, cattles are raised, and short duration crops like potato, buckwheat, barley and mustard are grown mostly in summer. The middle mountain cropping pattern constitutes rice/wheat cultivation in the irrigated lands and maize/millet or maize/soybean in the rainfed lands. Siwalik and Terai are similar in cropping system. Rice/wheat is the most dominant cropping combination pattern in these regions, but crops like sugarcane, pulses, oilseeds and vegetables are also commonly grown here.

There exists intricate relationship between climate, crop and the animal production and their long-term implication. Success of crop production is entirely linked with the weather

condition, and their relationship has a direct effect on the growth and development of a crop, since the physiological function of the crop is governed by the climatic parameters. The optimum requirement of air temperature and humidity for the behavior of various crops is depicted in the Table 5.5. Below or above the critical level of the parameters especially the air temperature and humidity, the growth of a crop will be negatively affected. Extreme events such as rainfalls causing flooding and landslides, droughts, heat stress, hot winds, cold waves, hailstones and snowfalls are undesirable; in resent years, their frequency seems to have increased noticeably in the country, and long dry spells and cold waves have negatively affected the crop production. These can lead to crop failure and eventually to a famine in the country. Similarly, high humidity creates a favorable environment for the growth of fungal and bacterial diseases. In addition, some insects and pests become active and damage the crops.

Table 5.5: The Optimum Range of Air temperatures for Successful Growth of Crops.

Crops	Maximum air temp. ^{o}C	Minimum air temp. ^{o}C	Average air temp ^{o}C	Effect of humidity
Rice	48	12	22-30	High
Maize	45	10	25	Very high
Wheat	35	5	15-20	Medium
Potato	30	10	12-20	Very high
Sugarcane	45	10	22-30	High
Banana	38	16	27	High
Peas	23	10	17	Very high
Beans	27	10	15-20	Medium
Sunflower	NA	NA	18-25	Low
Cabbage	24	10	17	Medium
Tomato	35	10	18-25	Low
Orange	38	13	23-30	Medium
Cotton	40	12	27-32	Low
Groundnut	33	18	22-28	Medium
Soybean	35	10	25-30	Medium

Source: Hunsigi and Krishna 1998; Balasubramaniyan and Palaniappan, 2001.

Note : NA = Not Available

In the context of South Asia as a whole, there is a strong linkage between the monsoon activity and the agricultural productivity. In the last decade or so, particularly Nepal and the Indo-Gangetic plains of India, just immediate south of the mountain region, used to experience sever sky overcast during winter affecting major winter crops like potato, oilseeds, pulses and onion. Yield reduction in 1997/98 ranged from 11 % to 38 % compared to the average of the proceeding 10 years (Table 5.6). As a result, food shortage and the resulting skyrocketing of market price noticeably upset the food balance in the following year. Scientific explanation for this, however, is not exactly clear yet. Frequent occurrence of cold waves and fog mixed with dust particles in the atmosphere could be the possible cause behind it. Recent report of brown clouds in the northern part of Indo-Gangetic plain could testify this. This is something that this region is unusually experiencing during winter times. Notwithstanding though, possible effect of Climate Change must not be ignored in these circumstances.

Table 5.6: Impact of Sky Overcast (cold wave) on Winter Crop Yields estimated in the Terai of Nepal, 1997/98

(Kg/ha)

Year	Potato	Toria	Sarson	Rayo	Lentil	Chickpea
1987/88	NA	NA	NA	NA	539	1320
1988/89	NA	703	563	728	NA	NA
1989/90	25540	NA	503	844	819	709
1990/91	19720	570	NA	NA	912	NA
1991/92	22280	949	NA	NA	NA	NA
1992/93	17360	NA	NA	NA	NA	NA
1993/94	22130	712	785	601	NA	1044
1994/95	23760	718	524	548	NA	NA
1995/96	17210	760	636	565	NA	NA
1996/97	22630	815	803	887	959	922
Mean	21330	747	569	733	807	999
1997/98	15390	474	505	513	504	619
Reduction (%)	27.8	36.5	11.2	30.0	37.6	38.0

Source: Sample survey and annual reports of potato, oilseeds, and pulses from 1987/88 to 1997/98, NARC**.**

Note: NA = Not Available

5.3.2 Potential Impacts on Livestock

The effect of climate on herding of livestock, for an example, is vividly illustrated by yaks behavior; these are an endemic and economic assets of the Himalayas, and are considered the most sensitive mountain animals to the changing temperatures. Yaks are raised in the elevation ranging from 3000 to 5000 m above mean sea level. In the peak winter when snowfalls begin, yaks are brought down to 3000 m elevation. Yak herd starts going up the mountain when mercury level begins to increase. Usually their upward movement is set on a fixed date. For example, in the lower Mustang, the community sets the date May 25 for upward journey and September 25 for downward journey. This is done to have equitable benefit for each herd on the natural resource distribution so as not to exhaust them. They follow the so called transhumance system of herding. Yaks are found in15 northern districts in Nepal. It is estimated that the yak population here is around 9000 and chauri 17000 (Joshi, 1982).

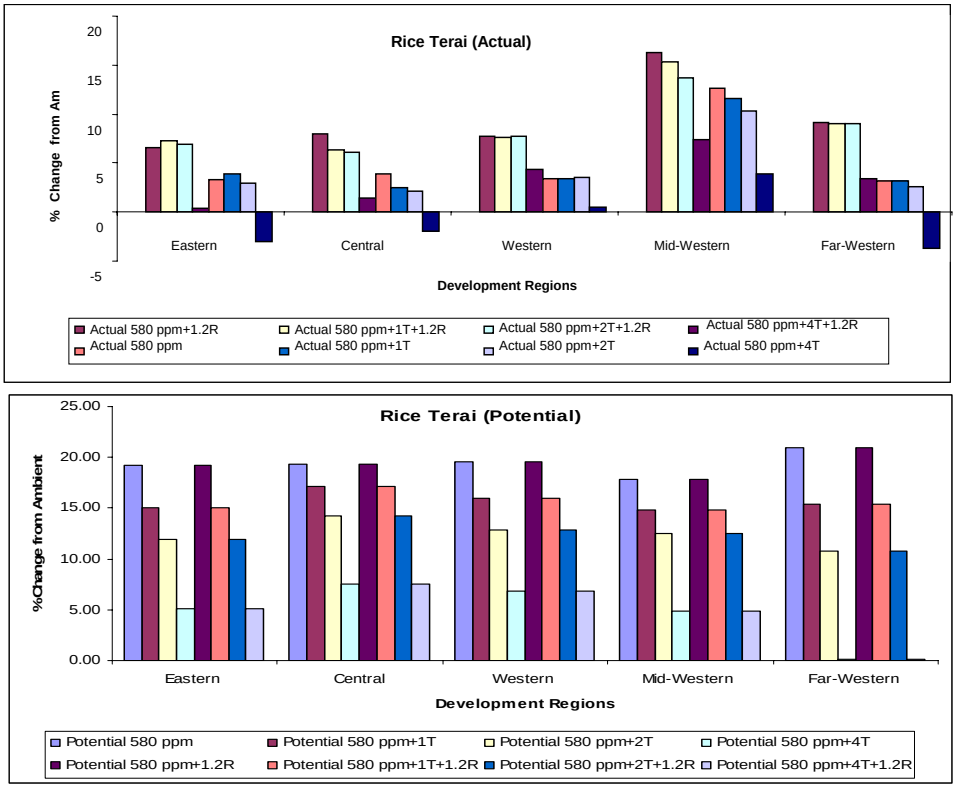
Movement of yaks from 3000 to 5000 m elevation and vice versa depends on the availability of forages and suitable ambient temperature. But the optimum temperature for yak is in between 0^{o} C and 10^{o} C although they can withstand far below the freezing point. It has been noticed that they are very sensitive and non-tolerant to the high temperatures. Chauri (crossbreed between yak and cow) by comparison can better withstand higher temperatures. The sensitiveness is observed easily either by their refusal to return to shelter or by their upward movement without the herdsman's notice.

A study conducted by Stem et. al. (1995) has indicated that large numbers of animals are unproductive and emit over 100 g of Methane per kg of milk production in developing countries against 15-20 g Methane per kg of milk production in many developed countries. Similarly, Nitrogen release from the crude protein feed is a problem here, which produces nitrate-nitrite pollution in the soil and water. Feeding the livestock using crude protein is unhealthy. Gill (2003) reported that reduction of crude protein use by 1 % could bring 8-10 % reduction in N-excretion. In other words, the feed with 3-4 % crude protein would yield 20-30 % reduction in N-excretion. This however can be further reduced by the supplementation of amino acids more cost effectively.

5.3.3 Potential Impacts on Crops

Rice varieties grown in the Terai, inner Terai and lower valleys are different from those grown in the hills. Khumal-4 variety is most popular and recommended for the hills, whereas, Mansuli and Sabitri are recommended for the Terai. In the mountains above 2000 m, cold tolerant varieties like Marshi Brown and Marshi White are recommended.

The Terai rice shows that its potential yield can be estimated to increase by about 18 to 21 % when CO_2 is doubled to 580 ppm (Figure 5.5a). However, with the increase of temperature beyond 4^o C, the yield is projected to decrease. An increase of temperature up to 4º C and rainfall to 20 % made the yield increase only from 0.09 to 7.5 %, and beyond that the yield level will continue to decline. In the hills, the condition is slightly different. The effect of temperature here is little more severe than in the Terai. At 4º C rise, the yield potential goes down by nearly 7 % less than the ambient (Figure 5.5b). The situation in the mountain region is found somewhat better than in the hills, but rice is grown negligibly there (Figure 5.5b).



Note : Am=Ambient ppm= parts per million T= temperature R= rainfall 1.00 = 100%

Figure 5.5a : Climate Change and its impact on Terai Rice

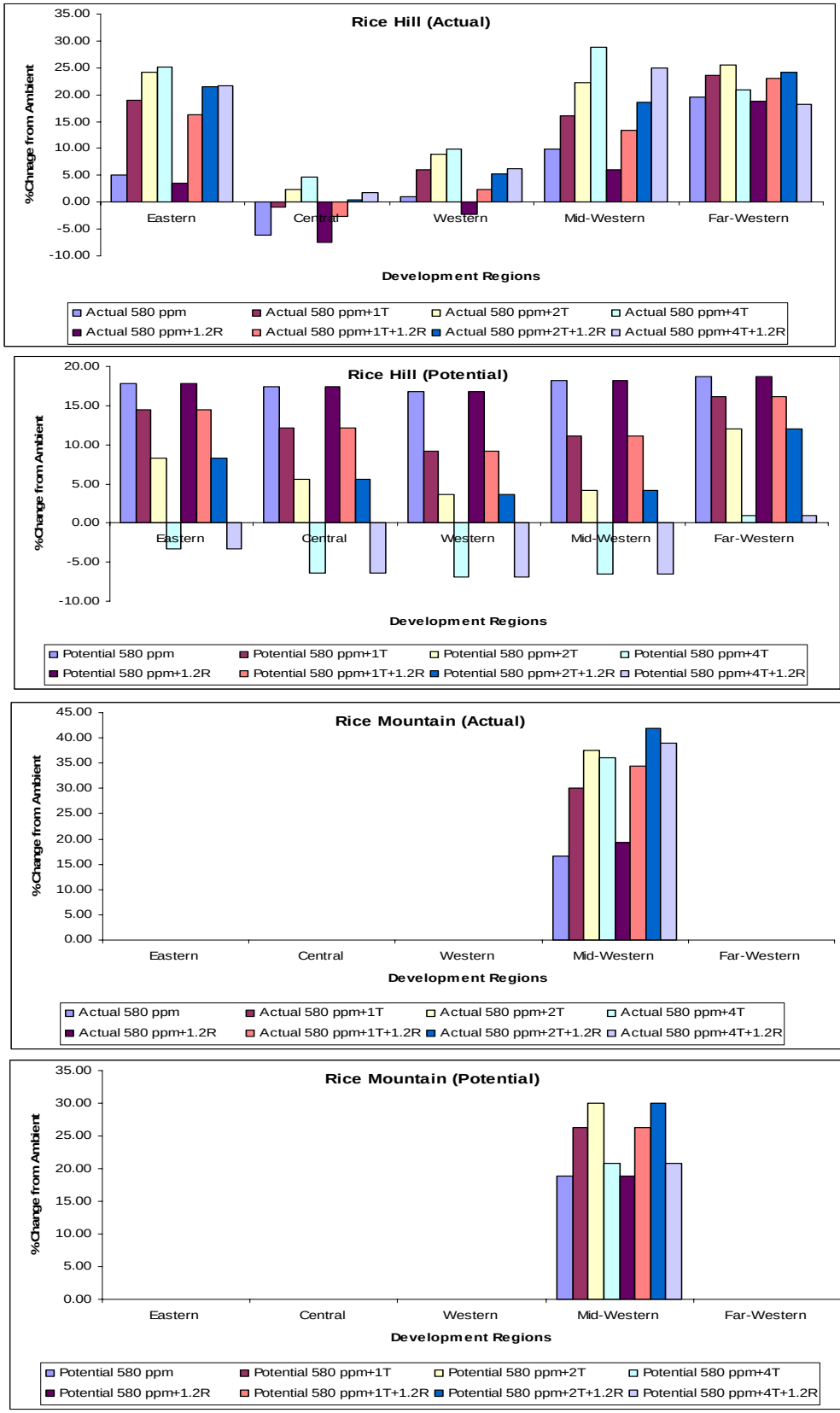


Figure 5.5b: Climate Change and its Impact on Hill and Mountain Rice

Wheat is cultivated in Terai as well as in hills and the mountains of Nepal. Few of the common varieties can be grown both in the hills and the Terai. Their adaptability in this sense is wider due to photo-insensitiveness and the thermal factor; varieties may differ however. Wheat is found to be more responsive to increased level of CO_2 than rice. The wheat yield potential goes as high as 60 %, when level of CO_2 is doubled (Figure 5.6a). The yield starts falling down with the rise in temperature; but the response to temperature in the hills is less than in Terai; in other words, the increase of yield at double CO_2 and the decline due to rise in temperature are not much. Similarly, the mountain environment has less effect on the potential yield with the rise in temperature, as there is insignificant decline of yield with temperature increase (Figure 5.6b). But unlike other regions, the actual yield of wheat in western region of Nepal increases with the rise in temperature. There is however a significant spatial variation on wheat yields. This indicates that the mountain environment is more favorable than others to adapt to the adverse temperature effects. In all the environments, rainfall does not contribute much to increase actual wheat yield under the irrigated condition, except the western region.

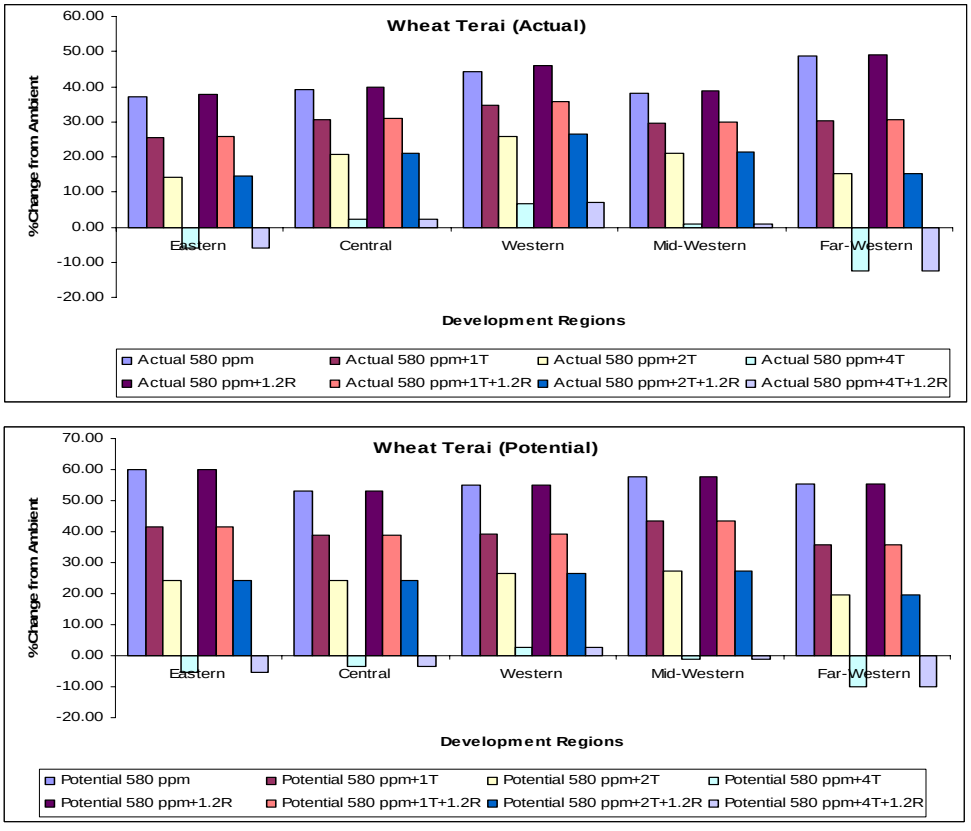


Figure 5.6a: Climate Change and its Impact on Terai Wheat

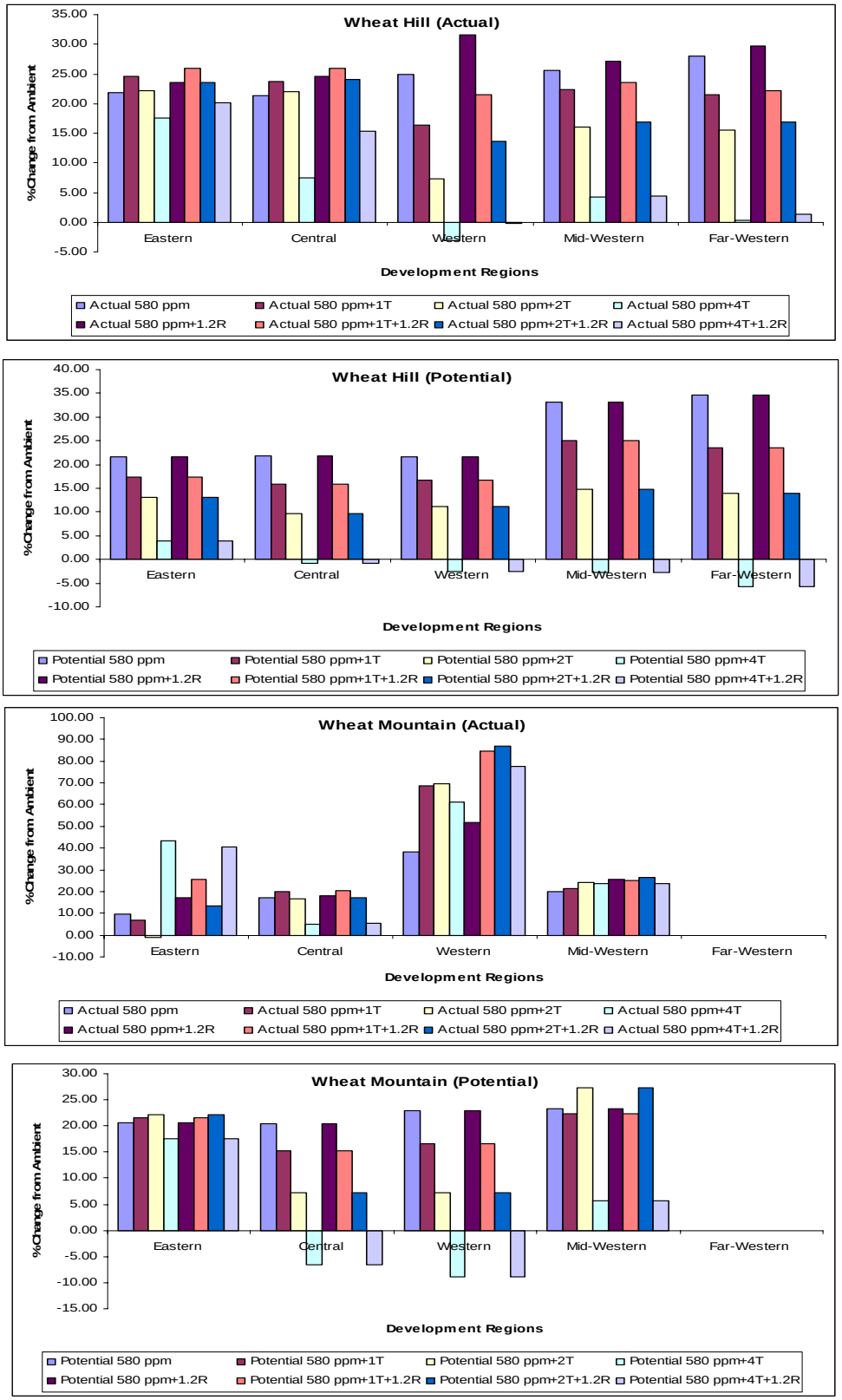


Figure 5.6b: Climate Change and its Impact on Hill and Mountain Wheat.

