NEPAL

SECOND NATIONAL COMMUNICATION

TO UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

Government of Nepal

Ministry of Science, Technology and Environment

December 2014

Government of Nepal
Ministry of Science, Technology & Environment

Ref. No:

FOREWORD

Nepal, being least developed and mountainous country, is more prone to climate change. Despite negligible contribution of greenhouse gases, Nepal has to face devastating impact of climate change on almost all sectors of development. We have already experienced the effect of climate change as flash floods, landslides, droughts, glacial melt and these are expected to be more severe in future. We are not only prone to such natural calamities but also face challenges towards severe diseases due to increase in temperature at an alarming rate.

Nepal has committed on taking serious efforts to address the detrimental effects of climate change hazards that will eventually lead towards the path of sustainable development. Recognizing adaptation as emerging priority, Nepal has adopted National Adaptation Programme of Action (NAPA) and Local Adaptation Plan of Action (LAPA) as strategic tools for developing appropriate adaptation measures. Nepal has also formulated Climate Change Policy to enhance climate resilience of the economy. In addition, Nepal initiated the Mountain Initiative for Climate Change to bring the mountainous countries together and build a common platform to support the Mountain Agenda. As a party to the United Nations Framework Convention on Climate Change (UNFCCC), Nepal has been actively engaging in the international climate change regime. As a part of our commitment to the regime, Nepal has prepared the Second National Communication. This report gives an opportunity to share climate relevant information with other countries and will help to mainstream climate change into national policies, plans and development. While addressing the challenges of climate change, mitigating its adverse effects is one of the highest priorities of the Government of Nepal.

This report provides clear insight about GHG inventory for base year 2000/01, increasing vulnerability, adaptation and mitigation potential for sustainable development. As per the report, among different sectors, Agriculture sector has been the key source for GHG emission while forest sector has been net source for sink. The share of Nepal in global GHGs emission gas increased from 0.025% in Initial National Communication to 0.027% in SNC. Considering this increment, Nepal has to adopt low greenhouse gas emission strategy.

Successful completion of this work would not have been possible without the technical support from United Nations Environment Programme (UNEP) and financial support from Global Environment Facility (GEF). The report has come to this stage with the support from various experts and agencies. In this regard, I would like to acknowledge ADAPT Nepal, CDES-TU, CIAS consulting firm, Green Consult Pvt. Ltd., GRID Pvt. Ltd. and other individual consultants for their consulting services.

I own my deep gratitude to Steering Committee members and National Climate Change Committee members for their invaluable advice and suggestions. I am indebted to peer reviewers Mr. Shiva Prasad Nepal, Mr. Jeebachh Mandal, Mr. Kedar Man Prajapati, Mr. Govind Bahadur Shrestha, Mr. Alok Kumar Mishra, Mr. Chakra Pani Sharma and Ms. Ramita Manandhar for their useful comments and suggestions representing DHM, MoE, MoUD, MFSC, MoI, MoFALD, MoAD respectively.

I would like to thank Dr. Ganesh Raj Joshi, Former Secretary, Government of Nepal, for reviewing this document. I would like to extend my gratitude to Mr. Batu Krishna Uprety, Mr. Prakash Mathema, then Joint-Secretaries of MoSTE and Mr. Lava Bahadur K.C., Former National Project Manager of SNC Project for their technical guidance and constant support to finalize this report.

I would like to take this opportunity to express my appreciation to Mr. Ritu Pantha, Director and National Project Manager, who took a lead to bring this document in its present shape. I would also like to thank, Mr. Sujan Subedi, Meteorologist and Program Officer, and other SNC team members Ms. Karuna Adhikaree, Mr. Binaya Joshi, Ms. Sabita Niroula, Ms. Deepika Ghimire, Ms. Laxmi Adhikari for their energetic and commendable work for successful completion of SNC report.

Finally, I would like to thank all the people who contributed directly or indirectly for the preparation of this report.

December 2014

(Ram Prasad Lamsal)
Joint Secretary
and
UNFCCC Focal Point

Office Address: Singhadurbar Kathmandu, Nepal
Tel. No.: 4211734, 4211641, 4211996 4211946, 4211894, 4211737 4211586, 4211698
Fax No.: +977-1-4211954
E-mail: info@moste.gov.np
Website: www.moste.gov.np

TABLE OF CONTENT

List of Tables

List of Figures

ACRONYMS

°C	Degree Centigrade
ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Centre
AGDP	Agricultural Gross Domestic Product
BCM	Billion Cubic Meter
BRCH	Building Resilience to Climate Related Hazards
BSP	Biogas Support Program
CBS	Central Bureau of Statistics
CC	Climate Change
CCMD	Climate Change Management Division
CCNN	Climate Change Network Nepal
CCU	Climate and Carbon Unit
CDES	Central Department of Environmental Science
CDM	Clean Development Mechanism
CF	Community Forest
CFGORRP	Community-based Flood and Glacial Lake Outburst Risk Reduction Project
CO_2	Carbon dioxide
COP	Conference of Parties
CVCA	Climate Vulnerability and Capacity Analysis
DANIDA	Danish Development Assistance
DCEP	District Climate and Energy Plan
DDC	District Development Committee
DEEU	District Energy and Environment Unit
DFID	Department for International Development
DHM	Department of Hydrology and Meteorology
DNPWC	Department of National Parks and Wildlife Conservation
DOF	Department of Forests
DOHS	Department of Health Services
DOI	Department of Irrigation
DOR	Department of Roads
DPR	Department of Plant Resources
DRR	Disaster Risk Reduction
DSCWM	Department of Soil Conservation and Watershed Management
DUDBC	Department of Urban Development & Building Construction
DWIDP	Department of Water Induced Disaster Prevention
DWSS	Department of Water Supply and Sewerage
EFDB	Emission Factor Database
EIA	Environmental Impact Assessment
ELA	Equilibrium Line Altitude
EM	Effective Microorganism
EMS	Environmental Management System