Maize has a broader ecological adaptation than rice with change of temperature and precipitation. Hence, maize of the same variety can be grown over large altitudinal variations. In Terai, the yield potential is only about 6 to 7 % above the ambient, when CO_2 is doubled (Figure 5.7a). and temperature rise has greater effect than wheat and rice. Also rainfall increase does not have much effect on the maize yield in Terai. But in the hills, the effect temperature is less than in Terai (Fig. 5.7b)

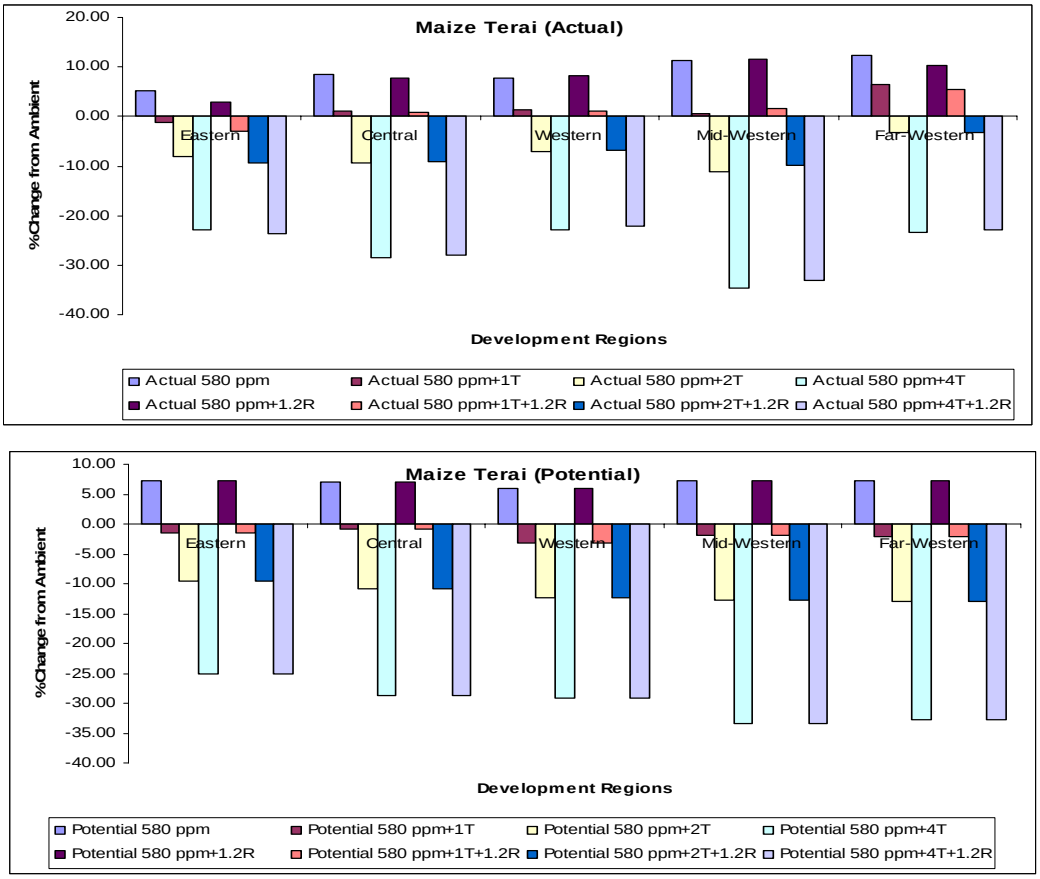


Figure 5.7a: Climate Change and its impact on Terai Maize

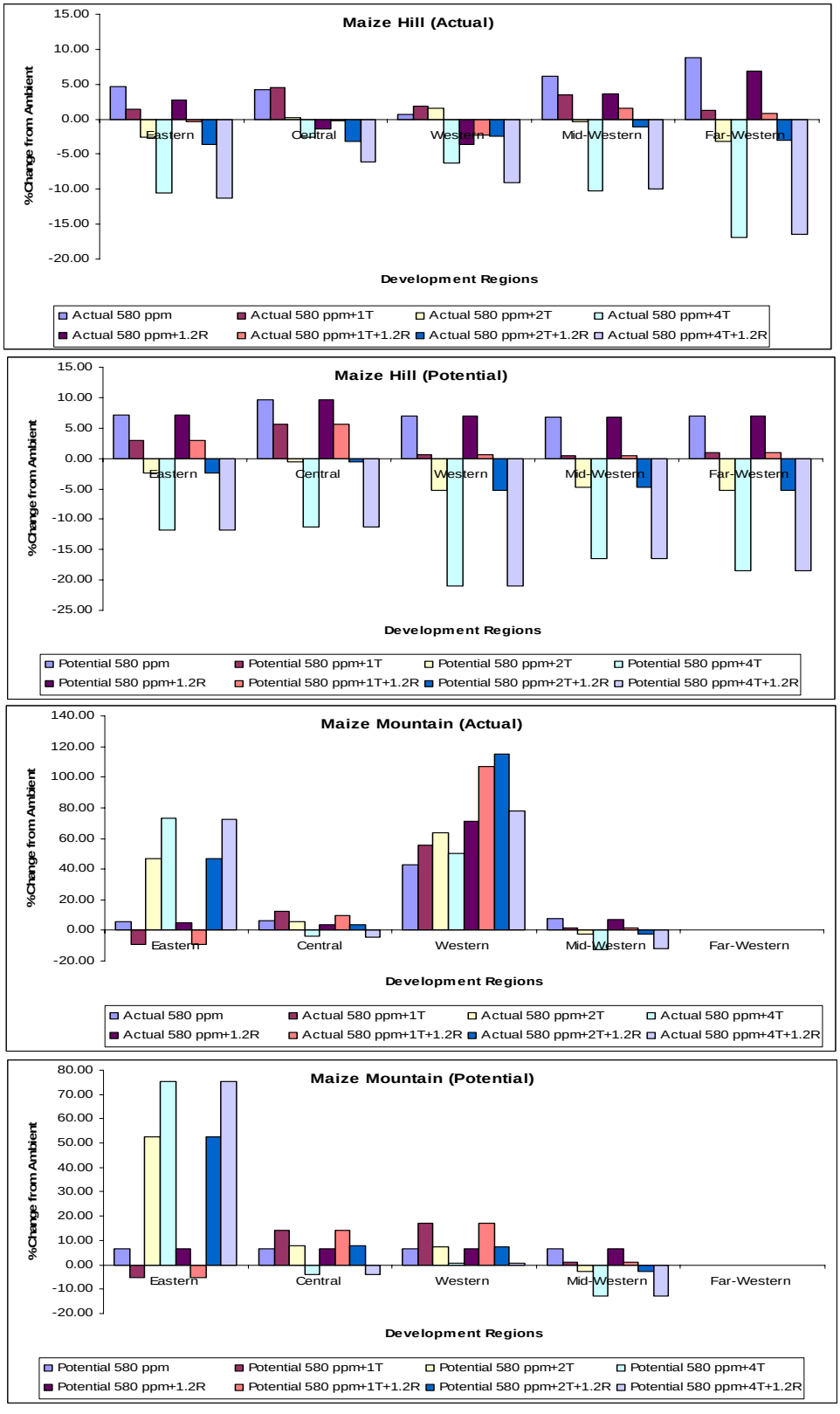


Figure 5.7b: Climate Change and Its Impact on Hill and Mountain Maize.

In the higher mountains, the potential yield of maize is projected to increase by about 7 % over the ambient due to doubling of CO_2 (Figure 5.7b). And the rise in temperature shows a mixed reaction in the maize yield. In conclusion, it can be said that due to increase in CO_2, there will not be appreciable increase in maize yield; rather there will be significant negative effects due to temperature rise, particularly in the Terai and hill environments. However, due to the uncertainties of the climate models and differences of impacts on yields amongst crops and regions, vulnerability of agriculture to Climate Change varies according to crops and location characteristics. The present vulnerability study in Nepal is very limited and hence, more comprehensive study is required to understand potential impacts on different economic crops and regions.

5.3.4 Rainfall Variability and Productivity

Using model techniques, attempts have been made to draw the relationship between the rainfall variability and rice and wheat productivity in five locations of varied altitude regimes of Western Development Region of Nepal (Figure 5.8a, b and c). There is always a threshold limit (upper as well as lower) of water requirement for a particular crop. A poor relationship between rice productivity and summer rainfall of five locations is depicted in Figures. However, at Baglung (950 m) and Chambas (1050 m) there was an indication of effect of rainfall on rice productivity but the relationship was not significant. Poor effect of rainfall on rice productivity could be either due to the fact that source of irrigation water was available during the entire growing stage of rice or the rainfall was adequate to meet the crop demand. But a greater effect of the winter rain on wheat productivity was observed (Figure 5.8). The effect was significant except at Baglung where there was a large environmental variation; as a result, the level of association was not consistent there.

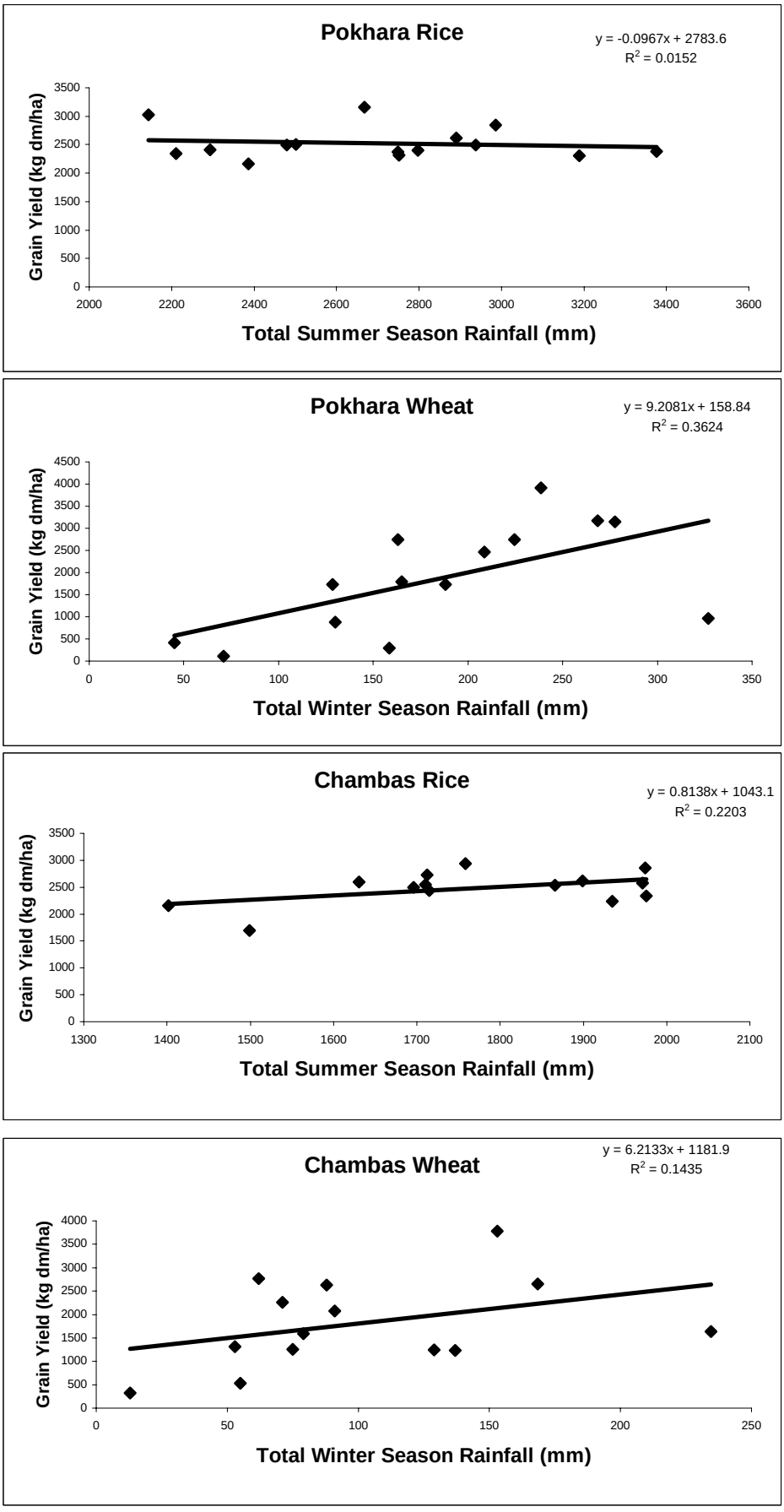


Figure 5.8a : Relationship Between Productivity and Rainfall in Rice and Wheat

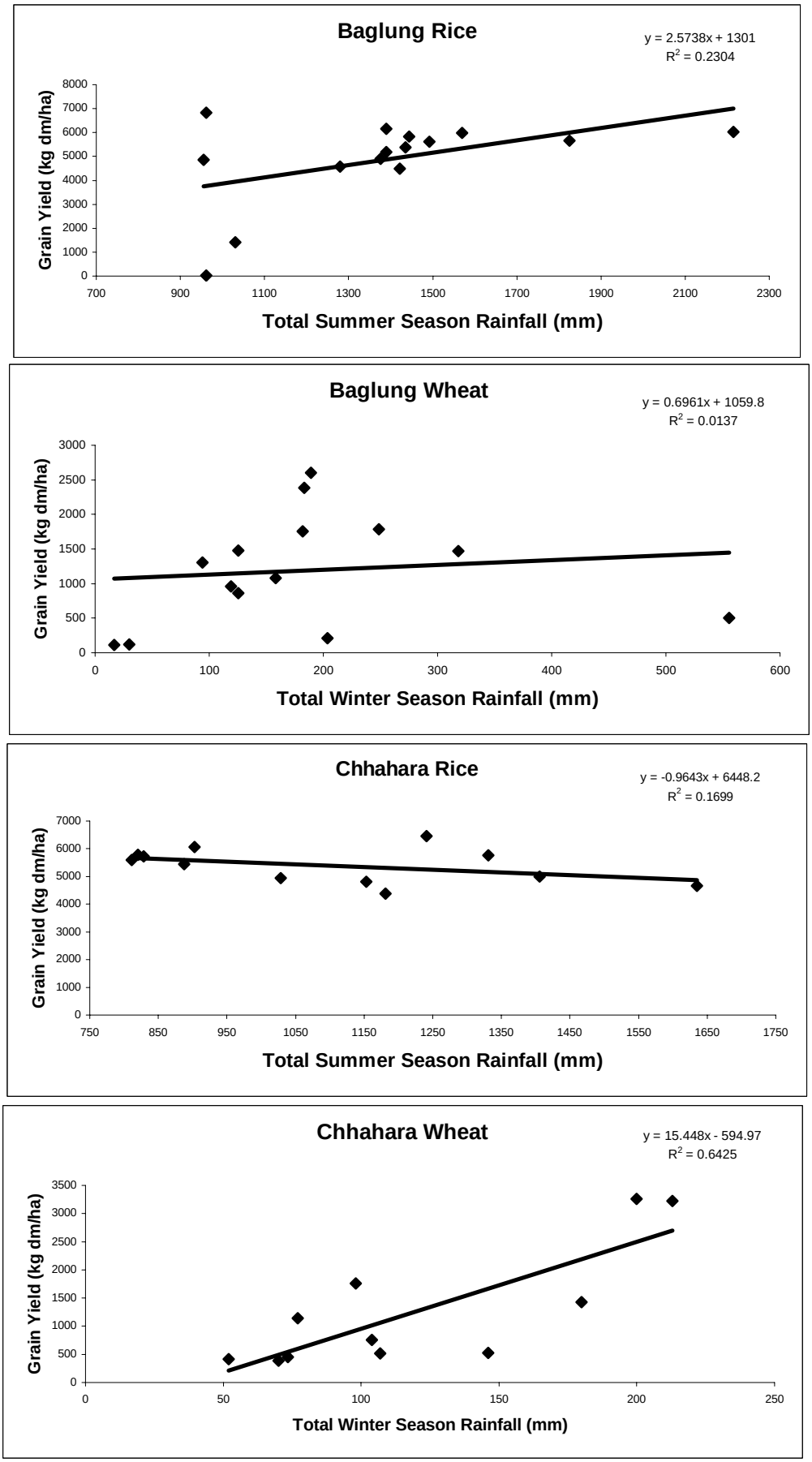


Figure 5.8b : Relationship between Productivity and Rainfall in Rice and Wheat

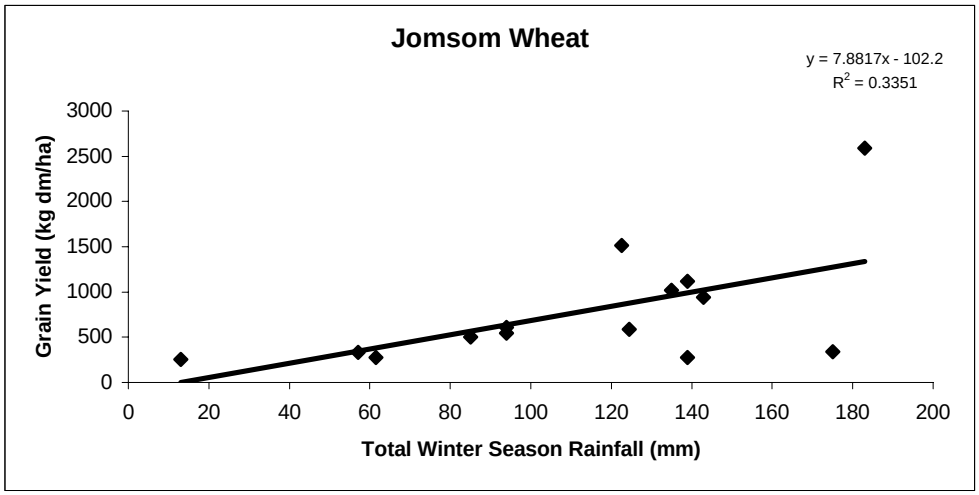


Figure 5.8c : Relationship between Productivity and Rainfall in Rice and Wheat.

5.3.5 Policy Framework and Adaptation Strategies

According to some estimates, there should be 30,000 tons of food storage in Nepal to face any food crisis, but the existing food storage capacity is too low. Keeping this in view, HMG, Nepal, has prepared a twenty-year Agriculture Perspective Plan (APP), starting with the Ninth Five-Year Plan (1996) onward, and sets an agricultural growth target of 5% per year. A technology based on green revolution is proposed in the APP that concentrates on major priority inputs like: Fertilizer, Irrigation, Roads & Power, and Technology. Its second promise is ample economic returns to farmers through increase in productivity of agricultural enterprises by substituting high-value commodities for low valued ones, and third, off-farm employment activities are to be promoted in order to increase their incomes to contribute to their livelihood security. Community forestry and leasehold forestry for the poor are emphasized in the hills and the mountain regions; private and commercial management of forests in Terai and in Siwalik to be managed as protected areas under an effective conservation plan; and National Parks and Wildlife Reserves to be managed with people's participation. In the natural resource managements two distinct programs are envisaged to have significant impact, for example, on poverty alleviation, environmental conservation and groundwater irrigation development in Nepal. Another area related to natural resources management are forests and rangelands management. Proposed policies under this heading are development and adoption of a national land use plan, better integration of related sector such as agriculture, livestock, forestry and soil conversation, and greater participation of local communities and the private sector in the management of forests and rangelands.

Also, through increased employment generation and cash crop production, there will be good income in the hands of poor to buy their required foods. As a supplementary, APP proposes to have labor-intensive public work program like maintenance of security/stock of food grains and increased role of NGO's in food distribution programs. Though limited, the present study of potential impacts due to Climate Change on agriculture suggests that Nepal is highly exposed and vulnerable to the risk of negative effects. These potential impacts may affect food production in Nepal greatly in coming years.

Following are the adaptation strategies suggested and identified specific to the country's circumstances and linked to its needs.

a) Resource conservation for agricultural sustainability

Rice-wheat cropping system is by far the most important and dominant cropping system in the country. Improvement of soil management through mechanisms such as minimum tillage practices in the rice-wheat production regimes should be developed. Under this resource conservation strategy, surface seeding, for instance, in the wheat and bed planting in rice allow minimum tillage; this can reduce the carbon loss as well as the cost of production and the water requirement by over 25% which will ultimately save large amount of carbon emissions from the existing rice-wheat farming system.

b) Development of genetically adaptive varieties

Many local varieties are important having good tolerance of stress conditions such as heat, drought, insects and disease. Comprehensive breeding strategy that can incorporate those local genes in rice and wheat should be developed and adopted. Rice and wheat crop varieties that can sustain better under rainfed and heat stress condition will help to reduce the process of global warming.

c) Hybrid maize program should be developed into a full-scale production system

Simulation model's projection that global warming will have significant negative effect on maize production should be seriously looked into. Hybrid maize production is still a long way in Nepal. But hybrid maize that can better grow under heat stress and significant yield advantage has great potential to boost the yield at least by 50%. Hybrid maize development therefore helps reduce the negative effect of Climate Change as indicated by the model.

d) Crop diversification program should be encouraged

Growing mono crop will likely to have greater risk exposed to the frequent extreme climatic events. Crop diversification program including multiple as well as mixed cropping system should be promoted. The crop diversification program will give better insurance averting the risk of crop failure, and it will also diversify income sources and conserve the natural resources. Horticulture plantation and other cash crops in the hill environment should be promoted as a better choice than the cereal crop. Moreover, Terai plain should be devoted for the cereal crop production only.