ESP	Environmental Support Program
FAO	Food and Agriculture Organization
FCHV	Female Community Health Volunteers
FCPF	Forest Carbon Partnership Facility
FECOFUN	Federation of community Forestry Users Nepal
FMC	Fund Management Committee
FY	Fiscal Year
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographic Information System
GLOF	Glacier Lake Outburst Flood
GoN	Government of Nepal
GSI	Gender and Social Inclusion
ha	Hectare
HDI	Human Development Index
HDR	Human Development Report
HMS	Hydro Meteorological Services
IA	Implementing Agency
ICIMOD	International Centre for Integrated Mountain Development
IITM	Indian Institute of Tropical Meteorology
INC	Initial National Communication
INGO	International Non Governmental Organization
INPS	Integrated Nepal Power System
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
IUCN	International Union for Conservation of Nature
IWM	Improved Water Mill
IWRM	Integrated Water Resources Management
KCAMC	Kanchenjunga Area Management Committee
KCAP	Kanchenjunga Conservation Area Project
KU	Kathmandu University
LAPA	Local Adaptation Plan of Action
LRMP	Land Resource Mapping Project
LVI	Livelihood Vulnerability Index
MDG	Millennium Development Goal
MOAC	Ministry of Agriculture and Cooperative
MOAD	Ministry of Agricultural Development
MOE	Ministry of Environment
MOEST	Ministry of Environment, Science and Technology
MOF	Ministry of Finance
MOFALD	Ministry of Federal Affairs and Local Development
MOFSC	Ministry of Forests and Soil Conservation

MOHP	Ministry of Health and Population
MOPE	Ministry of Population and Environment
MOST	Ministry of Science and Technology
MOSTE	Ministry of Science, Technology and Environment
MW	Megawatt
NAPA	National Adaptation Programme of Action
NARC	Nepal Agricultural Research Council
NARDF	National Agricultural Research and Development Fund
NAST	National Academy of Science and Technology
NCCKMC	Nepal Climate Change Knowledge Management Center
NCCSP	Nepal Climate Change Support Program
NDHS	Nepal Demographic and Health Survey
NEA	Nepal Electricity Authority
NFI	National Forest Inventory
NGO	Non Governmental Organization
NHEICC	National Health Education, Information and Communication Center
NLSS	Nepal Living Standards Survey
NMVOCs	Non-Methane Volatile Organic Compounds
NPC	National Planning Commission
NTFP	Non-Timber Forest Product
NTNC	National Trust for Nature Conservation
NWSC	Nepal Water Supply Corporation
PPCR	Pilot Project on Climate Resilience
PRECIS	Providing Regional Climate for Impact Studies
QUMP	Quantifying Uncertainty in Model Predictions
RCM	Regional Circulation Model
REDD	Reduce Emission through Degradation and Deforestation
REP	Renewable Energy Projects
RERL	Renewable Energy for Rural Livelihood
RET	Renewable Energy Technology
ROR	Run of the River
R-PIN	Readiness Plan Idea Note
RT	Renewable Technology
SBSTA	Subsidiary Body for Scientific and Technical Advice
SDC	Swiss Agency for Development and Cooperation
SDM	Statistical Downscaling Model
SEWIN	Scaling Up Early Warning System in Nepal
SNC	Second National Communication
SNV	Netherland Development Organization
SPCR	Strategic Program for Climate Resilience
SRES	Special Report on Emission Scenarios
SRI	System of Rice Intensification
SWD	Solid Waste Disposal
SWM	Solid Waste Management

TAR	Third Assessment Report
TNA	Technology Needs Assessment
TU	Tribhuvan University
TWC	Technical Working Committee
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USAID	United States Agency for International Development
UV	Ultra Violet
VDC	Village Development Committee
VOCs	Volatile Organic Compounds
WASH	Water, Sanitation and Hygiene
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization
WWF	World Wild Life Fund

EXECUTIVE SUMMARY

(I) National Circumstances

Nepal occupies a land area of 147,181 sq. km with an average stretch of 885 km from east to west and width of 193 km from the north to south. Nepal exhibits a wide range of climatic conditions varying from tropical from the south to alpine/arctic in the north due to topographic extremes. The rainfall distribution pattern also varies considerably in both north-south and east-west directions. Nearly 80% of the annual rainfall occurs during summer monsoon. The population of Nepal has increased from 9.4 million in 1961, 23.3 million in 2001, to 26.5 million in 2011. The urban population is growing rapidly from 4% in 1971 to 13.9% in 2001 and is expected to reach 26.7% by 2021. This increasing urbanization increases new settlements even in highly vulnerable flood plains, landslide prone areas and along river banks. Only about 56% of the households in Nepal have access to electricity.

Nepal is one of the least developed countries of the world. Agriculture is the mainstay of the country's economy, which contributes nearly one-third to the Gross Domestic Product (GDP). Agriculture sector is also the base of livelihood of nearly 80% people and employs about 66% of the labor force of the country. Nepal Labor Force Survey, 2008 reveals that a total of 253 thousand persons aged 15 years and above are estimated to be currently unemployed in Nepal with an annual unemployment rate of 2.1% and an increase of 42% over the decade. Every year, a workforce of four hundred enters into the labor market. Nepal has made significant progress in reducing poverty. The percentage of population living below poverty line has dropped from 42% in 1995/96 to 31% in 2003/04 and to 25.4% in 2008/09.

Nepal heavily relies on traditional source of energy which is about 87% whereas the share of electricity and renewable energy is not significant. Agriculture land occupies about 21% of the total land, that is second to the forest in land use category, of which only 59% of the agriculture land (1.766 million ha) is irrigable. Nepal's transport sector is dominated by road transport. The number of vehicles is increasing rapidly that has reached 924,000 in 2009/10. Industry sector in Nepal is dominated by cottage, small and medium-size industries which contribute very low 7% to the national GDP. Forest occupies the largest part of the total land area of the country. Forest and shrub together cover 39.6% of the country's total land area but has decreased at an annual rate of 0.2% from 1978/79 to 1994. Nepal is rich in biodiversity. About 23.23% of the country's land is under protected area where many endemic species, protected species and endangered species are conserved. Nepal has abundant water resources with about 225 BCM of total average annual surface runoff from all river system in country but only about 15 BCM has so far been utilized. About 1350 tons of solid waste is generated daily in the country out of which 383 tons is generated by Kathmandu which is collected, transported and dumped on the public land by many municipalities.