Diversified cropping already in practice in Nepal in the hilly regions is very much common now a days ensuring good harvest of the crops. Also the farmers need to follow strategies such as fixing the date of sowing and the kind of variety that can cope with undesirable climate events. In Nepal, indigenous agriculture practices have been adapted to suite local environmental conditions; for example, early maturing barley is chosen in the high mountains to avoid the climatic risk.

e) Promotion of organic based farming

In place of chemical fertilizers, or chemicals and pesticides which face undesirable environmental pollution, organic based farming as a complimentary approach should be encouraged and promoted using many indigenous technologies available in the country.

f) Discourage the slash and burn agricultural system

Slash and burn agricultural system is a common practice among many indigenous communities in Nepal. Slash and burn practices for the expansion of agricultural land are one of the chief causes of deforestation & GHG emission and should be discouraged though legal as well as technical measures to slow down the deforestation in the hills.

g) Development of early warning system

Development of a warning system of hailstone occurrence prior to harvest time could save a lot. Similarly forecast of winter cold wave could save winter crops like potato, oilseed, crops, lentil and winter vegetables from being badly damaged. Because of this implementation of an early warning system of hails as well as a reliable forecasting method for cold wave condition should be developed soon.

h) Agro-forestry and forage development

There has been a growing concern for degraded forestland or abandoned land. This is an acute problem particularly in the hills. For mitigation, a "Leasehold Forestry and Forage Development Project" under the joint implementation of the Department of Forest and Soil Conservation, Department of Livestock, Asian Development Bank and NARC is in implementation to conserve and rehabilitate the degraded forest lands through the participation of poor and rural hill farmers by leasing land to them for 40 years which consequently should lead to poverty alleviation.

i) A comprehensive land use policy

For sequestering the CO_2 by conserving forest areas, a certain ratio between the forest area and agricultural land in the land use system should be maintained and implemented. For this, a comprehensive policy on land use system should be adopted through a sound co-legislative approach.

j) Manage the Methane emission

Rice is the most important crop for Nepal and may likely emit still larger amounts of Methane in future. Minimization of Methane and Nitrous oxide emissions from the rice fields can be achieved through improvements in the efficiency of fertilizer use (such as sulfur coated urea), slow releasing of fertilizers, and irrigation management (such as alternate flooding and drying the rice fields). Similarly, selection of rainfed varieties would help reduce the Methane emissions.

k) Promotion of biogas as a source

Biogas has been considered as an efficient alternative technology for the rural Nepal supplementing the fuel wood energy consumption and for environment protection. On an average, a bio-gas plant can save an equivalent of 3 metric tons of fuel wood and 40 liters of kerosene annually (Silwal, 1999). At the same, time biogas slurry is also a good source of fertilizer that can partially compensate the chemical fertilizer requirement for crop production (Karki, 2002). Overall the biogas is a save technology to replace fuel wood and help mitigate global warming. Promotion of biogas, therefore, should be increasingly adopted particularly at rural level.

l) Manage the livestock production

Improving ruminant livestock's digestion through better feeding to minimize Methane emissions may be a potential adaptation strategy of Nepal. Mixing of urea molasses in the straw feeding is a common recommended practice to have better digestion, and this works to reduce Methane emissions from ruminant animals. Similarly, supplementation of amino acids in the livestock feed costs little but effectively reduce the N-excretion responsible for nitrate-nitrite pollution in the soil and water. Similarly large numbers of livestock animals in the hills are rated unproductive and are responsible for the Methane emissions. Those animals therefore should be discarded.

Therefore, in higher elevation, strategic breeding program between yak and cow should be developed to have varieties with better adaptation to the global warming than simply breeding the yaks only.

In summary, preservation, conservation and improvement of crop varieties suitable for local conditions, improvement of cropping practices to reduce water use, promotion of crop diversification program and analysis of potential crop substitution in different regions are some of the recommended measures that can be considered as preliminary adaptation options. Besides, studies on these issues are to be continuously improved and followed up.

5.4 Water Resources

More than 6000 rivers and rivulets originating from a total drainage area of about 194,471 km^2 flow through Nepal with 76 % of this drainage area being contained within Nepal. The amount of dry season flow in an average year in Nepal is estimated to be 12 % of the annual total flow. Failure of monsoon to bring rain water in the right time with even distribution over the country can severely impede the economy of Nepal. With population growth rate exceeding 2 % per year and with increasing standard of living and increasing industrial development, it is certain that water crisis in the coming years will grow principally in the dry seasons. Thus, water stress and water scarcity may worsen in future. In fact, water demand in Nepal is estimated to increase by seven-fold within the next 25 years.

In addition to abundant surface water, Nepal is also endowed with extensive ground water resources. Ground water is a potential source of water in most of the Terai and in some middle valleys like Kathmandu valley and the Dang valley. The Terai is underlain by a thick

sequence of sediments of alluvial origin which makes this area one of the most potential regions of productive aquifers in the subcontinent. A tentative assessment of groundwater availability in Terai by geo-hydrologists indicates the availability of about 12 billion m^3 (WECS, 1999). It is estimated that about 5.8, 8.8 and 9.6 (estimated from different methods) billion m^3 can be safely extracted annually for irrigation and other purposes, and they are rechargeable (UNDP, 1993). Currently about 138,908 and 23,955 ha of land are being reported to be irrigated by shallow and deep tube wells respectively (UMPIDN, 1995). The land area with good scope of ground water development for irrigation is estimated to be far more than 360,000 ha, most of which would allow year round irrigation in existing rainfed cultivation.

Anticipated changes in hydrological cycle and the depletion of water resources therefore are some of the top environmental challenges Nepal is going to face due to Climate Change. The water related problems as such are likely to be more severe in Asian countries like Nepal where the monsoon, characterized by high precipitation variability, is the dominating climatic force. For this reason, Nepal has been giving importance to environment protection and sustainable water resources development for the last couple of decades.

Despite a huge amount of water available in Nepal, only about 2 % is withdrawn for various uses. Most parts of Nepal suffer from water shortage problem in majority of the months because of great variation in seasonal precipitation.

5.4.1 Water Resources Demand and Use

From the beginning of the Fifth Five-Year Plan (1975-1980), Nepal has been giving thrust on environmental protection and sustainable water resource development (Upreti, 2001). The last Ninth Five-Year Plan (1997-2002), formulated by the National Planning Commission, has recognized the importance particularly of soil and water conservation in Nepal (NPC, 1997; MOPE, 2000). Presently, His Majesty's Government of Nepal has developed an action plan for the implementation of a Water Resources Strategy–Nepal, 2002. The action plan has an ambitious expectation to increase hydropower from the existing capacity of 527 MW to 22,000 MW and also increase year-round irrigation facilities beyond the existing 17 % up to 90 % irrigated lands and also increase access to safe drinking water supply from the existing 66 % coverage of population to 100 % population in the next 25-year period (WECS, 2002). The water availability in Nepal is presented in Table 5.7 and the per capita distribution of

water is presented in Figure 5.9 under three major global Climate Change scenarios: A1, A2, and B1; these Climate Change related scenarios were developed for each country by a specialized agency (Watson, 2001).

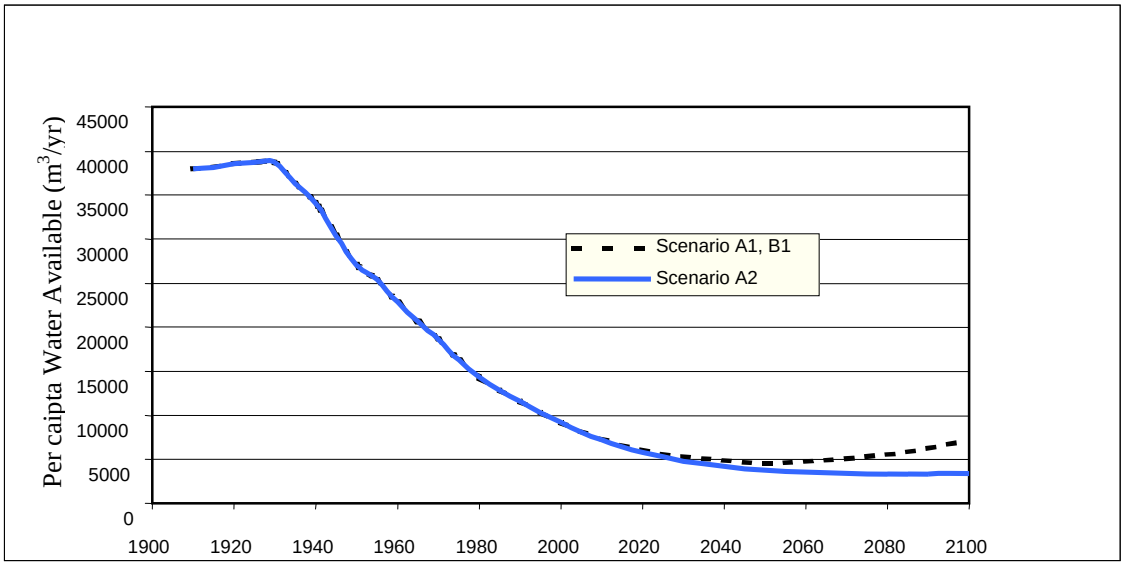


Figure 5.9: Per Capita Water Availability in Nepal (under A1, A2, and B1 Climate Change Scenarios)

The Water and Energy Commission report (WECS, 2002) shows that the water demand to meet the expected 22,000 MW power is 60 km^3. If we consider the water demand for irrigation and domestic water supply as 15000 m^3/ha and 70 liters per capita per day (Subba, 2001) respectively, the required supply for consumptive use by the year 2100 is 28 km^3. Table 5.7 shows that the available water in Nepal is 215 km^3. These computations highlight the fact that the water demand is much less than the available water even at the end of Twenty-First Century. But, if we consider the available water in low flow season, it is only about 12 %, i.e. 26 km^3. Water scarcity is then eminent unless the water resources are properly managed as the high demand of water for consumptive use as well as for hydropower occurs in dry season.

Table 5.7: Total Water Available in Nepal

River	Area (km^2)	Discharge (m^3/s)	Vol (km^3)	Depth (m)	Remark/Period
Mahakali	15260	294	18.5	1.22	Estimated.
Karnali	42800	1360	42.9	1.00	1963-1995
Rapti	5150	141	4.4	0.86	1964-1995
Narayani	31100	1570	49.5	1.59	1963-2001
Bagmati	2700	138	4.4	1.61	1987-2001
Kosi	54100	1550	48.9	0.90	1977-2001
Kankai	1148	54	1.7	1.48	1977-2001
Rest - Nepal	35773	1407	44.4	1.24	Estimated
Total	188031	6514	214.7		
				Avg. 1.24	

5.4.2 Snow and Glacier

In its report 'Climate Change 2001', the IPCC has indicated with high confidence that the retreat of most glaciers in the world is projected to accelerate, and many small glaciers may even disappear. In Nepal, glaciers have been retreating rapidly for the past few decades. Out of 2323 glacial lakes reported in Nepal (ICIMOD, 2001), 20 lakes are found potentially dangerous. Hence, apart from landslides and river erosions, the mountainous regions are also quite susceptible to disastrous hazards due to glacial lake outburst floods.

Snow and glaciers cover about 10 % of the area of Nepal and contribute 10 % to the stream flows (Sharma, 1993). Snow and glaciers are not only the most sensitive physical features to Climatic Changes but also the indicator of such changes. Changes in snow and glacier area may also contribute to the creation of additional source for Greenhouse Gases such as increased vegetative cover and increased evapo-transpiration.

Since the snowline in the Himalayan region lies close to the 5000 m elevation, the snow and glaciers become sensitive just above this level. Table 5.8 presents the areas of major river basins lying in between 5000 m and 5500 m elevation at 100 m intervals. The data presented

in the table shows that about 23 % of the basin areas of the Himalayan watersheds (excluding the Terai) lies above 5000 m elevation.

Table 5.8: Temperature Sensitive Glaciated Areas of the Major River Basins in Nepal.

River Basin	Basin Area (km^2)	Basin Area (km^2) within the elevation (m) range					
		5000-5100	5100-5200	5200-5300	5300-5400	5400-5500	≥5000
Saptakoshi	60196	2320	2190	2006	1722	1499	15955
Narayani	37749	646	673	685	683	669	6280
Karnali	46375	1294	1487	1212	1040	951	8059
Mahakali	16718	213	217	206	171	172	1492

Considering the average environmental lapse rate of 6.5^o C /km, almost 20 % of the glaciated area above 5000 m is likely to be snow and glacier free area at an increase of air temperature by 1^o C. Two degree centigrade rise in temperature can lead in the retreat of glaciers by 300 m causing the loss of almost 40 % of the area. Similarly, 3^o C and 4^o C rise in temperature can result in the loss of 58 % and 70 % of snow and glacier areas respectively. Such changes in glacier areas are likely to contribute to the development of glacier lakes increasing potential GLOF hazards.

Snow and glacier areas are considered natural storage of freshwater. The implication of retreating snowline is the increased river flow during monsoons and decreased flow during low-flow season. It has direct impact on firm power of a hydropower project. Building of more storage capacities may be required as a solution to this problem in the long run.

5.4.3 Potential Impacts on Water Resources

In the present assessment, Water Balance Model (WATBAL) and Deterministic Model (HFAM) have been used to study potential impacts of Climate Change on water resources in Nepal. Selection of these models was based on their availability and applicability. Both models are widely used in Climate Change impact studies. For the calibration and validation of WATBAL model, monthly data for the period from 1987 to 1990 were used whereas, for the calibration and validation of HFAM model, daily data for the same period were used. For both models, simulated hydrograph of 1990 was created for the analysis of the Climate Change scenario. Potential and the extreme river discharge conditions expected by models

were the main features considered by the scenario. Scenarios were created for no change conditions to the rise in temperature (T) up to 4º C and increase in precipitation (P) up to 50 % (Table 5.9 & 5.10).

The vulnerability assessment involving incremental Climate Change scenarios in the Water Balance Model shows that the presently available amount of surface water resources may remain stable even with 4º C rise in temperature. But in this scenario of 4º C rise in temperature and with 20 % increase in precipitation, the surface water potential, for example, of the Karanali river basin will be increased by 13%. Vulnerability studies using Hydro-comp Forecast and Analysis Model also predict similar results.

The study was carried out on three major snow-fed river basins of Nepal, namely, the Karnali at Chisapani, the Narayani at Narayanghat and the Koshi at Chatara. Besides, Bagmati river originating from the surrounding hills of Kathmandu valley has also been considered as a case of rainfed river for hydrological and water resources impact assessment. The selected basins cover only the mountainous areas as no data are available downstream of the Terai.

The output of these Water Balance and Deterministic Models with different combination of temperature and precipitation changes presented in Table 5.9 and Table 5.10 also contains the results for the cases of average, minimum and maximum discharge conditions for all the four river basins considered in this study.

Obviously Table 5.9 and Table 5.10 show that the impact of precipitation change on river discharge is more dramatic than that of temperature change. This study thus indicates that no major change in hydrological behavior is expected with the increase in temperature even up to 4º C in a scenario of existing precipitation. However, change in precipitation as a result of Climate Change can have higher percentage of changes in river discharge compared to the change in temperature.

Table 5.9: Estimated River Discharge in Percentage in Different Combination of Climate Change Scenarios applied to WatBal.

Karnali River	Average			Maximum			Minimum		
	T_0	T_1	T_4	T_0	T_1	T_4	T_0	T_1	T_4
P_0	1.00	0.98	0.90	1.00	0.98	0.89	1.00	1.00	0.99
P_{10}	1.12	1.10	1.01	1.14	1.11	1.02	1.00	1.00	0.99
P_{20}	1.24	1.21	1.13	1.27	1.25	1.15	1.00	1.00	0.99
P_{30}	1.35	1.33	1.25	1.41	1.38	1.27	1.00	1.00	0.99
P_{40}	1.47	1.45	1.36	1.55	1.52	1.40	1.00	1.00	0.99
P_{50}	1.62	1.59	1.48	1.71	1.67	1.55	1.00	1.00	0.99
Narayani River									
P_0	1.00	1.00	0.99	1.00	1.00	0.99	1.00	1.00	1.00
P_{10}	1.10	1.10	1.09	1.13	1.13	1.11	1.02	1.02	1.02
P_{20}	1.20	1.20	1.19	1.26	1.26	1.24	1.03	1.03	1.03
P_{30}	1.30	1.30	1.29	1.39	1.39	1.37	1.05	1.05	1.05
P_{40}	1.40	1.40	1.39	1.52	1.52	1.50	1.07	1.07	1.07
P_{50}	1.52	1.52	1.50	1.68	1.68	1.66	1.11	1.11	1.11
Kosi River									
P_0	1.00	0.98	0.90	1.00	0.98	0.89	1.00	1.00	0.99
P_{10}	1.16	1.13	1.05	1.19	1.16	1.06	1.02	1.02	1.01
P_{20}	1.31	1.29	1.19	1.37	1.34	1.24	1.05	1.04	1.03
P_{30}	1.47	1.44	1.33	1.56	1.53	1.41	1.07	1.07	1.06
P_{40}	1.62	1.59	1.48	1.74	1.71	1.58	1.09	1.09	1.08
P_{50}	1.86	1.83	1.71	2.00	1.96	1.84	1.12	1.11	1.10
Bagmati River									
P_0	1.00	0.99	0.93	1.00	0.99	0.93	1.00	1.00	1.00
P_{10}	1.19	1.18	1.11	1.24	1.23	1.15	1.00	1.00	1.00
P_{20}	1.39	1.37	1.29	1.48	1.47	1.37	1.00	1.00	1.00
P_{30}	1.58	1.57	1.46	1.72	1.70	1.58	1.00	1.00	1.00
P_{40}	1.78	1.76	1.64	1.96	1.94	1.80	1.00	1.00	1.00
P_{50}	2.14	2.14	2.08	2.57	2.56	2.51	1.01	1.01	1.01

Note : Subscript in P shows change in precipitation in percentage

:Subscript in T shows the rise in temperature in ^{o}C

:1.00 = normal (100 percentage)

Table 5.10: Estimated River Discharge in Percentage in Different Combination of Climate Change Scenarios applied to HFAM.

Karnali River	Average			Maximum			Minimum		
	T_0	T_1	T_4	T_0	T_1	T_4	T_0	T_1	T_4
P_0	1.00	0.99	0.94	1.00	0.99	0.97	1.00	0.99	0.98
P_{10}	1.12	1.02	1.02	1.13	1.08	1.08	1.13	0.99	0.99
P_{20}	1.27	1.19	1.17	1.37	1.32	1.29	1.10	0.99	0.99
P_{30}	1.42	1.36	1.33	1.61	1.56	1.49	1.07	1.00	1.00
P_{40}	1.58	1.54	1.48	1.85	1.80	1.69	1.04	1.00	1.00
P_{50}	1.73	1.71	1.64	2.09	2.04	1.89	1.01	1.01	1.01
Narayani River									
P_0	1.00	0.99	0.97	1.00	1.00	0.99	1.00	1.00	1.00
P_{10}	1.15	1.14	1.13	1.16	1.16	1.16	1.00	1.00	1.00
P_{20}	1.31	1.30	1.28	1.32	1.32	1.32	1.00	1.00	1.00
P_{30}	1.47	1.46	1.44	1.48	1.48	1.48	1.00	1.00	1.00
P_{40}	1.62	1.62	1.60	1.64	1.64	1.64	1.00	1.00	1.00
P_{50}	1.78	1.78	1.76	1.80	1.80	1.80	1.00	1.00	1.00
Kosi River									
P_0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P_{10}	1.17	1.17	1.17	1.15	1.15	1.15	1.01	1.01	1.01
P_{20}	1.34	1.34	1.34	1.31	1.31	1.31	1.01	1.01	1.01
P_{30}	1.52	1.52	1.52	1.47	1.47	1.47	1.01	1.01	1.01
P_{40}	1.69	1.69	1.69	1.62	1.62	1.62	1.02	1.02	1.02
P_{50}	1.87	1.87	1.87	1.78	1.78	1.78	1.02	1.02	1.02
Bagmati River									
P_0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P_{10}	1.14	1.14	1.14	1.14	1.14	1.14	1.00	1.00	1.00
P_{20}	1.28	1.28	1.28	1.27	1.27	1.27	1.00	1.00	1.00
P_{30}	1.43	1.42	1.42	1.41	1.41	1.41	1.00	1.00	1.00
P_{40}	1.57	1.56	1.56	1.55	1.55	1.55	1.00	1.00	1.00
P_{50}	1.73	1.73	1.73	1.69	1.69	1.69	1.00	1.00	1.00

5.4.4 Erosion and Sedimentation

The Himalayan region is considered as the greatest source of global ocean-ward sediment flux. Since Nepal shares one of the wettest and steepest areas of the Himalayan region, it contributes significant sediments to the Gangetic plain and to the Bay of Bengal. As water is the main agent of erosion and sediment transport, the pattern of sediment transport is directly influenced by the pattern of changes in precipitation and runoff. Hence this study, besides being of water resources, also focuses on assessment of the vulnerability of the Himalayan watersheds in terms of erosion and sediment transport.

Frequent increase of landslides and soil erosions affecting Nepal is a major threat. This is a serious concern because mountain settlement areas of Nepal are prone to landslides and flooding, and hence, likely to be very vulnerable to Climate Change. This vulnerability is particularly exacerbated during extreme weather events. In the present study it was found that increase in precipitation by more than 20 % is likely to cause significant increase in sediment delivery rate of the basin. This increase in annual sediment yield can be expected in a scenario of 50 % increase in annual precipitation amount (Figure 5.10).

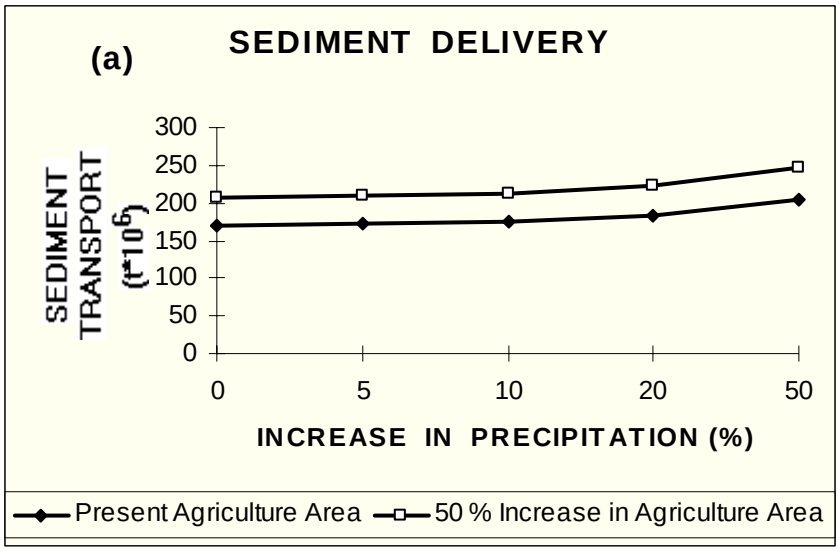


Figure 5.10: Predicted Change in Sediment Delivery of the Kosi Basin in Projected Scenario of Change in Precipitation and Agriculture Area.

5.4.5 Adaptation Options in Water Resources

In Water Resource sector and particularly in hydrology, generic adaptive measures, which have been studied and tested in different parts of the world, can be considered for Nepal as well. But due to unique physiographic conditions of the Himalayan region of Nepal, several additional adaptive measures must also be considered for better effectiveness in impact reduction. In this backdrop the following are the adaptive measures proposed for Nepal.

Besides the two generic options described above, the following description includes several additional adaptive measures for Nepal.

5.4.5.1 Understanding of the System

The following activities can be promoted as adaptive measures for the understanding of water resources system:

- Testing of new innovative models
- Promotion of research on case studies in different geographical regions within the country
- Promotion of research based bilateral, regional, and international collaboration in the sector to understand the problems in the regional and global contexts.
- Studies on strategies regarding the sustainability of programs including the sustainability of institutional and financial aspects.

5.4.5.2 Management of the System

The major findings of IPCC reports regarding adaptation in water resources are generally summarized as, "Unmanaged systems are likely to be most vulnerable to Climate Change." Besides promoting the integrated research on improved technologies, proper management of water resources also requires the awareness of general public particularly in proper water-use and proper use of the efficient technologies. Hence, any plan of the government aimed at education and poverty alleviation directly contributes to the improved management of the water resources system. The following are some of the generic adaptive measures applicable in the context of water resource management in Nepal.

- More efficient management of existing poor water supply infrastructures
- Institutional arrangement to limit water demand
- Establishment of efficient hydrological forecasting system
- Strengthening of watershed management programs
- Introduction of improved water management technologies
- Introduction of drip irrigation scheme
- Introduction of less water intensive crops
- Coordination of water resources development among government and NGOs avoiding duplication
- Systematic reduction on government subsiding and donor dependencies
- Encouragement and incentives on water conservation
- Promotion of groundwater recharge technologies

5.4.5.3 Promotion of Indigenous and Sustainable Technologies

Small farmer-based irrigation schemes and water mills (locally known as *Ghatta*) are extensively used in the mountainous areas of Nepal. These Ghattas used for grinding purposes can be upgraded into power plants with a little additional effort. There exist several examples of successful implementation of such technologies on small rivers and rivulets. Adequate efforts should be spent which would be directed on the promotion of knowledge and advantages in such indigenous technologies in Nepal.

Despite a great potential for large-scale water resources management system in Terai and in a few valleys in Nepal, implementation on such a scale is too costly since most of the mountainous areas are remote. A general observation of indigenous water resources technologies in Nepal indicates extensive use of water being made on small rivers, rivulets and springs rather than on large rivers. Hence the drying of springs in winter and the occurrence of flash floods in summer are major concerns for the local inhabitants compared to hydrological changes on large rivers. Similarly, for resource-poor country like Nepal, community based programs have good potential for the sustainable development of economic

activity programs as demonstrated by the experience of community-based system in the forestry sector (Sharma, 1997).

5.4.5.4 Water Harvesting

Heavy precipitation with large temporal variation is a typical problem facing the management of water resources in the region, and the problem is likely to be intensified in the future with anticipated scenarios of Climate Change as discussed in the preceding sections of this report. Promotion of water harvesting can be an adaptive strategy for existing as well as projected impacts as such on water resources. Water harvesting systems are particularly suitable for the mountainous regions where majority of the population have to spend a lot of physical energy and time to fetch water from far away springs. In addition, large amounts of precipitation in the mountainous region make it an area of higher potential for water harvesting. Water harvesting through the use of tanks and small ponds and reservoirs may also contribute towards minimizing the occurrence of floods in downstream areas and towards increased agriculture productivity. Water harvesting system has successfully been tested in some parts of Nepal already.

The water resources management should also pay special attention to water and soil conservation techniques since fertility and the availability or non-availability of water is likely to be the critical aspects of Climate Change induced impacts. Inter-basin transfer of waters should also be considered for adaptive measures in some hot spots such as the Kathmandu Valley where water stress is already noticeable with the existing supply which is less than three-fourth of the demand here.

5.4.5.5 Promotion of Regional and International Cooperation

Impact of Climatic Change on hydrology has regional dimensions as the effects in headwater areas also propagate into downstream valleys and plains. The effect of enhanced monsoon precipitation of summer and decreased stream-flow of winter envisaged under global warming will not only be confined within Nepal but will affect the downstream basins shared by the most populous region of India and Bangladesh too.

Cooperation exists in the region in the field of information exchange and resource development concerning waters. Such cooperation should be comprehensive enough to deal

with Climate Change impacts on water resource sector also as most of the big rivers are of international nature. For instance, all the three major rivers of Nepal – The Karnali, the Narayani, and the Kosi-originating in China, flows through Nepal towards India. These rivers with major contribution to the Ganges in India ultimately drain to the Bay of Bengal via Bangladesh. Basin-scale adaptive measures for these rivers need bilateral and regional cooperation. Regional cooperation, therefore, is required for any large-scale water resource development involving construction of big reservoirs.

Construction of such medium or big reservoirs can be a good strategy for adaptive measures as these help to reduce the negative impact caused by Climate Change induced rainfall variability. Evaporation suppression technology should also be considered for controlling enhanced evaporative losses resulting from increased temperature.

Several multipurpose water resources schemes are being planned in Nepal under bilateral cooperation between India and Nepal. For example, the proposed Kosi High Dam, which is likely to be one of the largest dams of the world, is presently being investigated for feasibility. Such investigations should provide adequate scope for handling variability caused by the potential Climatic Changes.

5.4.5.6 Development of Disaster Mitigation Measures

Water induced disasters in the form of floods and droughts are common in Nepal primarily because of extremities and variability associated with monsoon climate. Development and burst of glacial lakes as a result of high elevation warming have also been the major concern for Nepal where more than 2000 glacial lakes have been identified. Steep topography and young geology with improper use of lands have been playing additional roles in causing extensive damages to lives and properties besides the loss of fertile topsoil cover. Reversal of such trends will enhance the sustainability of resources and conducive to the success of the adaptive measures.

Nepal has a recent experience in mitigating potential GLOF hazard in the basin of Tama Kosi, a tributary to the Kosi river. Mitigation activities included siphoning of lake water, establishment of a flood alarm system, and reducing the water level by constructing an outlet channel. This sort of mitigation measures reaching a cost of half a million dollar supported by

donor agencies is too high for a country like Nepal. Adaptive measures for such GLOF hazards should consider possibly less expensive and low-tech alternatives that could be implemented with native resources.

Nepal has not yet been able to undertake or workout on effective flood forecasting system primarily due to non-existent real time data transmission network. Establishment of such a system, dissemination of flood warnings and strengthening of institutions responsible for disaster mitigation work must get high priority to be considered as adaptive measures. In addition, the disaster management system should also consider the establishment of medium and long-term flow forecasting system for advanced preparedness. Integrated watershed management with proper hazard zoning for overall benefits including adaptive measures could be a strategy for reducing disaster effects and sustainable use of water. Capacity building for disaster measures directly contributes towards developing suitable adaptive measures required for dealing with extremities resulting from Climatic Changes.

5.5 Bio-diversity

As already mentioned forest and shrubs respectively cover 29 % and 10.6 % of the total land area in Nepal and are distributed all over the country from Terai to Alpine regions of Nepal. Forest has been shrinking in Nepal mainly due to human activities. Terai forest has decreased at an annual rate of 1.3 %, while hill forest has decreased at the rate of 2.3 % from 1978/79 to 1994/95. In the whole of the country from 1978/79 to 1994/95, forest area has decreased at an annual rate of 1.7 %, whereas forest and shrub together have decreased at an annual rate of 0.5 % (FRISP, 1999). Change in forest and shrub cover in different development regions in Nepal is presented in Table 5.11.

Table 5.11: Forest and Shrub Cover Changes by Development Regions

Region	LRMP 1978-79 ('000ha)		NFI 1989-96 ('000ha)		Change (%)	
	Forest	Shrub	Forest	Shrub	Forest	Shrub
FWDR	989.5	60.4	687.4	263.9	-31	+337
MWDR	1649.7	77.3	1192.4	442.0	-28	+472
WDR	924.0	137.3	734.3	256.9	-21	+87
CDR	1104.9	222.8	918.6	233.8	-17	+6
EDR	948.7	192.1	736.1	362.6	-22	+84
Total	5616.8	689.9	4268.8	1559.2	-24	+126

Note: FWDR = Far Western Development Region
MWDR = Mid Western Development Region
WDR = Western Development Region
CDR = Central Development Region
EDR = Eastern Development Region
LRMP = Land Resource Mapping Project; NFI = National Forest Inventory

Nepal has also rich and fascinating biological diversity. The Terai forest was once regarded as the biggest and richest sanctuary of wildlife in Asia. There are 180 species of mammals, 844 species of birds, 175 species of fishes, 614 species of butterflies and 63 species of reptiles in the country. Out of the world's 220,529 species of flowering plants, Nepal is home to 5,800 species. Nepal has almost 2.2% of the world's flora. Among the reported species, 246 plant species occur as endemic to Nepal and are distributed mostly between 3000 m to 4000 m altitudes**.**

5.5.1 Potential Impacts on Bio-diversity

Undoubtedly, Climate Change will significantly affect natural forests. To assess potential impacts on biodiversity, climate data for $1xCO_2$ and $2xCO_2$ were obtained from Climate Change scenarios developed using CCCM and GFD3 models. Increase of 2º C of temperature and 20 % of rainfall to the observed data of 80 stations under the existing $1xCO_2$ level were also used for projecting scenarios of forest types. As one of the final outcomes, Holdridge vegetation map was prepared from data of 80 meteorological stations using Holdridge model system. The vegetation change due to double Carbon dioxide ($2xCO_2$) was also mapped using this Holdridge system, and variations in vegetation patterns were recorded.

Out of the 39 forest type zones categorized by Holdridge model, Nepal is depicted having 15 types (excluding snow area) under the existing Carbon dioxide ($1xCO_2$) condition (Figure 5.11). These forests are tropical moist, tropical dry, tropical wet, subtropical moist, subtropical wet, subtropical dry, warm temperate rain, warm temperate moist, warm temperate wet, warm temperate dry, cool temperate moist, cool temperate wet, cool temperate dry, cool temperate steppe and boreal dry bush. Under $2xCO_2$ condition, there will remain only 12 types of vegetation: tropical dry, tropical moist, tropical rain, subtropical dry, subtropical moist, subtropical wet, subtropical rain, warm temperate dry, warm moist, warm wet, warm thorn steppe and desert bush (Figure 5.12).

But under the incremental scenario (2^oC temperature rise and 20% increase in precipitation) projected by the model, vegetation pattern in Nepal would be different than the existing ones (Figure5.13). Out of eighty, 38 station locations will have change in vegetation pattern; tropical and subtropical moist forest will extend in area, subtropical and warm temperate dry forest will change to warm temperate moist forest in Jumla, cool temperate, steppe and thorn steppe will emerge in warm temperate and desert bush in existing cool temperate regions of Mustang, and forest cool temperate moist forest of this area will convert into warm temperate moist forest.

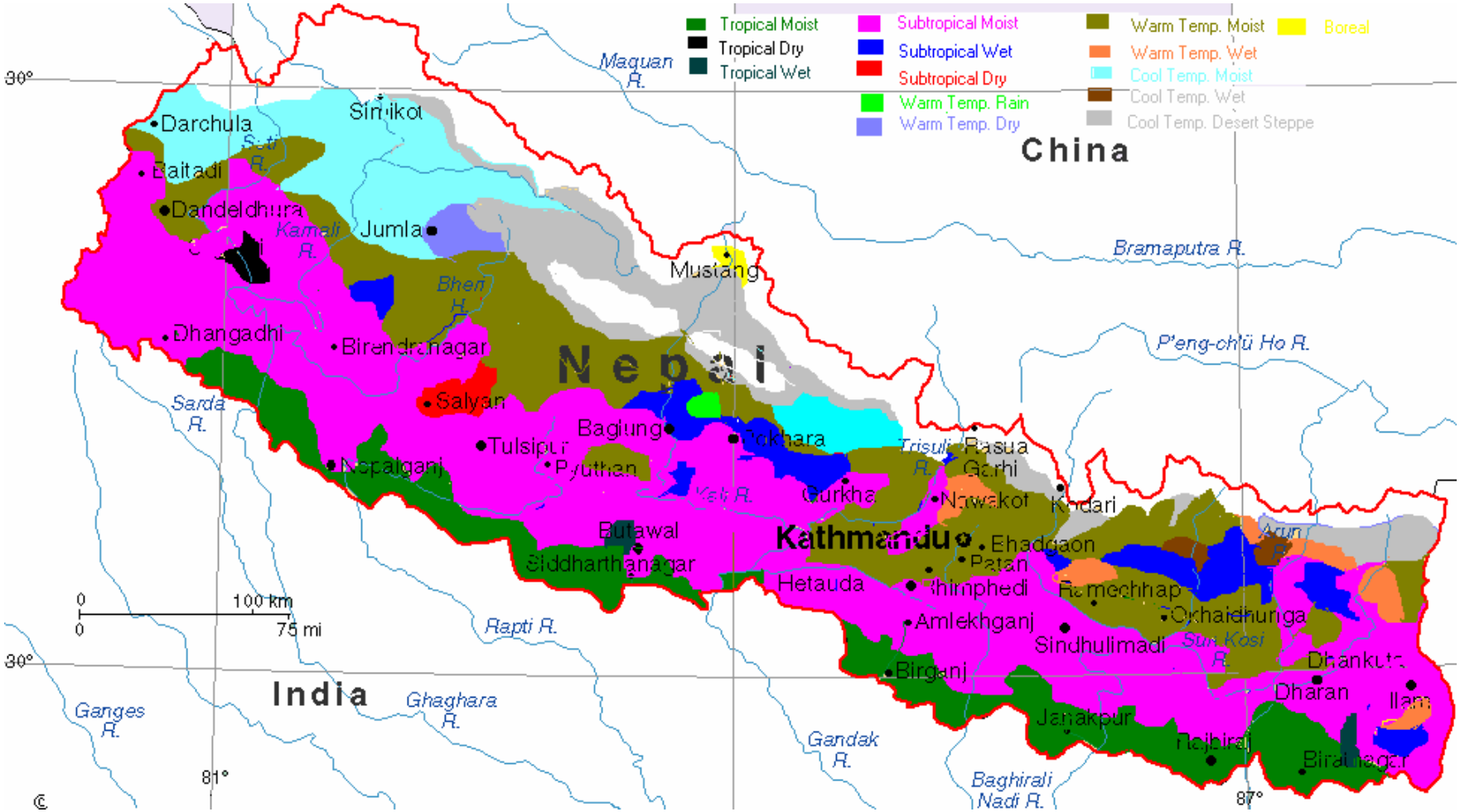


Figure 5.11: Forest Types and their Distribution in Nepal based on Holdridge Classification (at existing 1xCO_2 condition)

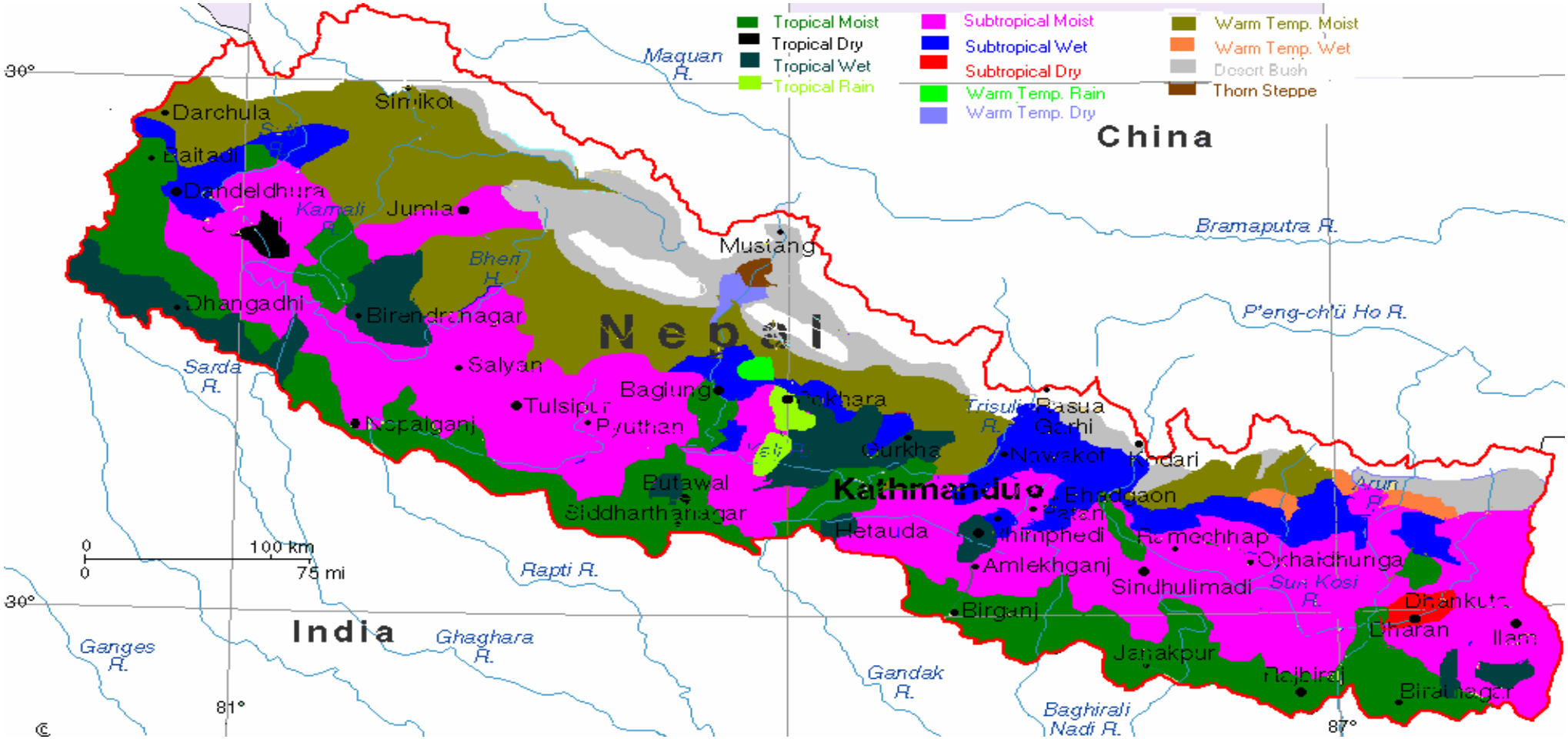


Figure 5.12: Forest Types and their Distribution in Nepal based on Holdridge Classification (at $2xCO_2$ condition)