(II) National GHG Inventory

The GHG Inventory for SNC provides information on Nepal's anthropogenic emission by sources and removal by sinks of direct GHG – viz. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) – and indirect gases – viz. NO_x, CO, NMVOC and SO_2 – covering the sectors of energy, industrial process, agriculture, land use, land use change and forestry (LULUCF), and solid waste for the baseline year 2000/01. The summary is presented as follows.

(A) Energy sector: Traditional and commercial energy sources are dominant in Nepal, which include fuel wood, animal waste, agricultural residue, and hydropower. Nepal predominantly depends on the fossil fuel for its energy requirements. Fossil fuel combustion oxidizes the carbon present in the fuel, resulting into the emission of CO_2. Some carbon is also released in the form of CO, CH_4, and non-methane hydro carbon which is oxidized to CO_2 in a decade. Other emission includes N_2O, SO_2, and black carbon.

The energy sector includes GHG emission from the combustion of fuels for the production of energy. The energy consuming sectors have been classified as follows: residential, commercial, transport, industrial and agricultural sector. The GHG inventory finds that about 71% of the total CO_2 equivalent emission from the energy sector in 2000/01 is from the fuel combusted in the residential sector for heating and lighting purposes.

The overall GHG emission from the energy sector is in increasing trend. According to the INC, the energy sector emitted 3266 Gg of CO_2 equivalent in the base year 1994/95. According to the GHG inventory, in the baseline year 2000/01, the energy sector in Nepal emitted 6894.64 Gg of CO_2 eq. Out of this, 2763.28 Gg was emitted as CO_2, 163.96 Gg as CH_4 and as 2.22 Gg as N_2O. The residential sector is the largest GHG emitter (71%) from energy use. The transport and industrial sectors each emitted about 12% of the total CO_2 equivalent emission in 2000/01. The remaining 5% GHG emission was from fuel combusted in the commercial and agricultural sector.

(B) Industrial process sector: The GHGs are mainly emitted during industrial production process which involves the chemical or physical transformation of raw materials into intermediate or final products. Since Nepal is not an industrialized country, the industrial process sector is a small source of GHG emission. In the GHG Inventory, emission has been worked out only for cement, lime and steel industries. Among the three major GHGs, only CO_2 has been estimated from these industries. In the baseline year 2000/01, CO_2 emission was estimated to be 130.86 Gg, with over 90% contribution coming from cement production.

(C) Agricultural sector: Agricultural production activities contribute directly to the emission of GHGs through enteric fermentation, manure management, rice cultivation, and soil management. Methane (CH_4) and nitrous oxide (N_2O) are the major GHGs emitted from the agricultural activities. The GHG Inventory for the SNC excludes savanna burning and histosols. The long term net emission of CO_2 from the burning of crop residues is considered to be zero.

In the baseline year 2000/01, the agriculture sector emitted a total of 18285.08 Gg of CO_2 eq., comprising of 470.08 Gg of CH_4 and 27.14 Gg of N_2O. Major source of CH_4 emission is from domestic livestock enteric fermentation and manure management which emitted 468.52 Gg of CH_4. Likewise, Direct nitrous oxide emission from agricultural fields, excluding cultivation of histosols totaled 13.26 Gg of N_2O (4110.6 Gg of CO_2 eq.), whereas nitrous oxide emission from animal production and animal waste management system contributed 7.65 Gg of N_2O (2371.5 Gg of CO_2 eq.).

(D) Land Use, Land Use Change and Forest (LULUCF) sector: Forests act as both sink and source for CO_2 emission. Since the growth rate of vegetation is largely responsible for sink, it is necessary to update the data. Deforestation and forest fire plays vital role in GHG emission from this sector. Other factors such as change in forest and other woody biomass stocks, forest and grassland conversion, abandonment of managed lands, carbon dioxide emission and removal from soil are also responsible for emission.

The GHG Inventory for SNC estimates that 8,062.35 kt dm of carbon (or 29561.95 Gg of CO_2) was removed from the atmosphere in 2000/01 due to biomass increment of forest and other woody biomass stocks. The inventory estimates that a total of 2386.28 tons of carbon was released from biomass burning, and a total of 1,039.48 kt C was released as 10-year average delayed emission

from decay. The sum is equivalent to 12,561.12 Gg CO_2. Likewise, the burning of cleared forest released 16.75 Gg of CH_4. CO_2 removal from biomass accumulation also occurs as a result of the abandonment of cultivated land and pasture. The inventory estimates that in 2000/01, 33.34 kt of carbon was accumulated from 13.4 k ha area of abandoned and re-grown land, which is equivalent to 122.55 Gg of CO_2. The inventory estimates an annual loss of 1186 Gg of carbon, which is equivalent to 4347 Gg of CO_2.

(E) Waste sector: Rapid urban growth in Nepal has resulted into increased volume of waste disposal, which is a prime source of methane emission. Domestic/commercial solid waste management system as well as domestic/industrial waste water handling practices influence GHG emission from the waste sector.

Emission in waste sector is a function of consumption rate and population. In the baseline year 2000/01, according to the GHG Inventory for SNC, the GHG emission from the waste sector in Nepal only accounted for 2.7% of the total national GHG emission. For the baseline year 2000/01, the GHG Inventory for SNC estimated total methane emission from solid waste and wastewater handling system at 16.74 Gg in which domestic and commercial solid waste disposal contributed 12.16 Gg (73%), and domestic and commercial wastewater handling contributed 3.33 Gg (20%). Methane emission from industrial wastewater handling was estimated at 1.25 Gg (7%).

The GHG emission from human sewage is N_2O. The conversion of ammonium-nitrogen (NH_4-N) to N_2O during nitrification and conversion of nitrate nitrogen (NO_3-N) to N_2O during de-nitrification is the result of the presence of nitrogen in human sewage. In the base year 2000/01, the estimated amount of N_2O emission from human sewage was 1.19 Gg and CH_4 emission was 1.19 Gg; the total turned out to be 720.44 Gg of CO_2 eq.