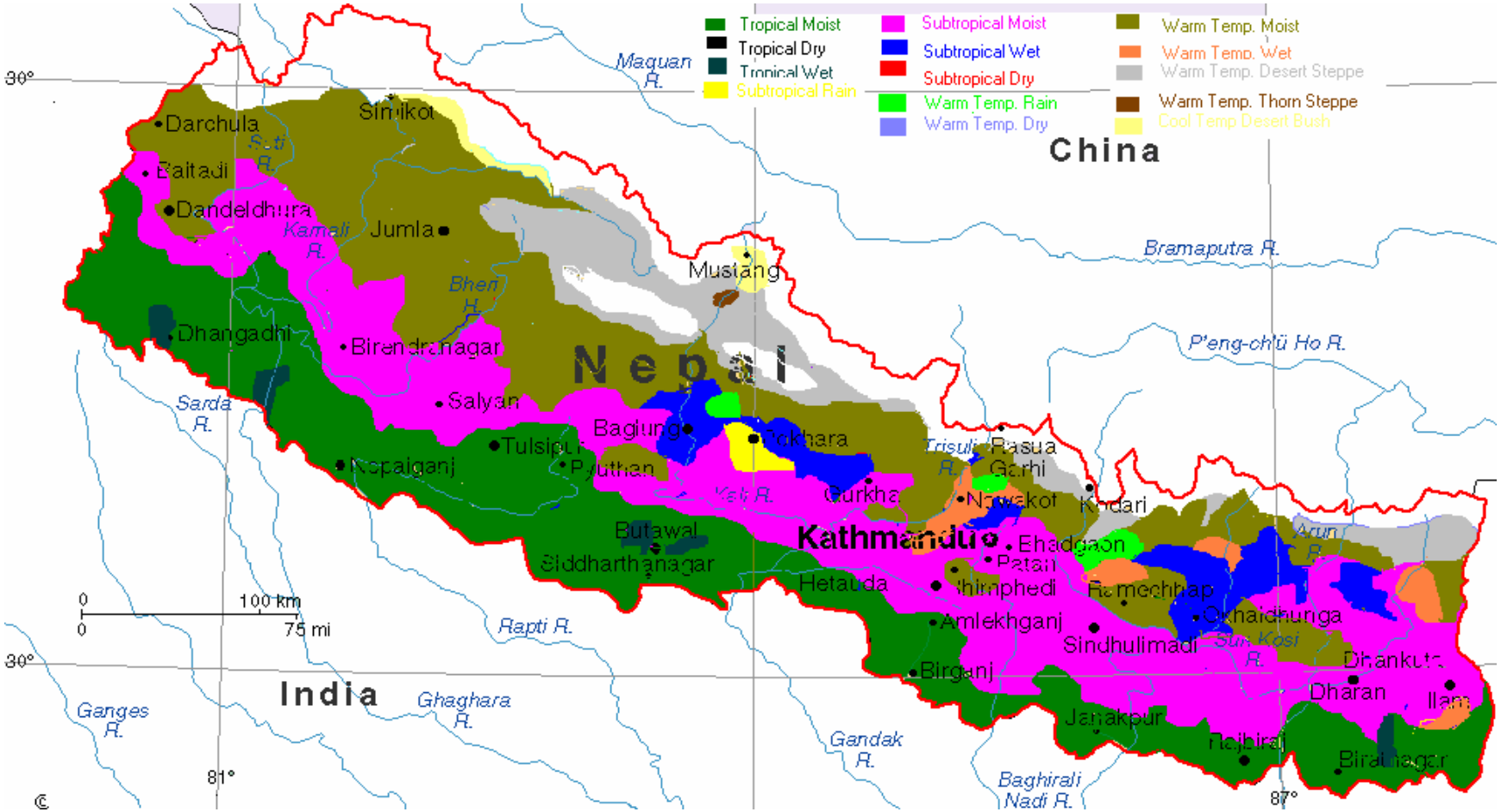


Figure 5.13: Forest Types and their Distribution in Nepal based on Holdridge Classification (at 20% Precipitation and 2°C Temperature Incremental)

This study indicates that the tropical wet forest and warm temperate rain forest will disappear, and cool temperate vegetation will turn to warm temperate vegetation. Existing classification reveals that there does not exist rain forest in tropical and subtropical regions in the country, but they are expected to emerge under $2xCO_2$ condition. Warming effect will be significant in the sub-alpine and alpine regions of Nepal. The vegetation regime in general could be pushed up as much as 500 m in elevation.

This was the first attempt in Nepal to study the impacts of Climate Change on forests. Some limitations were noticed during this study. The three major limitations were:

- Gaps in forest data
- Holdridge model (Holdex) was not exactly available; instead Holdridge Life Zone Classification model was in fact used. Exact change in area of different forest types was difficult to be determined due to mountainous topography, particularly in mid hills and mountains.
- Uncertainty associated with the results of the climate simulation models used, particularly the GCMs

These limitations imply a need for further efforts to achieve more reliable results to establish realistic impacts on forest due to Climate Change.

5.5.2 Adaptation Options in Bio-diversity

Since there are different types of forest areas in Nepal, those classified as national reserve forests are being given protection by law. These protected forest areas include national parks, wildlife sanctuaries and watersheds. In spite of these protections by law, however forest poaching and encroachment are not uncommon due to weak enforcement of the laws.

Now there are double threats to these vegetations vis-a-vis deforestation and Climate Change. Hence, all the adaptive measures to reduce vulnerability to vegetation should be focused towards increasing and conserving vegetative coverage and at the same time minimizing effects of Climatic Change. And also, forest communities and populations if fragmented and small, are more vulnerable to the new stresses brought about by Climate Change. Following adaptive measures can be undertaken in the above contexts:

- Refine climatological projection and increase the understanding of how climate affects species. Such studies allow to identify those areas, where communities will be most stressed, as well as alternate areas where they might be saved
- Extensive planting of trees particularly in mid-hills to absorb Carbon dioxide could help mitigate Carbon dioxide concentration
- Adaptations measures in land use and landscape management, agro-forestry and species-selection, silvi-culture in different ecological zones need to be planned.
- Promotion and protection of natural regeneration is required at to be emphasized local levels.
- Identify/prioritize species that are relatively vulnerable to Climate Change (endangered species, endemic species) and reforest sensitive areas with drought, heat, flood tolerant varieties
- Develop regional plans for non-reserve habitats to conserve populations and resources lying outside protected areas.
- Development and implementation of new and efficient management techniques are needed in reforestation and transplantation programs.
- Ecological research and monitoring will yield information on vulnerability and adaptation. Such studies would provide scientific basis for the flexible regional planning to derive and to develop appropriate adaptation measures.

5.6 Health

Effect on human health is the outcome of several factors, the main being the environment. Human health is already at risk from a number of diseases, malnutritions, etc. Human induced Climate Change may soon become another major contributor to the spread of infectious diseases. Many vector-borne and water-borne infectious diseases are known to be sensitive to changes in climatic conditions.

Thus Climate Change will have both direct and indirect impacts on human health. Indirect impacts of Climate Change to health may come from crop damage or water shortage. More direct impacts are vector-borne diseases. Rising temperatures may make certain diseases more active.

The health data of Nepal reveal that Diarrhea, Dysentery and Malaria, Kala-azar and Encephalitis are the top five diseases in the country. Moreover, Encephalitis, Malaria and Kala-azar (*Visceral leishmaniasis*) have lately become the great public health concerns. More than 5.5 million people are believed to be at risk from Kala-azar disease. Japanese Encephalitis (*Flavi-virus*), another infectious disease, especially affects the children. The occurrence of this disease is 40 per 10000 populations in which one third of the patients dies and one third has serious *neuralgis segullae*.

5.6.1 Potential Impacts on Health

Because of the poor state of health services in Nepal, public health can indeed be at higher risks than before from unfavorable effects of Climate Change. Malaria and Japanese Encephalitis are the two most common vector-borne diseases in the country, mosquito being the vector of these diseases.

The general trend of Malaria positive cases was found increasing during the period 1963 to 1985, and then decreased due to mitigation measures taken (Figure 5.14). Central Nepal recorded the highest number of Malaria positive cases, whereas the Mid-Western Nepal had the least reported cases. Malaria positive cases are normally found maximum during wet summers (Figure 5.15). Malaria positive cases are reported, when the average annual temperature is between 14 and 27º C, with the highest number of cases at 24-25º C in the tropical zone. Malaria cases are also found in the subtropical (18-24º C) and warm temperate (14-18º C) regions of Nepal. Obviously rise in temperature due to Climate Change will increase the Malaria cases; particularly subtropical and warm temperate regions of Nepal will be more conducive to the diseases. Temperatures between 22 and 32º C are very favorable for Malaria diseases to develop and complete their cycle, while those above 32-34º C could reduce their survival rates substantially. Thus the range of temperatures in Nepal is suitable for the Malaria parasites to exist & develop.

Kala-azar (Visceral leishmaniasis) cases have also shown increasing trend in the last two decades (Figure 5.16). This trend is becoming more pronounced in the recent years. Kala-azar reached epidemic form in eastern and central regions of Nepal especially in the Terai districts. Most vulnerable are the poor people and rural cattle keepers. This disease occurs mainly in the summer season when the vector is very active and gets optimum environment

for breeding. Previously, Kala-azar was found only in the eastern and central Terai regions of the kingdom, but in 1998, cases were recorded in other non-indigenous districts as well. Changing climate may be one of the factors for its emergence in new areas.

Similarly, the Japanese Encephalitis occurs mainly at the average annual temperature range of 23-26ºC, and increase in temperature will make the subtropical regions more vulnerable to this disease. Vulnerability is becoming serious in Nepal as the number of patients of this disease is increasing every year in the country most probably due to rising trend of temperatures (Figure 5.17).

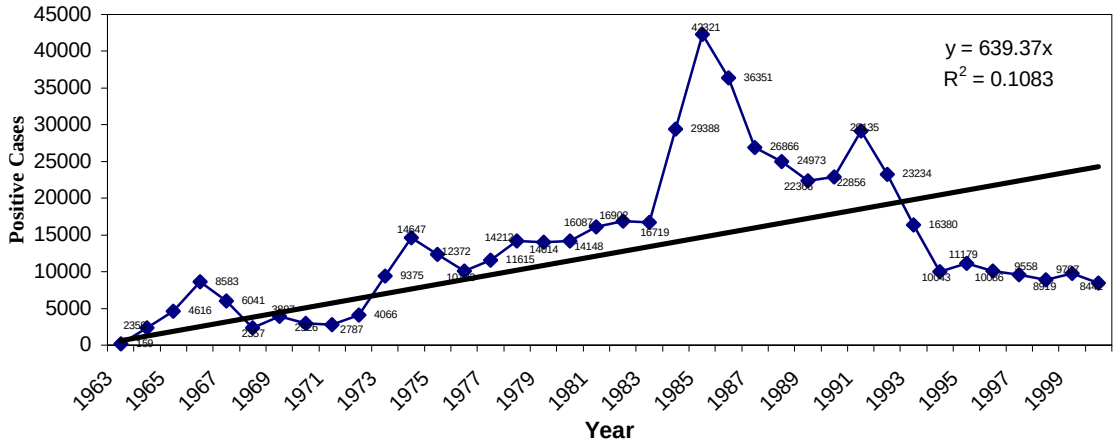


Figure 5.14 : National Annual Total Positive Malaria Cases

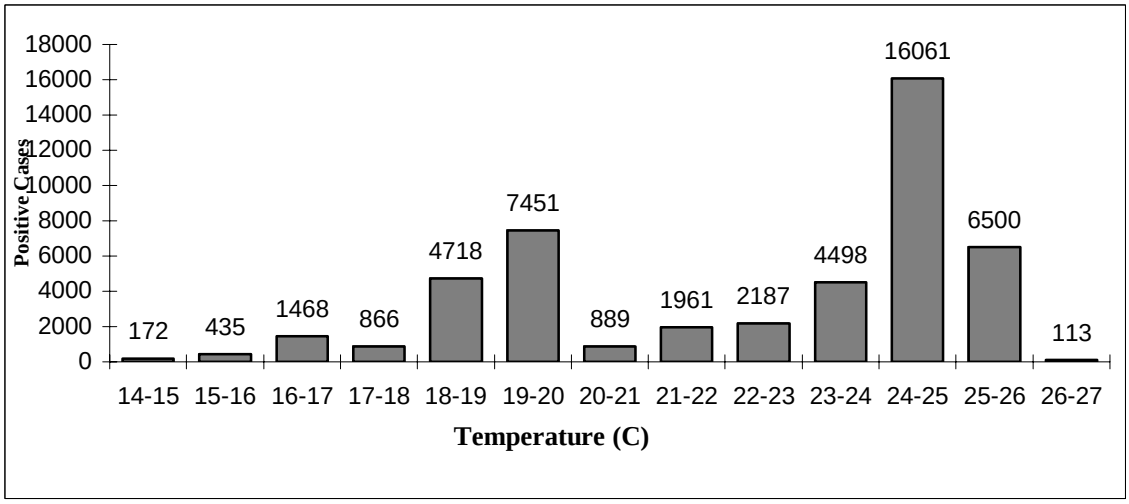


Figure 5.15: Average Temperature and Positive Cases of Malaria in Nepal

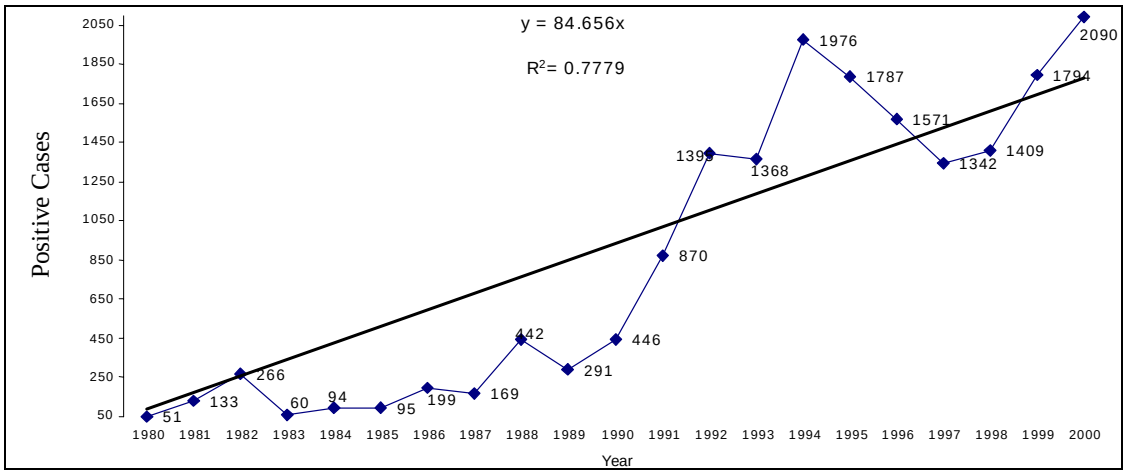


Figure 5.16: Annual Total Positive Cases of Kalajar in Nepal

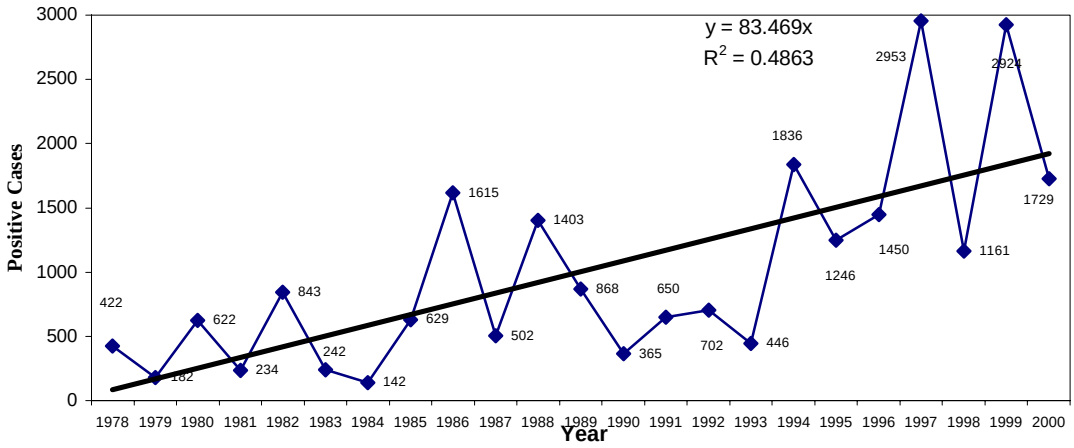


Figure 5.17: Annual Total Positive Cases of Japanese Encephalitis in Nepal

5.6.2 Adaptation Options in Health

Since three diseases (Malaria, Kala-azar and Japanese Encephalitis) occur mainly in the Terai regions of Nepal, they spread through mosquitoes that flourish well in hot (up to 40º C) and polluted stagnant wetlands. The cleanliness of the area is the most important requirement for adaptation. DDT has been used effectively in Nepal to control these diseases. However, serious consideration must be taken of the potential side effects of such adaptation measures as the use of chemicals to control mosquitoes. But Nepal has already experienced

the emergence of chemical resistant mosquitoes. Hence, research and development of alternative approaches to cure and eliminate these diseases are needed. Quarantine program needs to be strengthened, and effective mechanism on eradication and disease control program should be given more emphasis. In this regard, ethnobotanical information may be useful to prevent or control these diseases. Promotion of health education for creating community awareness to diseases may be an effective adaptive measure to prevent occurrences these diseases.

CHAPTER-6

Policies and Measures

6.1 Introduction

Climate Change is a new concept in Nepal. The understanding of this science, its mitigation aspects, impacts and adaptation and relevance to Nepalese economy are mainly restricted to a few institutions and individuals. However, Climate Change related activities in Nepal have been growing since the country's participation at COP sessions. Of late, there has been increased national consultations and activities relevant to the UNFCCC. These consultations and activities, while not constituting stated government policy, however, give indication of increasing national concern on issues related to Climate Change and its future impacts on the country's economy. In addition, the country has undertaken a number of environmental related measures as part of the policy of the government to achieve sustainable development path. Hence, these policy measures apart from making the process of development sustainable will also have to be undertaken to address Climate Change issues as well.

6.2 National Sustainable Development Policy

Since 1957 His Majesty's Government of Nepal has been implementing National Economic and Social Development Plans to guide the social and economic development in the country. Increasing deterioration of natural resources and environment since the past few decades prompted the government to seriously act on natural resource and environment conservation. The principles of sustainable development have formally been integrated into Nepal’s national planning processes, incorporating the spirit of Agenda 21. Beginning with the Eighth-Plan (1992-1997), the environment agenda has continued through the Ninth Plan (1997-2002) and now into the Tenth Plan (2002-2007) as well. These principles have since been incorporated in all the major Perspective Plans, Master Plans, Strategies, Acts, Regulations, Guidelines and Rules formulated in the country since 1992 (after UNCED in Rio) in different areas such as forestry, agriculture, water resources, environmental management, and local governance including the protection of rights of women and children. These commitments have also been reflected in a number of international conventions related to environment and human rights issues to which Nepal has since been a Party. Balance between socio-economic development and conservation of natural resources and environment has been the basis for sustainable development policy of Nepal.