(III) Mitigation Measures

(A) Energy sector: Increasing plant efficiency; switching to lower-carbon fuels (for e.g., from coal to gas); reducing losses in the transmission and distribution of electricity and fuels; increasing the use of renewable energy (such as solar, hydropower, wind, and biomass energy); and early applications of Carbon Capture and Storage (e.g. storage of removed CO_2 from natural gas). Market-based instruments for GHG mitigation in the energy sector include GHG and energy taxes, cap-and-trade systems and subsidies for renewable energy. Regulatory measures consist of specifying the use of low carbon fuels, and setting performance and emission standards. Hybrid measures include tradable emission permits and renewable portfolio standards. Government funded research, development and demonstration activities are also vital in establishing a low-carbon energy supply sector.

(B) Industrial process sector: The main sources of CO_2 in cement manufacturing are combustion of fossil fuel and limestone calcinations. Approximately, half of the CO_2 emitted by the cement industry originates from the fuel, and half from the calcinations that convert raw materials into clinker. Applying different efficient technologies helps in achieving moderate reduction of GHG emission. Fuel switching should also be considered. Policy interventions are required to establish hydropower as main source of energy, promote energy efficient technology and establish Cleaner Production Centre, and implement Environment Management System (EMS).

(C) Agricultural sector: The mitigation measures suggested for reducing GHG emission in agricultural sector include decreasing the use of artificial fertilizer to minimize N_2O emission and improving cultivation methods (e.g., the no-till approach) to increase carbon storage in soil; establishing hay meadows with high- yielding fodder legumes and grasses under high nutrient supply condition to reduce grazing pressure on forests; increasing cropping intensity, organic farming, promotion of integrated soil fertility (crop intensification and diversification); improving

crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; increasing area under organic farming; improving traditional agricultural practices; establishing farmers' cooperatives that will oversee proper utilization of forage resources through monitoring of stock numbers, grazing duration and grazing time, nutrient management and shrub and weed control; and dedicated energy crops to replace fossil fuel use and improved energy efficiency.

Policies in the agricultural sector include market-based mechanisms such as offset programs and conservation easements, as well as regulatory measures in the form of incentives and taxes. Proper guidelines for farmers are also necessary that include appropriate farming practices, cultivation technologies, and livestock management.

(D) Land Use, Land Use Change and Forest (LULUCF) sector: There are three types of relevant activities that can be used to mitigate climate change: reducing GHG emission, increasing carbon sequestration, and carbon substitution. Carbon sequestration through afforestation/reforestation has received little attention in Nepal's forest sector as existing community forests are not eligible for the CDM under Kyoto Protocol – though if communities reforest or afforest on a degraded land this could be accepted by the CDM.

The recommended mitigation measures include reforestation, protecting existing forests, and substituting wood fuel with other fuels; afforestation, forest management to reduce deforestation; harvested wood product management; use of forestry products for bio-energy to replace fossil fuel use, and carbon sequestration by promoting healthy forests (including urban forestry) and natural open space.

Policies for forest protection and afforestation have to cover a wide range of areas including land tenure and ownership for small farmers. The use of incentive programs such as pay for conservation services, market mechanisms such as offset programs for sequestration projects, and enforcing bans on logging in protected areas.

(E) Waste sector: Mitigation measures in the waste sector include source reduction through waste prevention, recycling, composting, waste-to-energy incineration and CH4, capture from landfills and wastewater. Policies for waste minimization and GHG reduction include taxes on solid waste disposal (bag fees), market incentives (e.g. offsets) for improved waste management and recovery of CH_4, and regulatory standards for waste disposal and wastewater management (e.g., mandatory capture of landfill gas).

Specific mitigation options include use of 3R Principles; waste segregation, reduction at source; composting; anaerobic digestion for biogas; sanitary landfill sites with methane capture; healthcare waste management, proper statutory framework; public participation; private sector partnership; tax waiver for recycling enterprises; and financial management. Regulation is required to ban entry of recyclable waste in landfill.

(IV) Efforts to Reduce Vulnerability

(A) Agricultural sector: A number of efforts have been initiated by the Government of Nepal to reduce the vulnerability of climate change. These include: System of Rice Intensification (SRI); green manure; conservation tillage practices; use of plastic house and water sprinklers; sustainable agriculture soil and water conservation; slope stabilization and landslide control; rainwater harvesting, rangeland and forage improvement; cultivation on river beds and shrub land; livestock shed improvement; bio-energy; and adoption of biogas. These efforts are in initial stage and need further up-scaling along with other new initiatives.

Adaptation measures in the agricultural sector include development of drought resistant varieties; development and extension of agronomic practices; extension of soil and water conservation technologies; improvement in rangeland management and fodder production; reducing heat stresses in livestock; and disaster risk reduction.

(B) Water resources sector: Recommended adaptation measures include promoting adaptation through implementation of water induced disaster management policy and plan; community-level disaster preparedness program; GLOF monitoring and disaster risk reduction; empowering vulnerable communities through sustainable IWRM; develop and implement Watershed management policy and plan; integrated irrigation planning and management with agricultural development; improved management of existing irrigation systems and implementation of alternative irrigation techniques; development of year round irrigation in support of intensification and diversification of agriculture; improved ground water development/ management with legislative provisions; development of multipurpose cost effective storage projects; program to improve power system planning; and extension of hydrological and meteorological networks of DHM in Himalaya, Bhabar and Terai belts.

(C) Forestry and biodiversity sector: Government of Nepal has been initiating a number of efforts to reduce the impacts of climate change on forests and biodiversity. Various awareness raising programs have been launched. Community forest user groups are managing about 28.3% of total forest contributing to conservation of forest and biodiversity. The forest of 12 buffer zones has also been handed over to community user groups which is directly attributing to conservation and protection of endangered and protected wildlife. These community groups are also being supported by the government to formulate and implement appropriate adaptation action plan. Government has enlisted more wetlands in Ramsar list with a view to develop and protect these wetlands with priority.