After the UN Conference on Environment and Development (UNCED) in Rio, HMG/N established the Environmental Protection Council (EPC) under the chairmanship of the Prime Minister in 1992. Thereafter Nepal Environmental Policy and Action Plan (NEPAP) 1993 was introduced. NEPAP focused on the following five areas: (1) sustainable management of natural resources; (2) population, health and sanitation, and poverty alleviation; (3) safeguarding national heritage; (4) mitigating adverse environmental impact and (5) legislation, institutions, education and public awareness. NEPAP was followed by sectoral action plans on water resources, forestry, and industry in 1998. Besides, Nepal has also enforced Environment Protection Act (1996) , Environment Protection Rules (1997) and Ozone Depleting Substance Consumption (Control) Rules, 2001 with the objective of maintaining a clean and healthy environment by minimizing adverse impacts in the pursuit of economic development. During the course of the preparatory process of report for the World Summit on Sustainable Development (WSSD) including the formulation of the Sustainable Development Agenda for Nepal (SDAN) and preparation of the National Assessment Report, the government constituted a 20 member National Commission on Sustainable Development (NCSD) under the chairmanship of the Prime Minister to promote sustainable development and inter-ministerial coordination.

In National Report 2002 prepared for the World Summit on Sustainable Development (WSSD), held in Johannesburg, Nepal had identified the main constraints encountered in implementing sustainable development strategies, and ensured adopting forward- looking approaches to promote sustainable development in the country. This report was prepared in line with the Earth Council Guidelines for National Assessment. Since the country report prepared for the UN Conference on Environment and Development, 1992, was a benchmark for assessing Nepal's achievement for implementation of Agenda 21, the draft of Sustainable Development Agenda for Nepal (SDAN) and country profile for Rio+10 were reviewed through consultative processes and the feedback was incorporated in the final WSSD report .

6.3 Environment Management

Since the promulgation of Parliamentary Democracy through the Constitution of the Kingdom of Nepal, 1990, it is now the explicit policy of the government to give priority to the protection, preservation and development of environment in the country. It is clearly stated "The State shall give priority to the protection of the environment and also to the prevention of its further damage due to physical development activities by increasing

awareness of the general public about environmental cleanliness, and the State shall also make arrangements for the special protection of the rare wildlife, the forests and the vegetation".

The National Conservation Strategy (NCS) for Nepal has developed the modest conceptual framework with plan of action "to strike a balance between the needs of growing population and those of nature conservation" (HMG 1990).

From the beginning of Ninth Five-year Plan (1997-2002), HMG/N has initiated integrated approach to inter-link between poverty alleviation, population growth and environment identified as critical issues of the Nepalese economy with agriculture and water resources playing major roles in the economic development of the country with improvements hand in hand in the environment.

Also the Local Self-Governance Act, 1998, and its Rules, empower the local bodies such as DDC, VCD and the municipalities by outlining their environmental functions comprising of local-level planning of the environment, forest and bio-diversity conservation and use, and pollution control etc.

The Ministry of Population and Environment (MOPE) has enforced the following Environmental Management strategies owing to the long term climate change affects:

- Enforcement of Nepal vehicular emission standards , 2056 (1999) for new vehicle import
- Emission standards for functioning vehicles have been enforced
- Registration of new two-stroke vehicles has been prohibited in the country
- Ambient Air Quality Standard have been specified
- Standards of Effluents from different kinds of industries have been specified.
- Scrap/Old equipment & Material can only be imported after the permission from MOPE
- Six Air Quality Monitoring stations (PM10, TSP, No2, So2, Benzene) have been functioning 24 Hrs daily

6.4 Environment Related Laws, Polices and Plans

6.4.1 Legal Measures

The Constitution of the Kingdom of Nepal, 2047 BS (1990), makes it a duty for the State to incorporate environmental matters into its policy process. In view of this consideration therefore, in Nepal there are more than forty legislative enactments, which are directly or indirectly related to the environmental matter. The following list provides a glimpse of these laws and regulations relevant to the environment related sectors.

1. The Town Development Act, 1988, empowers the Town Development Board to issue public notification to control and prohibit actions that pollute the environment (Art. 9)
2. The Civil Aviation Act, 2015 (1958), contains a provision to control the noise level of the aircraft and to prevent atmospheric pollution (Art. 3 (2)
3. Labor Act, 1991, states that the working environment must have adequate ventilation and lighting arrangements, and if any emission of gas, dirt or other pollutants is bound to occur in the courses of operation, necessary arrangements are to be made so that they do not accumulate in the working place (Art. 27).
4. The Aquatic Animals Protection Act, 2017 (1961), has forbidden the use of explosives and poisonous substances in water for killing animals (Art. 3).
5. Public Road Act, 1974, directs the state to maintain environmental amenity, and the Department of Road is required to plant trees along all public roads (Art. 16).
6. Mines and Minerals Act, 1985, have made provisions for prohibiting the use of gases that may cause atmospheric pollution.
7. The Urban Construction Plan Implementation Act, 2019 (1972), prohibits any activities that may impair the natural beauty, tourist significance, scenery and public health or cause atmospheric pollution in any other way in the urban area.
8. His Majesty King Mahendra Trust for Nature Conservation Act, 1982, aims to protect natural resources against damage.
9. The Tourism Act, 2035 (1978), had made it mandatory for mountaineers to keep the atmosphere clean and abide by the specified conditions (Act. 30)
10. The Soil Conservation and Watershed Management Act, 2039 (1982), had laid down provisions for the proper protection and utilization of land, natural resources and watersheds.

11. The Pesticides Act, 1991, contains provisions regarding import, export, production and consumption of pesticides for which government clearance is compulsory.
12. The Solid Waste (Management and Resource Mobilization) Act, 2044 (1986), includes provisions for arranging pollution free disposal of solid waste in the functions, duties and powers of the Solid Waste Management and Resources Mobilization Center.
13. The Nepal Water Supply Corporation Act, 2046 (1989), has empowered the Nepal Water Supply Corporation to take necessary steps to control water pollution. Similarly, there is a legal provision to penalize any one found contaminating the drinking water (Art 5.1.10; 18.1.2 & 19. 2.1).
14. The Municipality Act, 2048 (1991), has stipulated legal provisions for environmental protection, removal of objects detrimental to public health, the issuance of directives for the control of atmospheric pollution and undertaking project screening in such a manner which conserves and enhances the environment (Art. 15).
15. District Development Committee Act, 1991, also makes provisions for the cleanliness to the Districts, and empowers the Board to impose fines on those who break the directives of the Board [Art. 18 (1) & 39 (2)].
16. Village Development Committee Act, 1991, contains many provisions for improving the cleanliness and environment of the villages (Art. 14).
17. The Industrial Enterprises Act, 2049 (1992), has provisions for a licensing system for the establishment of textile, cement, carpet washing, soap stone crushing and forestry-based medium and large-scale industries as they affect public health and the environment (Art. 9)
18. The Water Resources Act, 2049 (1992), prohibits any action that may pollute water resources, and maintains that the utilization of the resources should be made without causing any considerable damage to the environment through soil erosion, floods, landslides or any other similar reason (Art. 19 & 20).
19. The Forest Act, 2049 (1992), and the National Parks and Wildlife Conservation Act, 2030 (1973), are inspired with the objectives of protecting forests and wildlife.
20. The Vehicle and Transport Management Act, 2049 (1992), maintains that the means of transport are to be operated keeping the pollution level under control (Art. 24).

21. The Environment Protection Act, 1996, and Environment Protection Regulation, 1997, came into existence to enforcing effective & storage measures for the conservation of the Nepalese environment.
22. In view of meeting the national obligations of Nepal, with respect to Vienna Convention, Montreal Protocol and London Amendment, for protecting the ozone layer, His Majesty's Government has in accordance with the Nepal Treaty Act, 1990 (2047), and the power conformed by the article 24 of the Environment Protection Act 1996, enforced the Environmental Protection Rules since 19 February 2001 in the country. Further, 'Notice on Annual Consumption, Import Quantity and Phase-out Rates of Ozone Depleting Substances', 'Ozone Depleting Substance Consumption (Control) Rules, 2001' and ' Procedures, Conditions and Specifications, Quantitative Standard and Annual Phase-out Rates for Import of the Ozone Depleting Substance have been prepared and implemented by His Majesty's Government of Nepal.

6.4.2 Existing Policy/Strategy

The National Conservation Strategy (NCS)

His Majesty's Government in 1988 approved the National Conservation Strategy for Nepal (NCS) is a major step to systematically develop an appropriate strategy for environment and resources conservation in Nepal. NCS links material, cultural and spiritual needs of the people with four elements of conservation strategy namely proper use, protection, preservation and restoration. The strategy emphasizes 4 objectives as follows:

a) Satisfy the basic material, spiritual and cultural needs of the people of Nepal, for both present and future generations.
b) Ensure the sustainable use of Nepal's land and renewable resources.
c) Preserve the biological diversity of Nepal in order to maintain and improve the variety of yields and the quality of crops and livestock and to maintain the variety of wild species, both plant and animal.
d) Maintain essential ecological and life-support systems, such as soil regeneration, nutrient recycling and the protection and clearing of water and air.

Specific to air, noise and water pollution, the government has also recommended/adopted policies on:

- Industrial effluent discharge, noise abatement standards, and corrective mitigation and

preventive measures

-Establishment of air and water quality monitoring and evaluation systems

Nepal Environmental Policy and Action Plan (NEPAP)

During the Eighth Plan period, Nepal Environmental Policy and Action Plan (NEPAP) was prepared as part of HMG's continuing efforts to incorporate environmental concerns into the country's development processes. The Environmental Protection Council endorsed it in 1993. There are five main aims of environmental policy.

a) To manage efficiently and sustainably country's natural and physical resources,
b) To balance development efforts and environmental conservation for sustainable fulfillment of the basic needs of the people,
c) To safeguard national heritage
d) To mitigate the adverse environmental impacts of development projects and human actions, and
e) To integrate environment and development through institutions, adequate legislation and economic incentives, and sufficient public resources.

NEPAP analyses the country's environmental issues in a multi-sectoral framework and sets forth policies, strategies and action plans for maintaining the country's natural environment, the health and safety of its population and its cultural heritage as economic development occurs. Also phase II of NEPAP has developed detailed programs, including investments on forestry, water resources and industry among others. NEPAP unfortunately was weak in its implementation and did not again the ground effectively.

- **The Eight-Plan (1992-1997)**

The other specific and notable achievements during this Plan period included items as follows:

- Establishment of Ministry of Population and Environment
- Enactment of Environment Protection Act (1996) and promulgation of Environment Protection Regulations (1997)

- **The Ninth-Plan (1997-2002)**

The launching of the Ninth-Plan was guided by the philosophy: development for people, with the people and by the people. It had the main objective of poverty alleviation and had prioritized agriculture, industrialization and tourism development. Environment management was further re-

emphasized to consider it as a national level policy, and the accompanying sectoral policies also included several strategies, which could contribute to improve the environmental conditions. Some important policies on Environment and Natural Resource Management of the Ninth -Plan were as follows:

a) Major projects will be required to have an Environment Impact Assessment (EIA) before they are approved,
b) All development projects including local level projects will take environment into consideration during their design and implementation,
c) Incentives will be provided to local institutions, communities, NGOs & private sectors which voluntarily promote and practice environmental conservation measures,
d) Custom, Tax and Investment Policies will be investigated in the context of Environment Policy requirements /consideration,
e) Formulation of air, water, noise, and land-related pollution control management plans,
f) Vehicular Emission Standards fixation,
g) Establishment and Implementation of Emission Standards for air pollution and an appropriate management plan to check emissions from industrial premises,
h) Commitment for specifying Air Pollution Standards.

- **The Tenth-Plan (2002-2007)**

The current Tenth-Plan of the government is specific in policy as follows:

a) Preserve the biological diversity in order to maintain and improve the variety of yields and the quality of crops and livestock, and to maintain the variety of wild species in both plants and animals

b) Pollution control activities will be launched with special priority

c) Special programs will be conducted in the sector of health and environment, environmental education as well as environmental awareness activities

d) Environment conservation programs will be conducted in effective manner

- **Sustainable Development Agenda For Nepal (SDAN)**

The Sustainable Development Agenda for Nepal (SDAN) is prepared by the National Planning Commission (NPC) in close collaboration with the Ministry of Population and Environment (MOPE).

The over-arching goal of sustainable development in Nepal is to expedite a process that reduces poverty and provides to its citizens and successive generations not just the basic means of livelihood, but also the broadest of opportunities in the social, economic, political, cultural, and ecological aspects of their lives.

This begins with the pursuit of increased per capita income afforded by a stable population size that generates a viable and environmentally sound domestic resource base to create and nurture institutions of the state, markets, and civil society, whose services can be accessed equitably by all Nepalese.

Basic development processes are to be overseen by accountable units of government with representation of women and men of all ethnicity and socio-economic status, whose management of resources, including the environment, is to be governed by an imperative that the ability of future Nepali generations to sustain or improve upon their quality of life and livelihoods is kept intact.

A corollary inherent in viewing sustainable development in Nepal in these broad terms is a national resolve to pursue happy, healthy, and secure lives as citizens who lead a life of honor and dignity in a tolerant, just and democratic nation.

6.5 Policies and Measures Related to Climate Change

Some five years following the ratification of the UNFCCC, His Majesty's Government of Nepal undertook the current Climate Change Enabling Activities Project with funds from GEF; under this program a high level project Steering Committee (SC) was established. The government also set up a National Climate Change Committee (NCCC) and four separate National Study Teams (NSTs) to prepare the country’s response to Climate Change. The NCCC is chaired by the Director General of the Department of Hydrology & Meteorology of the Ministry of Science & Technology (MOST), while the SC is headed by the Secretary of the Ministry of Population and Environment (MOPE), which is the agency serving as Nepal's focal point for United Nations Framework Convention on Climate and serves also as the Secretariat to the Environment Protection Council established in 1994 and chaired by the Prime Minister. The National Environment Protection Council was instituted to serve as the highest decision making body on all matters related to the environment. Further, MOPE acts as the secretariat to National Commission for Sustainable Development chaired by the Prime Minister.

His Majesty's Government should take into account the principles of the Convention in formulating policies related to Climate Change in Nepal. Climate Change policies and issues have to be integrated into the national economic and social development plans & programs.

They need to be incorporated in environmental policies and plans of the country also where appropriate.

6.5.1 Policy for Energy Sector

Trends in energy consumption generally follow the economic growth of the country. Keeping in view the significance of energy in national development the energy sector during the Eighth Five-year Plan (1992-1997), received high priority. The plan had sought implementation of the following strategies:

a) To maximize the development of indigenous energy resources
b) To promote fuel efficient stoves with a strategy to minimize fuel wood consumption
c) To promote cost effective and environmentally sensitive energy conservation and demand management practices
d) To devise appropriate mechanisms for financing hydropower projects through commercial sources, as well as encouraging other means of financing
e) To formulate rational energy pricing so that it reflects the social costs without compromising overall national goals
f) To enter into energy import/export agreement keeping in mind the national interest
g) To give authority to the respective ministries to solve the environmental problems associated with energy supply and demand
h) To examine the possibility of transferring ownership of government-owned energy sector utilities to the private sector. Further, the government for the first time also fixed 5 MW capacity target for Micro-Hydro (MH) development. During this plan period only 24 percent of the target was fulfilled

In the Ninth Five-year Plan (1997-2002), the MH development target was fixed at 5.2 MW capacities and focused on a coordinated approach to rural energy development. The Tenth-Plan (2002-07) emphasizes on an integrated approach with focus towards poverty alleviation and sustainable development through decentralized mechanisms like the establishment of rural energy development fund at the village and district levels.

Energy switching has been emphasized in 9^{th} and 10^{th} Plan with several alternative energy sources to reduce the domestic use of wood and fossil fuels with more use of hydropower and

bio-gas. Besides, Nepal has implemented policies to import Euro-1 standard vehicles to increase the efficiency of the transport sector and reduce pollution from this sector.

6.5.2 Policy for Forest Sector

Forests serve as important carbon sinks. The principal policy of Nepal is to conserve the forests. As forest resources are important to the natural ecosystem as well as to the livelihood of the rural communities, it is vital to introduce policies that harmonize forest utilization and conservation. More intensive conservation and reforestation approaches are required to ensure that at least 40 % of land area retains forest cover.

Improperly managed forest concession combined with the expansion of agriculture and conversion of forestlands to other uses, as well as population growth and economic expansion, have resulted in a serious decline of forest cover. The government has formulated several policies and measures to expand forest areas in the country. Massive landslides and erosions in the mountain region prompted the government to take serious action against deforestation.

The enactment of Forest Act 1993 has given local communities the rights to form a forest user group consisting of traditional users. These forests also have to be managed under sustainable forest management principle. The rationale behind the act is that with appropriate rights, the communities that directly and indirectly depend on forest resources will ensure that their sources of supply are sustained.

Besides, HMG of Nepal has declared 18 % of the total land areas as conservation forests. These areas include National Park, non-Hunting Areas, and Wildlife Sanctuaries. Various measures have been employed to protect the conservation forests. However, despite considerable promotion over a long period of time, reforestation and afforestation activities lagged far behind those of deforestation.

6.5.3 Policy for Water Resource Sector

i) Preparation of Water Management Plan

The draft water policy emphasizes the efficient use of water. However, it is important that the plan should take into account Climate Change impacts also. Since, the sources of water have

to be protected; the plan should also pay attention to the protection of the upper watershed in the country. The Water Resources Management plan would any case have benefits beyond Climate Change mitigation.

ii) The indiscrimination exploration of ground water in Kathmandu is causing concern. The availability of water has not been assist. In the min time a policy should be monitor the construction of tube/Agriculture wells in Kathmandu and Terai zone.

6.5.4 Policy for Agriculture Sector

The existing government policy on Agriculture sector takes no account of the anticipated Climate Change impacts. There is, therefore, a need for revising the existing Agriculture policy taking into account the Climate Change aspects. This need has to be strongly addressed to and an action plan is required for implementing the policy. Particular attention should be placed on breeding strong drought/paste/disease resistant varieties and the development of measures for soil and water conservation. It is also essential that adequate funds need to be provided for conducting research to address the impacts of Climate Change in agriculture.

6.5.5 Policy for Vulnerability and Adaptation

The magnitude of policies and measures for Climate Change adaptation is strongly dependent on the ability to identify extent of impact and therefore of the vulnerability to Climate Change of economic and social systems, both in space and time. While research and development activities related to Greenhouse Gas Inventory in Nepal have progressed satisfactorily, those that address vulnerability and adaptation have yet to proceed satisfactorily. Various constraints have been identified, most important of which is the lack of technical capability to apply the results of Global Climate Models to local areas. Moreover, impacts and vulnerability studies are important for identifying and analyzing potential adaptation measures that are vital for sustainable development of Nepal, particularly for the agriculture and water resources sectors. The lack of comprehensive research in these areas therefore seriously limit the ability to make appropriate policy recommendations.

Further research and development on vulnerability are essential to asses the potential impacts of sudden changes in climate on economic and social systems. As vulnerability research is highly dynamic, Nepal needs substantial support from advanced countries that have undertaken comprehension research works in this area. Since agriculture and forests are vital

to the livelihood of more than two thirds of the population, in the country, the impact assessment and the vulnerability of agriculture, water resources and forest areas to Climate Change need to be given priority. Other sectors that also are important and require assessment are tourism and energy.

6.6 Status in International and Regional Cooperation

Climate Change is a very important but critical global environmental issue or concern facing mankind. While dealing with this international concern, Nepal as a small developing country likes to believe that taking collective action based upon the convention principle of "common but differentiated responsibilities" is the only solution to the problem. Consideration of the extent of efficiency in any undertaking and the aspect of equity status must be taken into account simultaneously as well as carefully when the country tries to pursue or formulate polices and measures related to Climate Change. As far as possible, Nepal though a Non-Annex I Party likes to participate and cooperate in all possibilities within the Framework Convention in international and regional activities dealing with this Climate Change issue.

Looking back on the technical aspect of this global phenomenon of Climate Change, Nepal had first time involved and participated itself through a bilateral cooperation in studies and development of country’s national GHG emission inventory and to some extent mitigation as well as vulnerability and adaptation aspects in the mid of 1990s.

Besides, national experts and professionals have been taking active participation for the past decade or so in different technical sessions of IPCC and Framework Convention conferences. There has been a occasion where Nepal was able to host important IPCC session in Kathmandu. In a number of regional as well as international seminars or workshops related to Climate Change, Nepal has sent its experts for participation.

In August 2000, Nepal received financial support from GEF to prepare its Initial National Communication to the UNFCCC. Taking advantage of promoting & enhancing Nepal's own capacity building in the subject, the country has in many occasions extended cooperation and has exchanged knowledge & experience with other countries regionally & internationally. Considering the availability of opportunities under the provisions of UNFCCC, Nepal wishes to welcome activities like AIJ or IJ and had once initiated country's response for conducting a pilot AIJ project in cooperation with a Annex I Party to conduct Methane emission mitigation

project. The project supposed to be implemented in early 1990 however couldn't materialize due to lack of sufficient support. In the meantime, a Country Study Program in Climate Change with financial and technical support from the US was launched successfully and completed in late 1990s.

In recent several occasions, Nepal has tried to do exercises in understanding various aspects of "flexibility mechanism" defined under CDM of Kyoto Protocol and take advantage of this concept in the propositions of projects and programs for donor agencies funding which aim towards reduction of GHG emissions. Currently, Nepal has been involving itself in considering and planning to include the aspect of environmental impact due to Climate Change in the country's sustainable development programs or works. Because of the past COP sessions, necessary rules and procedures have been established for the applicability of CDM though, it is essential for the Parties involved in developing or undertaking of these flexible mechanisms to understand that the UNFCCC principle defining "common but differentiate responsibilities" and equity must not be ignored. The Climate Change problem obviously is multi-dimensional and needs active participation from countries worldwide, and Asia being the largest continent can offer significant and important contribution in solving and doing research in the subject. Nepal believes that regional cooperation and sharing of experiences and information can also be very instrumental in this direction. Obviously at present, SAARC at the sub-regional level has been trying to stand as an important forum for offering and sharing support for the member country's commitments in meeting the UNFCCC obligations. SAARC could mobilize cooperation from the member countries and focus their efforts and understanding in conducting research and studies on Climate Change issues and problem. The closeness or similarity in the aspect of the SAARC cultures and economic built-ups will have immense potential in formulation of Climate Change modules and their application to the region. Mutual understanding and cooperation as such may have optimum advantage in the use of resources needed for developing complicated climate models in the analysis of multidimensional scenarios. Capacity building processes and efforts can be accelerated in this region by this mechanism of information and experience exchange.

6.7 Technology Transfer

Technology transfer in the context of Climate Change must be viewed differently from the process of technology transfer that occurs in normal trading and commercial activities. Technology transfer in this sense must be perceived within the principle of the United

Nations Framework Convention on Climate Change and the Kyoto Protocol. Serious consideration must therefore be given to equity issues that could arise from Climate Change impacts or mitigation measures. The developed countries that are mainly responsible for the present accumulation of GHGs in the atmosphere and that are highly capable of adapting to Climate Change must assist developing countries especially the least developed ones like Nepal to cope with the phenomena. Thus the transfer of technology through market mechanisms alone will not be sufficient, and some other forms of market intervention is necessary. In particular, barriers to technology transfer should be eliminated to enhance favorable conditions in this aspect.

Assessment of Technological Needs

On of the main constraints to developing a more accurate and reliable inventory of Greenhouse Gases in Nepal is the absence of local emission factors for the key sectors such as agriculture, energy and forests; and the lack of sufficient data for inventory estimation is another hurdle encountered in the process. Nepal has also faced the problem or shortage of adequately trained manpower to undertake inventory work on a regular basis.

The determination of local emission factors requires intensive research work, and Nepal as any other underdeveloped countries faces serious financial difficulties to conduct such research. The setting up of regional and international network for information and technological exchange could facilitate this work. Building the capacity of relevant agencies to update the GHG inventory on regular basis is also vital to enhancing national inventory work.

The national Greenhouse Gas Inventory shows the status of emissions and provides the background for development of mitigation options. In the case of Nepal, mitigation options were identified mainly on the basis of their technical potential, and the so-called "No-regrets" options were identified mainly on the basis of this principle. These options do not add higher costs to a particular activity but contribute to Climate Change benefits. They also conform to Nepal's sustainable development efforts.

Assessment of vulnerability to Climate Change and adaptation measures in Nepal are at an early stage of development. Technological improvement is critically needed. Experience suggests that the development of regional or sub-regional climate models that reduce the

level of uncertainty are vital for reliable vulnerability analysis. Specific models to analyze the vulnerably sensitive major areas such as agriculture, water resources, forests and health also must be developed to make the scenario assessments reasonable. Absence of technology critical to these areas highlights the importance of transferring soft technology to the country.

Capacity Building

Capacity building is an integral part of technology transfer and is very important in enabling Nepal to participate and contribute effectively in the Climate Change studies and fulfilling the country's obligation to the convention. Climate Change issues are relatively recent and very dynamic and complex for Nepal. New technical and technical development issues are constantly emerging. The dynamic nature of the topics and their scientific technical complexity require that national experts be updated continuously to this to ensure that the latest developments are closely followed. Capacity building for national staff is vital if Nepal is to play effective role and contribute in the global efforts to address Climate Change. Specific technological capability required to enhance the role of local institutions in Nepal include the following:

- Development of local emission factors for inventory assessment in different sectors
- Skills in comprehensive vulnerability/ impact assessment
- Capacity to choose suitable mitigation and adaptation options
- Competency in operating transferred technologies

The transfer of technology to strengthen local capacity must not be one way only. Exchanges of information and experiences and participation at regional and international forums should be promoted. The interaction and exchange of research experiences contribute immensely to capacity building. Technology transfer must also be comprehensive enough for adoption and sustained operation by local personnel. Significant material & financial losses can be incurred if the transferred technologies are terminated after the co-operation period due to the lack of capable personnel to carry out necessary task. Besides, the capacity of recipients to develop their own technology or adapt imported technology utilizing local resources must therefore be supported.

CHAPTER-7

Education, Training and Public Participation

7.1 Introduction

Education and public awareness are important parts of the overall policy response to the Climate Change issue. The UNFCCC has emphasized that education and public awareness can play a significant role in achieving an effective response to the rapid build-up of anthropogenic Greenhouse Gas emissions that cause Climate Change. Information dissemination, public participation and training programs to address Climate Change and its potential effects are the main activities to promote education and awareness among general public. Since the general public in Nepal do not have yet good understanding of the implications of Climate Change and the potential benefits of the response measures, a number of programs have been launched to educate, train and promote this kind of awareness among different groups of the general public and the media as well.

Therefore, the aim of these educational and pubic awareness programs is being directed towards the general mass and media with the massage about the benefits of mitigation and adaptation measures, which are accompanied by other positive environmental effects. They will lead the way towards the efforts to reduce harmful emissions into the atmosphere, to increase agricultural productivity, and improve the environment for fresh water supply to the population and so on. Additionally many others social problems will be solved, new opportunities for workplaces will be created and unfavorable Climate Change impacts on human health and on other social issues will be decreased. Because of this, programs of public awareness, public education, and media campaigns through newspapers, magazines, radios, and TV have become important parts of the country's current enabling activity works under the UNFCCC

These programs of education and public awareness are divided into four parts:

1) Educational programs for secondary schools
2) Popularization campaign in mass medias
3) Conducting workshops for general public and ecological NGOs
4) Conducting national workshops for the officials, policy and decision makers, who are responsible for planning strategies in development works in different sectors of country's economy that are influenced by Climate Change or depend on it.

7.2 Education and Training

His majesty's Government of Nepal has adopted a long-term strategy to carry out environmental education through a multi-disciplinary and holistic approach. As the country's future decision makers will be from the present student population, steps have been taken to include some basic concepts of the environment and Climate Change into school curriculum. A course titled "Environment, Population and Health" is being taught at present at the high schools of Nepal to familiarize the young learners with Climate Change and its impact issues. However, due to the changes that are taking place in the knowledge of Climate Change and associated issues, the contents of the current school syllabus have to be updated to include the latest Climate Change related information. Hence, text formats have been proposed (Annex- A and B) to include the updates in the contents of school syllabus.

Furthermore, institutions of higher learning in Nepal also offer various environment and climate related courses at graduate and post-graduate levels. Tribhuvan University, a leading university of Nepal, has been offering three years' B. Sc. course in Meteorology and M. Sc. as well. Also, Tribhuvan University and Kathmandu University are conducting B.Sc. Environment courses. From the year 2002, Tribhuvan University has also started Master's Degree courses in Environment. Apart from this, various institutions of the private sector, NGOs and the mass media are viewing positively and complementing the government's effort in promoting environmental education in the country.

The Ministry of Population and Environment has conducted a couple of training workshops and seminars to educate different stakeholders on various aspects of Climate Change and associated issues. The Department of Hydrology and Meteorology had also organized a workshop on Climate Change problem under the US Country Studies Program in 1990s, besides actively supporting various seminars and workshops on the subject conducted by environmental journalists and NGOs. Under the present project also, workshops and seminars on Climate Change issues have been organized for the stakeholders and relevant experts; topics for discussion presented at these programs included Climate Variability, Greenhouse Gas Inventories, Climate Change Impacts and Vulnerability etc. in Nepal.

A National Workshop for the country's development planners as well as policy and decision-makers and for host of other experts to enhance their capability to integrate Climate Change

concerns into medium and long term planning has taken place recently with very enthusiastic approach to all aspects of the topic.

7.3 General Public Awareness

Concerns over environmental issues among the public in Nepal vary widely. Public attitudes are largely influenced by mass media coverage of environmental matters. The extent of coverage by the mass media, in turn, depends on environment related events. For example, there is relatively greater environmental awareness among people in Kathmandu city since the past couple of years because of the air pollution problem in the city and the media's constant watch and reporting.

Despite the heightened public awareness of environmental issues in general, many people still lack understanding of the delicate inter-relationship between man and all species of animals and plants and the environment. Thus, few are able to relate day-to-day activities (such as emissions of GHGs) to environmental consequences both in short-term and long-term basis. While some forms of pollution such as discharging sludge into rivers can be readily observed, other kinds of environmental problems may take a much longer time to manifest themselves.

Fewer still have deep knowledge about the various institutional initiatives being taken at the national, regional, international, multilateral or global level to improve the environment. More importantly, issues on Climate Change do not generally receive much attention it deserves in the electronic media. Nevertheless Ministry of Population and Environment and the Department of Hydrology and Meteorology are actively engaged in enhancing public awareness through advertisements, news, articles etc. in both the print and the electronic media. Similarly, these government organizations also have provided time and again support to various organizations of environmental journalists in conducting workshops and seminars on Climate Change and related issues attended by different stakeholders. Some journals, particularly dedicated to environmental issues are also regularly published by related journalists' organizations which greatly help to enhance public knowledge and awareness on environmental issues.

Local communities also play vital role in promoting public awareness. A number of laws and regulations are in force in Nepal to increase the participation of local communities in the

conservation of natural resources. Community forests are an example of how local communities can successfully participate in the management of forest resources and their growth. Such local participation in natural resources management enhances awareness of sustainable development processes as well.

Since print and electronic media share a vital role in promoting awareness among general public, journalists need to be trained and encouraged for their cooperation for this purpose. Community Based Organizations (CBOs) and NGOs can significantly create or enhance awareness regarding Climate Change and related issues in diverse segments of rural societies.

7.4 Public Participation and the Role of NGOs

A significant number of NGOs in Nepal are actively participating in rural development and natural resources management since the past decade. Because of their important roles as such, NGOs are very effective in enhancing awareness among local communities on environmental concerns. They are also an important source of activity and information, which have often contributed towards increasing the level of environmental awareness among the general public at large. In keeping with the strategy of the government to promote and pursue sustainable development, NGOs in Nepal are also advocating the adaptation and implementation of various plans and projects on sustainable development at the local, national, regional and international levels.

The role of NGOs will grow in the future. It is evident that a sufficient part of the work in the area of Climate Change such as reduction of GHGs by reforestation, using of renewable sources of energy, methane utilization and so on can be implemented by local NGOs. The other sphere of their activity can be participation in political dialogue with the government on different matters related to prices or tariffs on energy, demonstration projects, removing barriers for renewable energy use and development of legislative base for introduction of global ecology issues.

The private sectors have also contributed in raising public awareness on natural resources conservation and environment protection by actively participating in activities like reforestation/afforestation programs and voluntary introduction of clean technology also in the country.

Thus implementation of the government's recent policies and measures and the contributions of NGOs and the private sectors have helped greatly in enhancing these public awarenesses. Participation of the local communities in natural resource management has also strengthened these initiatives. All these sector's combined effort has significantly contributed to the promotion of such education and public awareness among the Nepalese people. This in turn is promoting sustainable developments in Nepal. The government of Nepal has also enacted Local Self-Governance Act to ensure active local body participation for achieving and promoting sustainable developments and environmental protections.

7.5 Center for Climate Change Studies & Research

Although Nepal's present contribution to address of Climate Change is negligible compared to the developed countries and some larger developing countries, it remains vulnerable to the economic, ecological and social impacts of Climate Change. Realizing this problem in the context of implementing Water Resources Policy of Nepal, it has recommended for setting up a Center for Climate Change Studies. Prior to this policy formulation, the Central Department of Hydrology and Meteorology, Tribhuvan University, had established a Climate Change Study Group on 1st September 2001. Department of Hydrology and Meteorology is primarily responsible for weather forecasting and rainfall pattern prediction. Ministry of Population and Environment (MOPE) acts as the focal point to all climate change related activities. MOPE has three primary objectives: to serve as a focal point for developing the government's domestic policy on environment including climate change, as well as a broad communications strategy and programming on various environmental and climate change issues; to coordinate, in cooperation with provincial officials, the development of a National Implementation. In this regards the national level, Climate Change Study & Research Center as recommended should be established in the MOPE.

This Center will have to work in close collaboration with all related agencies, and the outcome of studies or research carried out should be made available to policy-making bodies in the government and other concerned institutions.

CHAPTER-8

Recommended Research/Studies

Research and scientific assessments play a vital role in improving the understanding of the potential impacts of Climate Change in Nepal with specific reference to their scale and timing. Such investigations will enable the development and assessment of appropriate adaptation strategies. There is a clear need for a coherent national approach to provide the tools and organization to understand the impacts of Climate Change as opposed to continued reliance on individual agency initiatives. Such an approach would also promote integrated impact studies, which would improve the information and data available to decision-makers in all sectors for developing plans and future policies on Climate Change.

8.1 Research/Studies

8.1.1 Energy Sector

a) Hydropower will be the preferred option for power generation at present as the annual runoff in the country is 202 billion m^3 and economical hydropower potential is 46 thousand-megawatt. Besides energy supplied from this source is clean and does not emit Greenhouse Gases.

b) Undertake a study of the economic and environmental impact of identified hydropower potential.

c) Undertake an in-depth Integrated Resource Planning study on Energy Conservation and other Demand Side Management (DMS) measures.

d) In the rural areas use of alternative energy should be encouraged.

8.1.2 Industry Sector

Develop and enforce emission standards related to GHGs in the industrial sector, and promote studies on energy efficiency in the industrial processes.

8.1.3 Transport Sector

a) Carry out research/studies on the selection of suitable material for road construction. Work already carried out can be extended to accommodate Climate Change concerns.

b) Develop representative emission factors for different fuels and vehicle types.

c) Improve methodologies for estimation of emissions in the transport sector in absolute terms as well as in related terms.

d) Introduce a suitable vehicle inspection and monitoring program.

e) Promote adoption studies on electrical vehicles in the country

8.1.4 Agriculture Sector

a) Develop drought tolerant crop varieties and study the use of traditional varieties.

b) Estimate the change in production rates with Carbon dioxide fertilization and temperature increase on different crops - rice, field crops, vegetables, plantation crops.

c) Study the role of agro-silvicultral systems in Nepal- which are regarded as Carbon dioxide sinks and sources of GHG emissions.

d) Undertake studies of economic models that determine the ability to mitigate Climate Change through emission reduction vs. the ability to adapt to such changes through adjustments in production functions.

e) Study the aspects of soil organic matter and nutrient cycling (rates of accumulations, decomposition, etc.) in relation to Climate Change and agricultural sustainability.

f) Study the effect of different traditional cultural practices such as green manuring, continuous cropping with fertilizer, multiple cropping, modified alley-farming, etc., on mitigating Climate Change impacts.

g) Study the effect of Climate Change impact on weed, pest and disease occurrence of cultivated crops and develop forecasting systems.

h) Identify agro-ecological zones particularly sensitive to Climate Change impacts and potential vulnerable areas.

i) Undertake studies to determine the probability of drought in different agricultural seasons and in different area.

j) Examine factors affecting Methane production in rice of different agro-ecological zones and farming practices.

k) Study of the impact of Climate Change on water availability and crop water requirements.

l) Promote rainfed farming and efficient utilization/conservation of water.

m) Develop integrated farming systems in relation to Climatic Change.

8.1.5 Forestry Sector

a) Conduct research and development of appropriate protocols for community forest management for agroforestry type projects. The selection of projects for GHG mitigation should be considered:

The potential social impacts, particularly for poverty reduction through improved management of community forest areas or development of agroforestry to farmers on the basis of potential for Carbon sequestration to be addressed.

Other potential benefits such as bio-diversity conservation or watershed protection should be studies.

b) Prepare protocols and guidelines for transferring resources for sustainable forestry and agroforestry to farmers on the basis of Carbon sequestration.

c) Develop effective systems (standards and procedures) for monitoring and regulating Carbon sequestration by forestry and other land use projects.

d) Evaluate socio economic benefits of Carbon offset projects. Regulatory systems should include mechanisms for selecting and promoting projects that contribute to the development of sustainable rural livelihood.

e) Develop a database of biomass for different types of vegetation in Nepal. Data can be derived from direct measurements of biomass representing the main vegetation types in the country.

8.1.6 Water Resources Sector

a) Identify new flood levels via hydrological and hydraulic modeling,

b) Study the impacts of climate variability and Climate Change on river flow regimes and on the ground water table as well as snow covered area in Nepal.

c) Develop effective measures to manage and mitigate water induced disasters.

d) Develop appropriate guidelines for sustainable management of water sheds and aquatic ecosystem.

e) Prepare a ground water extraction regulation policy.

8.1.7 Health Sector

a) Undertake research on low thermal environment management and control strategies in work places.

b) Conduct studies on epidemiological forecasting and early warming systems using RS/GIS technology applicable in high-risk areas for Malaria, Japanese Encephalitis, diarrhoeal disease and nutritional disorders.

c) Undertake prospective and retrospective studies on identified disease patterns such as eye and skin disorders relevant to Climatic Change.

d) Conduct studies on vector mosquito dynamics and change patterns on all vector borne diseases.

CHAPTER-9

Conclusions

The Earth's climate is projected to change because human activities are altering the chemical composition of the atmosphere through the build up of Greenhouse Gases (GHGs) primarily Carbon dioxide, Methane and Nitrous oxide. Nepal recognizes the importance of international cooperative efforts to address Climate Change and has plans to pursue study and research on the subject. Hence, the country is serious in efforts to address Climate Change issues and integrate it into the country's economic and social development plans.

Nepal's National Greenhouse Gas Inventory for 1994/95 shows gross emissions of CO_2 at about 24525 Gg with the land -use change and forestry sector contributing the largest share followed by energy sector, while the estimated removal of CO_2 by the forestry sector was about 14778 Gg resulting in the net emission of CO_2 to 9747 Gg in the same year. The total CH_4 emissions were estimated at 948 Gg in 1994/95 with rice cultivation and live stock as the main sources of it. Land use and deforestation as well as domestic and industrial wastes also contributed to the Methane emissions. The major source of Nitrous oxide in 1994/95 was agriculture soils. The total Nitrous oxide emission in 1994/95 was estimated at 31 Gg out of which agricultural sector contributed 29 Gg in which 93 % was contributed by agriculture soils and remaining 7 % by animal waste management system. Also, the indirect 1 Gg Nitrous oxide emission was produced from the sewage during treatment and disposal for the base year 1994/95. Besides, 1 Gg of Nitrous oxide was also released from the energy sector to the atmosphere.

Analysis shows mitigation options may be cost effective though, some of them may not be economically viable to pursue at the present time. Many of the policies and measures that have been implemented to date demonstrate that Nepal has actively participated in addressing Climate Change. For example, formulation of alternate energy policy and its implementation may prevent the emission of substantial amounts of GHGs. Potential Carbon sinks have been enhanced through aggressive reforestation and afforestation programs.

Various technical, political, social, and economic barriers exist that prevent Nepal from making greater contribution to GHG abatement. Unless the general public has deep understanding and appreciation of Climate Change issues and the implications of various options available to them, it is extremely difficult to implement new policies and measures, even if they are potentially beneficial to all the parties concerned.

Trend analysis of observed data on climate confirms that there is a rising trend of temperature in Nepal. Annual rate of temperature rise is found to be about 0.41^{o} C per decade. There is a decreasing trend of precipitation on annual basis (9.8mm/decade) in the month of April and May though, a rising trend of precipitation is observed during monsoon seasons.

Trends of monsoon onset and withdrawal from 21 years of data show that monsoon season is elongating in both the ends. Onset will occur earlier by 71 % of a day per annum and withdrawal will retreat by about 15 % of a day per annum. Although this trend appears to be elongating monsoon period for long, it is not likely to happen due to changes of seasons. In case of trend of withdrawal of monsoon it is not so distinct whereas trend of monsoon onset is quite distinct.

Doubling of CO_2 will have more of positive impact on major crops but the simultaneous rise of temperature will adversely affect warmer environment crop and C_4 crops. Response to temperature rise is more negative in maize than in wheat and rice. The yield reduction will be severe for all crops at 4^{o} C temperature rise. However, the potential yield reduction below the ambient at 4^{o} C will vary from 25 % to 33 % in the Terai, 11.3 % to 21.1 % in the hill and 3 % to 12.7 % in the mountain. Hence, mountain environment will be more favorable than the tropical flat land to cope with Climate Change phenomena.