Some recommended activities to cope with the changes in biodiversity and forest ecosystem include management of forests for protection of soil and conservation of water, with inclusion of socio-economic factors; preparation and implementation of forest fire management plan; monitoring of forest health through management of landscape-level ecosystem and corridor, improved ecological connectivity, restored ecosystem and species, and control of invasive species; landscape conservation providing more flexibility for species by ensuring horizontal and vertical connectivity to enable movement of species due to climate change; increased understanding of changes in habitat; emphasis on management of herbs; ex-situ conservation of threatened species; afforestation/reforestation and reduction of deforestation; improved protected areas in mountains; reduced anthropogenic stresses; provision of minimum flow water requirement in river for fish and aquatic species; and incentive for private landowner to join conservation talks; high altitude NTFP management; Terai wetland management; integrated forest management in Churia; forest management for water; high altitude range land conservation; management of birch forest to reduce encroachment by fir; and conservation of forests with lichens through reduce interference.

(D) Public health sector: The efforts from government to address climate and health issue have been very recent. Nepal Health Sector Program (NHSP-II) has addressed various environmental issues, including climate change and its impacts on the health of the people and other areas. Training manual for mainstreaming climate change and health issue from grassroots level to the district level has been prepared.

Adaptation measures at policy level against extreme weather heat wave and cold wave include implementation of housing standard; working environment standard; occupational safety; and effective surveillance mechanism. Likewise, policy measures against diarrheal disease include: implementation of WASH program throughout the country; enforcement of awareness program; monitoring and evaluation of WASH program; and water quality surveillance as per the National

Drinking Water Quality Standard 2005. Adaptation measures at policy level against vector borne disease include: integrated management plan for control of vector borne disease; enforcement for compliance with policy, acts and rules; and emphasis on surveillance of vectors and diseases.

(E) Climate change-induced disasters: National Adaptation Programme of Action (NAPA) has recommended a number of adaptation options for climate-induced disasters and selected two projects-community-based disaster management for facilitating climate adaptation, and GLOF Monitoring and Disaster Risk Reduction- to be implemented as a most urgent and immediate priority adaptation need of the country in order to reduce the impact of various types of disasters, including a number of adaptation options such as hazard/vulnerability mapping and zoning, strengthening of early-warning and forecasting system, enhancing capacity of governmental and non-governmental organizations, implementation of structural measures, promotion of afforestation and reforestation programmes and bio-engineering techniques, resettlement of vulnerable communities, among others.

Adaptation measures against climate-induced disasters include public awareness; improvement of degraded land; development of crops and promotion of agriculture practices; crop and livestock Insurance; implementation and promotion of water harvesting system and conservation ponds; conservation of Churia/Siwalik regions.

(F) Human settlement and infrastructure: Climate change impact on human settlement and infrastructure is primarily due to extreme weather changes than gradual climate changes (IPCC, 2007). Vulnerabilities to climate change depend considerably on specific geographic, sectoral and social contexts. Impacts on human settlements from climate change may be direct due to extreme events, as well as indirect through effects on other sectors like changes in water supply, agriculture productivity, and human migration (IPCC, 1996). Climate change may increase the vulnerability of infrastructure due to increased flooding and landslides. Detailed modeling of frequency and intensity of rainfall events in the context of global warming has been linked to increased intensity and frequency of flooding, with considerable damage to infrastructure (IPCC, 2001).

Adaptation measures include human settlement development strategy and policy with due consideration of climate change; improvement in settlement quality; resettlement plan for the vulnerable settlement; construction of modern infrastructures (such as roads, streets, avenues, boulevards and expressways); protection and conservation of built-up heritage and develop viewpoints over admirable landscapes; and infrastructure codes incorporating climate change dimension.

(G) Gender and social inclusion (GSI): Gender and Social Inclusion (GSI) is a cross-cutting issue, and thus should be embedded in all sectoral adaptation action plans. Therefore, separate action plan for GSI with budget has not been proposed in this study for SNC. However, considering the importance of GSI in adaptation to climate change, the sectoral adaptation plans should ensure the meaningful participation of women and socially excluded groups in the decision making in the meeting, campaign, training/workshop, interaction etc. as well as planning and implementation of adaptation activities.

(V) Other Issues

This study also includes discussion on technology development and transfer, research and systematic observation, and capacity development through education, training and public awareness. Likewise, the study has identified constraints and gaps in the climate change initiatives undertaken by the country, and assessed financial, technical and capacity needs to overcome obstacles for the coming days.

SNC PROJECT STEERING COMMITTEE

Secretary, Ministry of Environment (Chairperson)
Joint-Secretary, Office of the Prime Minister & Council of Ministers (Member)
Joint-Secretary, National Planning Commission Secretariat (Member)
Joint-Secretary, Water and Energy Commission Secretariat (Member)
Joint-Secretary, Ministry of Finance (Member)
Joint-Secretary, Ministry of Forests and Soil Conservation (Member)
Joint-Secretary, Ministry of Industry (Member)
Joint-Secretary, Ministry of Agriculture and Cooperatives (Member)
Joint-Secretary, Ministry of Labor and Transportation (Member)
Joint-Secretary, Ministry of Energy (Member)
Joint-Secretary, Ministry of Science and Technology (Member)
Joint-Secretary, Ministry of Law and Justice (Member)
Joint-Secretary, Ministry of Local Development (Member)
Joint-Secretary, Ministry of Education (Member)
Joint-Secretary, Ministry of Health and Population (Member)
Director General, Department of Hydrology and Meteorology (Member)
Representative, Nepal Academy of Science and Technology (Member)
Head, Central Department of Hydrology and Meteorology, Tribhuvan University (Member)
Executive Director, Alternative Energy Promotion Centre (Member)
President, NGO Federation Nepal (Member)
Representative, FNCCI (Member)
Chief Executive Officer, DDC Association (Member)
Prof. Dr. Pramod K. Jha, Ecologist, Central Department of Botany (Member)
Joint-Secretary (Technical) and Chief, Climate change Management Division, Ministry of Environment (Member-Secretary)