Changes in hydrological cycle and the depletion of water resources are some of the top environmental challenges facing Nepal in the context of global warming. It is estimated that a temperature rise of 4^{o} C can result in the loss of 70 % of snow and glacier area due to melting of snow and ice. This melt water will contribute to the faster development of glacier lakes, and this will lead to increased potential for glacier lake out burst flood hazards.

Forests of Nepal have been shrinking mainly because of anthropogenic activities. Present study shows that in future forests will have to face additional threats of Climate Change. According to Holdridge vegetation classification, presently Nepal has 15 types of vegetation whereas there will be a only 12 types of vegetation under 2 x CO_2 climatic conditions when there is a rise of temperature up to 5.8^{o} C.

Voluntary initiatives to reform the educational curricula by incorporating more subjects pertaining to energy use efficiency, natural resources conservation and environmental protection have been undertaken to build a solid foundation for Nepal's sustainable development programs and to yield benefit beyond its national boundaries. Internationally, Nepal has also been active in the UNFCCC process and in the process of developing a national policy on the CDM issues.

But, special political and socio-economic conditions and circumstances of Nepal time and again prevent the country from fully realizing the government's Climate Change related policy formulations. Its ability to understand fully the situation and the potential impacts and opportunities of abating the Climate Change risk is rather limited though. Nepal perceives that extensive study and development works on climatic vulnerability and adaptation are critically needed.

Technology transfer is an important mechanism to assist developing countries like Nepal to address Climate Change appropriately. Unfortunately, such a system suffers from lack of initiative on the part of developed countries. However, financial support and favorable terms and conditions could facilitate the transfer process and facilitate more access to appropriate technologies to the recipient countries. Nepal as a country with no fossil fuel deposits has a vast potential for renewable energy like hydropower, biomass and wind. Hence, the country is well placed to meet most of energy needs from emission free sources. Because of this, Nepal is in comfortable position to take advantage of the global concern over Climate Change and CDM when Kyoto protocol charts a course towards clean energy mechanism development and sharing amongst the parties. Nepal needs to prepare a host of projects that will be eligible for the CDM, and set up the national procedure for the certification of emission reduction trading.

Hence, coping with the challenge of Climate Change more effectively requires both financial and other forms of “soft and hard assistance” such as technical training, research support, public education, and pilot project development and management aid from the Parties of the convention and other development agencies. In this connection phase II of Climate Change enabling activities to be approved by the GEF is anticipated to provide the opportunity for Nepal to do exercises for assessment and identification of appropriate technologies required for adaptation purposes.

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Appendix –I

1) Steering Committee

Mr. Mohan Bahadur Karki, Secretary,
Ministry of Population and Environment----------Chairman

Mr. Dipendra Bikram Thapa, Joint Secretary,
Ministry of Population and Environment---------- Member

Mr. Purna Bhadra Adiga, Joint Secretary,
Ministry of Science and Technology----------Member

Mr. Madhu Sudan Bista, Joint Secretary,
Ministry of Forest and Soil Conservation---------- Member

Mr. Babu Ram Regmi, Joint Secretary,
Ministry of Law, Justice and Parliamentary Affairs----------Member

Dr. Madhav Ghimire, Joint Secretary,
Ministry of Finance---------- Member

Mr. Stalin Man Pradhan, Joint Secretary,
Ministry of Industry, Commerce and Supply---------- Member

Mr. Asheshwor Jha, Joint Secretary,
Ministry of Agriculture and Cooperative----------Member

Prof. Dr.Bidur Prasad Upadhyay, Professor,
Central Department of Hydrology & Meteorology, TU----------Member

Dr. Madan Lall Shrestha, Director General,
Department of Hydrology and Meteorology
Ministry of Science and Technology---------- Member Secretary

- Dr. Govinda Raj Bhatta, Dr. Mukti Narayan Shrestha and Mr. Lok Man Singh Karki, Secretaries of Ministry of Population and Environment participated in the capacity of Chairman during their respective tenures.
- Mr. Janak Raj Joshi and Dr. Jibgar Joshi, Joint Secretaries, Ministry of Environment and Population participated in the Steering Committee in the capacity of Members.
- Mr. Adarsha Prasad Pokhrel, participated in the Steering Committee in the capacity of Member Secretary during his tenure as Director General, Department of Hydrology and Meteorology
- Mr. Purushottam Kunwar, Under Secretary, Ministry of Population and Environment contributed to overall project management.

2) National Climate Change Committee **Appendix –II**

Dr. Madan Lall Shrestha, Director General,
Department of Hydrology and Meteorology
Ministry of Science and Technology----------Chairman

Tulsi Bhakta Prajapati, Under Secretary,
Ministry of Forest and Soil Conservation---------- Member

Mr. Purushottam Kunwar, Under Secretary
Ministry of Population and Environment---------- Member

Mr. Deepak Bahadur Khanal, Agriculture Economist
Ministry of Agriculture and Cooperative---------- Member

Mr. Prabeen Aryal,Senior Divisional Engineer
Ministry of Water Resources---------- Member

Dr. Sita Ram Joshi, Deputy Director General,
Nepal Bureau of Standards and Metrology
Ministry of Industry, Commerce, and Supply---------- Member

Mr. Shushil Agrawal, Director
Ministry of Labour and Transport Management---------- Member

Mr. Babu Kaji Bania, Section Officer
Ministry of Law, Justice and Parliamentary Affairs---------- Member

Prof. Dr. Bidur Prasad Upadhyay, Professor,
Central Department of Hydrology & Meteorology, TU----------Member

Mr. Janak Rai, Officer,
Federation of Nepalese Chamber of Commerce and Industry----------Member

Mr. Arjun Dhakal, Journalist
Nepalese Forum of Environmental Journalists---------- Member

Ms. Nira Shrestha Pradhan, Programe Officer,
International Union for Conservation of Nature----------Member

Prof. Dr. Govinda Prasad Sharma Ghimire, Dean,
Institute of Science and Technology, TU---------- Member

Dr. Madan Bahadur Basnyat, Executive Director
Alternate Energy Promotion Centre
Ministry of Science and Technology ----------Member

Dr. Prakash Chandra Adhikari, Head
Central Department of Geology, TU----------Member

Prof. Suresh Raj Chalise, Professor of Meteorology----------Member

Dr. Janak Lal Nayava, Consultant Meteorologist---------- Member

Mr. Nirmal Hari Rajbhandary, Senior Divisional Meteorologist,
Department of Hydrology & Meteorology
Ministry of Science and Technology ----------Member Secretary

- Mr. Adarsha Prasad Pokhrel, participated in the National Climate Change Committee in the capacity of Chairman during his tenure as Director General, Department of Hydrology and Meteorology

Appendix -III

3) National Study Team

Greenhouse Gas Inventory:
Dr. Madan Bahadur Basnyat, Executive Director, AEPC----------Team Leader
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Dr. Sita Ram Joshi, Deputy Director General, NBSM----------Member
Mr. Chiranjeevi Gautam ---------- Member
Mr. Lochan Pd. Devkota, Associate Professor
Central Department of Hydrology & Meteorology, TU----------Member

Vulnerability/Impact Assessment and Adaptation:
Mr. Ratna Prasad Nayaju, Senior Divisional Meteorologist, DHM----------Group Coordinator
Prof. Dr. Promod Kumar Jha, Head, Central Department of Botany, TU---------- Member
Dr. Kishor Sherchand, Head, Agronomy Division, NARC----------Member
Dr. Keshav Prasad Sharma, Senior Divisional Hydrologist, DHM---------- Member

Mitigation Options:
Dr. Prakash Chandra Adhikari, Head, Central Department of Geology, TU----------Team Leader
Mr. Bijaya Kumar Vaidya, Act. Deputy Director General, DHM---------- Member
Mr. Rabindra Nath Bhattarai, Director, Center for Pollution Study, IOE, TU---------- Member
Dr. Arun Bhakta Shrestha, Hydrologist, DHM----------Member

National Communications:
Prof. Dr. Bidur Prasad Upadhyay, Professor,
Central Department of Hydrology & Meteorology, TU----------Team Leader
Mr. Purna Bahadur Shrestha, Asst. Project Co-ordinator---------- Member
Mr.Surya Prasad Prajapati, Senior Divisional Meteorologist, DHM---------- Member
Mr.Vishwa Bhusan Amatya, Senior Advisor, AEPC/DANIDA----------Member

4) Reviewers:

Mr. Janak Raj Joshi

Mr. Adarsha Prasad Pokhrel

Mr. Bikash Raj Pandey

Dr. Binayak Bhadra

5) Editors:

Mr. Purushottam Kunwar

Mr. Gaurav Dahal

Annex-A

For Class IX:

Proposed text format updating the existing materials in the chapter (page 134) of the book "स्वास्थ्य, जनसंख्या तथा वातावरण शिक्षा" (Health, Population and Environmental Education) to introduce Climate Change background to the students.

वायुप्रदूषण♦

वायुमण्डलमा नाईट्रोजन, अक्सिजन, कार्बन डाईअक्साईड, आर्गन जस्ता ग्यासहरु हुन्छन । यी ग्यासहरुमा बाह्य तत्व तथा दूषित वस्तुहरु मिलेमा यिनीहरुको वास्तविक अवस्था बिग्रन्छ । बस, ट्रक, स-साना गाडीहरु जस्ता सवारी साधनहरु र उद्योगहरुबाट निस्कने, धूवाँ, धूलो, सल्फर डाइअक्साइड, कार्बन डाइअक्साइड, **मिथेन, नाइट्रस अक्साइड,** कार्बन मोनोअक्साइड, फोहोरमैलाको दुर्गन्ध आदि वायुमण्डलमा मिसिन्छन् । यसबाट वायुप्रदूषण हुन्छ । **साथै जलवायु प्रणालीमा पनि परिवर्तन (Climate Change) ल्याउछ ।**

(अ) वायुप्रदूषणका कारणहरु :- वायुप्रदूषण विभिन्न कारणहरुले गर्दा हुन्छ । ती मध्ये केही प्रमुख कारणहरु यस प्रकार छन् :

(क) सवारी साधनबाट निस्कने **कार्वन डाइअक्साइड तथा अन्य ग्याँस सहितका** धूवाँ, धूलो, फोहोरमैला आदिले हाम्रोदेशमा वायुप्रदूषण गरिरहेको छ । सहरी क्षेत्रमा सवारी साधनहरुको बढी चाप हुने हुनाले ती क्षेत्रहरुमा वायुप्रदूषण बढी हुन्छ ।

(ख) उद्योगहरुबाट निस्कने, धूवाँ, धूलो, फोहोरमैला आदिले पनि वायु प्रदूषण गराउँछ यिनीहरुबाट सल्फर डाइअक्साइड - Sulphur dioxide), कार्बन डाइअक्साइड (Carbon dioxide),**मिथेन(Methane),नाइट्रस अक्साइड((Nitrous Oxide)** जस्ता ग्याँसहरु निस्कन्छन् ।यी ग्याँसहरु एवम् विभिन्न किसिमका दूषित कणहरु हावामा मिसिनाले वायु प्दूषित हुन्छ ।

(ग) ग्रामीण क्षेत्रमा इन्धनको प्रमुख स्रोत दाउरा, गुइँठा, ढोड, छ्वाली आदि हुन् । यी वस्तुहरु खाना पकाउन र आगो ताप्नकलागि बालिन्छन् । यिनीहरुबाट वढी निस्कने **कार्वन, कार्वन डाइअक्साइड मिस्रीत** धूवाँ, दूषित कण आदिले वायुप्रदूषण गर्छन ।

(आ) वायुप्रदूषणका असरहरु:- वायुप्रदूषणबाट हुने विभिन्न असरमध्ये केही यस प्रकार छन् :

(क) गाउँघरमा भान्छा कोठामा हावाको आवतजावत तथा संवातन (Ventilation) हुनको लागि राम्रो व्यवस्था हुँदैन । यसले गर्दा बालेको दाउराबाट निस्कने धूवाँले भान्छाकोठा र घरभित्रको हावा **एवं वायुमण्डल समेत** प्रदूषित हुन्छ। कोठामा दूषितकणहरु, कार्बन डाइअक्साइड, कार्बन मोनोअक्साइड आदि रहेका हुन्छन् । यी वस्तुहरु वासप्रश्वास प्रक्रियाबाट हाम्रो शरीरभित्र प्रवेश गर्छन् । यसले गर्दा गाउँघरका कतिपय मानिसहरु श्वासप्रश्वास र आँखासम्बन्धि रोगबाट बढी पीडित हुन्छन् ।

(ख) सिमेन्ट उद्योग, ढुङ्गा वा मार्बल उद्योग, ईटा कारखाना आदिबाट निस्कने धूवाँ, धूलो र ग्याँसले **वरिपरिका तथा माथिल्लो** वायुलाई समेत प्रदूषित गर्छन् । दूषित हावामा भएका सूक्ष्म कणहरु मानिसको शरीरमा प्रवेश गर्दा कमजोर बनाउँछ यसको असरबाट मांसपेशीहरुको काममा बाधा पुग्छ । यसले गर्दा गर्भ तुहिने, रगतको कमी हुने र मृगौलामा असर पर्ने हुन्छ । यसबाट मानसिकतामा समेत असर पर्छ ।

(ग) प्रदुषित वायुमा भएका सल्फर डाइअक्साइड (Sulphur dioxide) **नाईट्रिक अक्साइड (Nitric oxide)**आदिले फलाम र धातुले बनेका ऐतिहासिक महत्वका मठमन्दिर,भवन,मूर्ति, स्मारक जस्ता सांस्कृतिक सम्पदालाई पनि नाश गर्छन ।

(घ) वायुप्रदुषण हुनाले वायुमडलको माथिल्लो तहमा कार्बन डाइअक्साइड, **मिथेन, नाइट्रस अक्साइड** र अन्य ग्यासहरु बाक्लो तह बनाएर रहन्छन् । यसले सूर्यको ताप पृथ्वीमा आउनलाई रौक्दैन तर पृथ्वी बाट उठ्ने तापलाई परावर्तन गरी **पृथ्वीमा नै फर्काइ दिन्छ** । जसले गर्दा पृथ्वीको सतहको तापक्रम बढ्छ । पृथ्वीको ताप वृद्धिले **समग्र जलवायुमा परिवर्तन (Climate Change) ल्याउछ** । यसका कारण सबै जीवजन्तुलाई ज्यादै नराम्रो असर पुरयाउँछ ।

♦ **Devnagari Script**

(ई) नियन्त्रणका उपायहरु :-वायुप्रदूषणको नियन्त्रण विभिन्न उपायहरुद्धारा गर्न सकिन्छ । केही मुख्य मुख्य उपायहरु तल दिइएकाछन्:

(क) पुराना सवारी साधनहरु जसबाट बढी धूवाँ निस्कन्छ तिनीहरुलाई चलाउन रोक्नुपर्छ । तिनीहरुको बेलाबेलामा जाचँ गर्ने कार्यक्रमहरु पनि सञ्चालन गर्नुपर्छ

(ख) फोहोरमैला सडक, बाटो, खाली स्थान आदिमा जहाँपायो त्यहीं फाल्न दिनुहुँदैन । फोहोरमैला संकलन गरी त्यसलाई तह लगाउनु पर्छ ।

(ग) ढुङ्गा पेल्ने कलकारखाना, सिमेन्ट उद्योग, इँटा भट्टा आदि उद्योगहरुबाट निस्कने धूवाँ एवम् धूलाका कणहरु **शक्ति कार्य क्षमता (Energy Efficiency) द्धारा** नियन्त्रण गर्नुपर्छ ।

(घ) इन्धनका स्रोत्रहरु जस्तै : काठदाउरा, गुईठा र कृषिजन्य उपजहरुको बदला वैकल्पिक इन्धनका स्रोतहरु प्रयोग गर्न प्रोत्साहन गर्नुपर्छ । सौर्यशक्ति, विधुत्शक्ति, जैविकउर्जा, वायुउर्जा जस्ता वैकल्पिक इन्धनका स्रोतहरुको प्रयोगले दुषित ग्याँसहरु घटाइ वायुप्रदूषण कम गर्न सहयोग पुरयाउँछ ।

(ङ) वायुप्रदूषण नियन्त्रणको लागि कानुनी व्यवस्था गरी प्रभावकारीरुपमा कार्यान्वयन गर्नुपर्छ ।

(च) प्रदूषणको रोकथाम तथा नियन्त्रणका प्रयास तथा कार्यक्रमहरुमा जनसहभागिता जुटाउनुपर्छ । यसले वायुप्रदूषण नियन्त्रणमा सहयोग पुरयाउँछ ।

(छ) खुला स्थानमा वृक्षारोपण गरी बोटबिरुवा वृद्धि गर्नाले प्रदूषण नियन्त्रण गर्न सहयोग पुग्छ ।

Note:- Bold letters are the proposed additions, the rest being the existing materials in the chapter.

Annex-B

For Class X:

Proposed text format updating the entire existing materials in the chapter (Page 55) of the book "स्वास्थ्य, जनसंख्या तथा वातावरण शिक्षा" (Health, Population and Environmental Education) to reinforce the Climate Change background of the students.

तापक्रम बृद्धि♦

विभिन्न उद्योगहरु, कलकारखाना आदि बाट उत्सर्जन हुने कार्वन डाइअक्साइड (CO_2), नाईट्रस अक्साइड (N_2O), मिथेन (CH_4) आदि जस्ता हरितगृह ग्याँसहरु माथिल्लो वायुमण्डलमा दिन प्रति दिन थुप्रिदै गईरहेको छ । यी ग्याँसहरुको कारणले पृथ्वीको सतहको तापक्रम वढ्दै आएको वैज्ञानिक रुपले पुष्टि भैसकेको छ । यसरी पृथ्वी सतहको तापक्रम बृद्धि हुनाले समग्र जलवायुमा परिवर्तनका लक्षणहरु देखा परिसकेका छन् जसले गर्दा पृथ्वीका सम्पूर्ण जीव तथा निर्जिव संरचनानै संकटमा पर्न सक्दछ ।

तापक्रम बढ्नाले हिम नदिहरु पग्ली खुम्चनु, हिम तालहरु ठूलो हुनु र फुट्नु, Antarctica र Arctic Ocean मा रहेका हिउँका ढिक्काहरु पग्लेर समुद्रमा मिसिनु, समुद्री सतह बढ्नु, कहिले अतिवृष्टि र कहिले अनावृष्टि हुनु आदि जलवायु परिवर्तन (Climate Change) का लक्षणहरु हुन् ।

वायुमण्डलमा त्यसरी थूप्रिदै गईरहेको ग्याँसहरुले सूर्यबाट आएका प्रकाशका किरणहरुलाई पृथ्वी सतहमा पुग्न रोक्दैनन् तर पृथ्वीको सतह बाट निस्कने विकिरण वायुमण्डलमा फर्कने क्रममा केहिलाई ती ग्याँसहरुले रोकी पुन : पृथ्वीमानै फर्काउने हुनाले पृथ्वीको सतहको तापक्रम बढेको हो र यस्तो प्रक्रृयालाई 'हरितगृह ग्याँस प्रभाव' भनिन्छ भने ती ग्याँसहरुलाई 'हरितगृह ग्याँस' भन्दछन् ।

यदि ती ग्याँसहरुको उच्च उत्सर्जन दरलाई कम नगर्ने हो भने पृथ्वीको समग्र ताप्रक्रम झन झन बढ्न गई सम्पूर्ण पारिस्थितिकीय प्रणाली (Ecosystem)मा नकारात्मक असरहरु देखा परी जीव जन्तु तथा वनस्पति समेत संकटमा पर्नेछ भन्ने बैज्ञानिकहरुको भनाई रहेको छ ।

हाम्रा भावी सन्ततीलाई त्यस्तो संकटबाट बचाउनका लागि आजै देखि नै ती हरितगृह ग्याँसको उत्सर्जन दरलाई कम गर्नु अत्यावस्यक छ । त्यसकारण आजै देखिनै हामीले निम्न क्रृयाकलापमा जोड दिनु पर्दछ :

(१) उद्योगहरुमा नयाँ नयाँ प्रविधि (New Technology) अपनाई तथा चालु भईरहेका यन्त्रको बेला बेलामा मर्मत तथा संभार गरी उर्जा कार्य क्षमता (Energy Efficiency) बढाउने

(२) ती उद्योगहरुबाट निस्कने हरितगृह ग्याँसलाई संकलन गरी अरु काममा उपयोग गर्ने ।

(३) परम्परागत (Conventional) उर्जाको प्रयोगको सट्टामा वैकल्पिक अथवा नविकरणीय (Renewable) उर्जाका प्रयोगलाई प्रबर्द्धन गर्ने आदी ।

♦ **Devnagari Script**