NATIONAL CLIMATE CHANGE COMMITTEE

Joint-Secretary (Technical and Chief), Climate Change Management Division, Ministry of Environment (Chairperson)
Under-Secretary (Technical), Department of Forests (Member)
Under-Secretary (Technical), Department of Transport Management (Member)
Under-Secretary (Technical), Department of Agriculture (Member)
Under-Secretary (Technical), Department of Livestock Services (Member)
Under-Secretary (Technical), Department of Industry (Member)
Under-Secretary (Technical), Department of Hydrology and Meteorology (Member)
Under-Secretary (Technical), Department of Electricity Development (Member)
Project Manager/Project Personnel of the Climate Change Projects Conducted by Government of Nepal (Member)
Under-Secretary (Technical), Department of Building Construction and Urban Development (Member)
Representative (Technical), Nepal Agriculture Research Council (Member)
Representative (Technical), Nepal Health Research Council (Member)
Representative (Technical Officer), Nepal Academy of Science and Technology (Member)
Chief, Climate Change and Carbon Unit, Alternative Energy Promotion Centre (Member)
Representative (Technical), Nepal Electricity Authority (Member)
Representative (Professor), Central Department of Environment Science, Tribhuvan University (Member)
Representative (Professor), Centre for Energy Studies, Institute of Engineering (Member)
Representative (Professor), Department of Environment Science, Kathmandu University (Member)

Executive Director, Municipality Association (Member)
Executive Director, VDC Association (Member)
Joint-Member, NEFEJ (Member)
Chief Executive Office, Forest Action (Member)
Representative, Clean Energy Bank (Member)
Representative, ICIMOD (Member)
President, Society of Hydrologist and Meteorologist (Member)
Chief, WINROCK International (Member)
Chief, Biogas Support Program (Member)
Representative, Independent Power Producer Association, Nepal (Member)
Mr. Purna B. Shrestha, Freelance-Expert and Ex-deputy Director General, Department of Hydrology and Meteorology (Member)
Mr. Govinda Tiwari, Freelance Expert (Member)
Dr. Prahlad K. Thapa, Economist, CECI Nepal (Member)
Under-Secretary, CCCSS (Member-Secretary)

SNC PROJECT TEAM

Mr. Ram Prasad Lamsal, Joint Secretary (Technical) and Chief Climate Change Management Division and National Project Director
Mr. Ritu Pantha, Director and National Project Manager
Mr. Sujan Subedi, Meteorologist and Program Officer
Ms. Karuna Adhikaree, Climate Change Officer
Ms. Sabita Niroula, Account Officer
Mr. Binaya Joshi, Former Assistant Climate Change Officer
Ms. Deepika Ghimire, Assistant Climate Change Officer
Ms. Laxmi Adhikari, Messenger

PEER REVIEW EXPERTS

Mr. Shiva Prasad Nepal, Senior Divisional Meteorologist, Department of Hydrology and Meteorology
Mr. Jeebachh Mandal, Senior Divisional Engineer, Ministry of Energy
Mr. Kedar Man Prajapati, Senior Divisional Engineer, Ministry of Urban Development
Ms.Ramita Manandhar, Senior Horticulture Development Officer, Ministry of Agricultural Development
Mr.Govind Bahadur Shrestha, Under-Secretary (Technical), Ministry of Forests and Soil Conservation
Mr. Alok Kumar Mishra, Under-Secretary (Technical), Ministry of Industry
Mr. Chakra Pani Sharma, Under-Secretary, Ministry of Federal Affairs and Local Development
Dr. Ganesh Raj Joshi, Former Secretary, Ministry of Science, Technology and Environment

Chapter 1

National Circumstances

1.1 Country Profile

1.1.1 Topography

Nepal occupies a total land area of 147,181 sq. km. It lies between 26^0 22' and 30^0 27' N latitudes and 80^0 04' and $88^0$12' E longitudes with an average stretch of 885 km from east to west and width of 193 km from north to south (NPC, 2010c). The country elevates from the 60 m above mean sea level in the south up to 8848 m above mean sea level, the highest peak of the world, Mt. Everest, in the north.

The country can be divided into five physiographic regions, namely i) The High Himal, almost always covered with snows, in the north with 24% area of the country ii) the High Mountains with 20% area, iii) Middle Mountains with 30% area, iv) The Siwaliks (Churia) with 12% area and v) the Terai (low lying plain areas), the northern extension of the Indo-Gangetic plain, in the south with 14% area of the country and having a width ranging from 26 to 32 km (Figure 1-1).

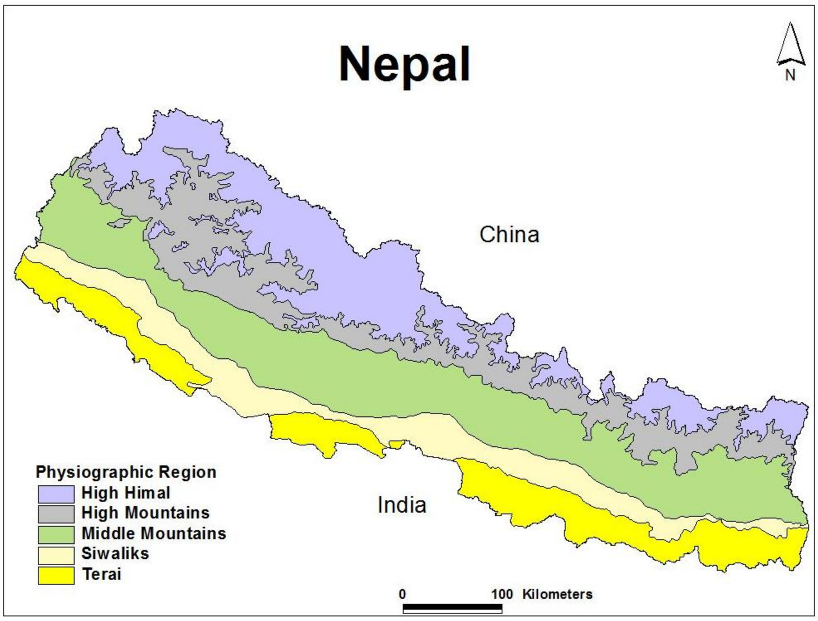


Figure 1-1: Nepal's physiographic regions

1.1.2 Climate

Nepal lies within a subtropical monsoon climate zone. Although locating near the northern limit of the tropics, due to topographic extremes from less than 100m to above 8000m within a short span of less than 140 km, Nepal exhibits a wide ranging climatic conditions varying from tropical in the south to alpine/arctic in the north. The alteration of southeast monsoon originating in the Arabian ocean (June to September) and westerly disturbance originating in the Mediterranean (December to February) also greatly contribute to local variations in climate. In general the physiographic setting of the country roughly corresponds to the climatic zoning (Table 1-1).

Table 1-1: Climatic division of Nepal

Physiographic zone	Elevation (m)	Climate
High Himal	above 5,000	Tundra-type & Arctic
High Mountains	4,000-5,000	Alpine
	3,000-4,000	Sub-alpine
Middle Mountain	2,000-3,000	Cool temperate monsoon
	1,000-2,000	Warm temperate monsoon
Siwalik Hills	500-1,000	Hot monsoon & Subtropical
Terai	below 500	Hot monsoon & Tropical

Based on the temporal variation in the weather system (monsoon and westerly disturbance) the country's weather could be divided into four distinct seasons in a year, namely pre-monsoon (March to May), monsoon (June to September), post-monsoon (October to November) and winter (December to February).

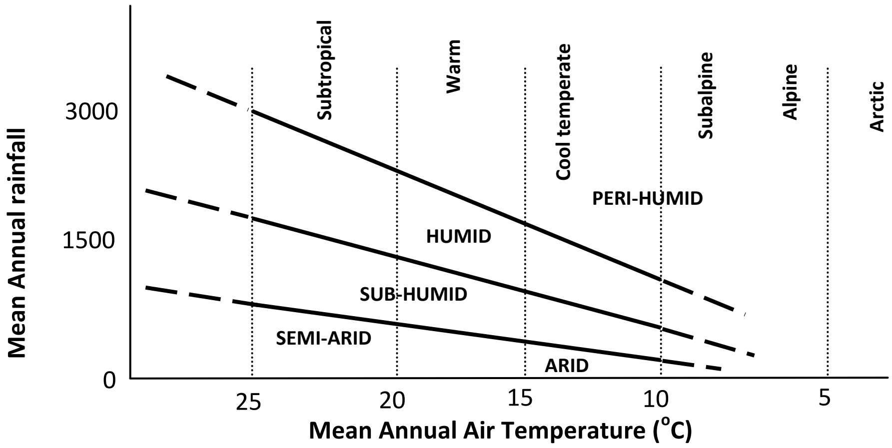


Figure 1-2: Temperature and precipitation dependent climatic condition (LRMP 1986)

The average rainfall of the country is about 1530 mm. However, there are sharp spatial and temporal variations in rainfall owing to the great variation in topography. Annual rainfall generally increases with elevation up to 3000 m, there after decline with elevation and latitude (Figure 1-2). The rainfall distribution pattern also varies considerably in both north-south and east-west directions (Figure 1-3).

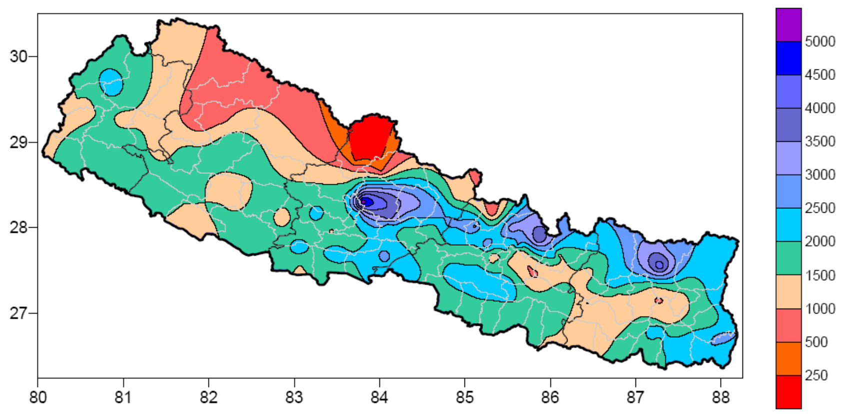


Figure 1-3: Annual mean rainfall distribution

Source: Society of Hydrologists and Meteorologists-Nepal, 2007. Note: Average of 30 years data (1976-2005) of monthly rainfall from 166 stations.

Nearly 80% of the annual rainfall occurs in the month of June through September due to the influence of the summer monsoon circulatory system and the rest in winter. The monsoon rain is more intense in the east and gradually decreases towards western part of the country, while the winter rain is more in the north-westward and less in the south-east part of the country. No specific trend has been observed through analysis of precipitation data from station records all over Nepal.

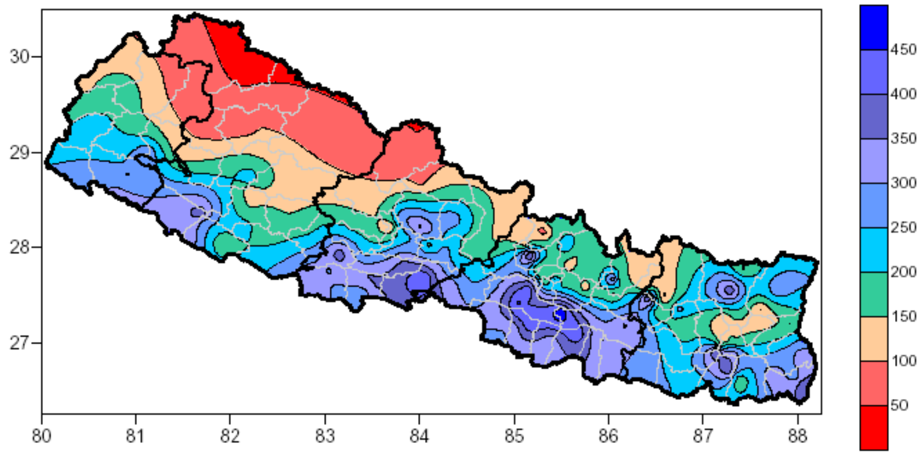


Figure 1-4: Extreme 24 hours rainfall (mm) distribution

Source: Society of Hydrologists and Meteorologists-Nepal, 2007

It has been observed that frequency of high intensity precipitation event (precipitation more than 100 mm within 24 hours) is increasing. The extreme rainfall distribution analysis based on 30 years data (1976 -2005) is quite different from the annual or seasonal distribution-Churia/Siwalik and the Terai Physiographic Regions receive lower total seasonal rainfall but with the highest 24 hour rainfall (Figure 1-4). Maximum and minimum of 24 hour extreme rainfall was recorded in Hetauda (482.2 mm) and Mustang (51mm) respectively. The highest extreme rainfall is observed mainly in the foothills of Chure/Siwalik Physiographic Region in the Central and the Western Nepal. The extreme 24 hours rainfall in Nepal are usually associated with floods in the Terai Physiographic Region and small to large scale mass wasting in the Chure/Siwalik, Middle Mountain and High Mountain Physiographic Region. The trend of such extreme rainfall is observed during the middle of monsoon.

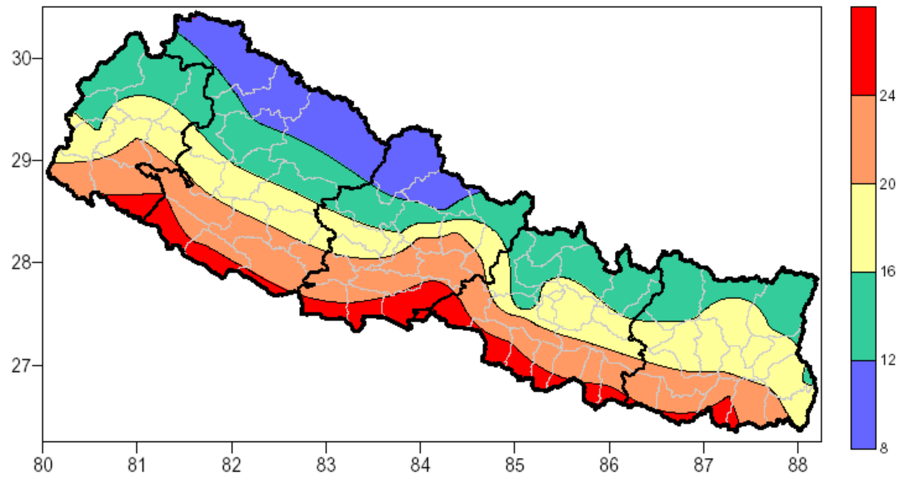


Figure 1-5: Spatial variation of mean annual temperature

Source: Society of Hydrologists and Meteorologists-Nepal, 2007

The spatial variation of mean annual temperature is influenced by the physiographic setting of the country (Figure 1-5). In general, temperature decreases gradually from south to north with the increasing altitude. The winter season (December to February) is the coldest season. Maximum temperature of the year occurs in May or early June. With the withdrawal of the monsoon, the temperature starts declining throughout the country.

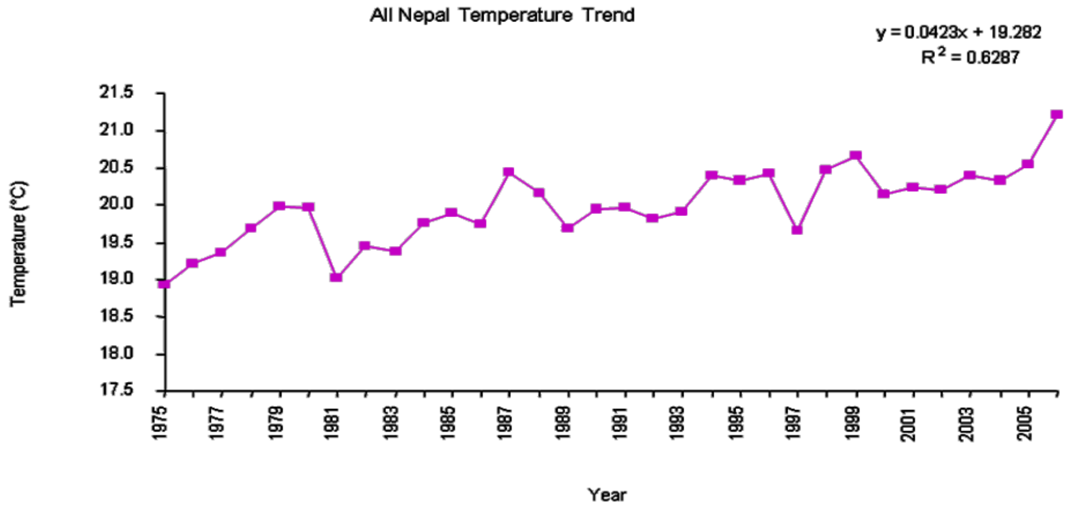


Figure 1-6: All Nepal temperature trend (1975-2006)

Source: Department of Hydrology and Meteorology

1.1.3 Social Condition

Demography: Nepal is a multi-ethnic, multi- lingual and multi-cultural country. Nepal's population comprises over 100 ethnic groups, who speak 92 languages. About 81.3% of the population are Hindus with 9.0% Buddhists, 4.4% Muslim, 3.1% Kirant and the rest other religions (CBS, 2011). Nepal's population has increased a little below threefold over the period of five decades, from 9.4 million in 1961, 23.3 million in 2001, to 26.5 million in 2011. As of 2011, about 83% of the population lives in rural areas and the rest live in the urban areas. The urban population is growing rapidly from 4% in 1971 to 13.9% in 2001 and is expected to reach 26.7% by 2021.

Table 1-2: Population and growth rate

Year	1961	1971	1981	1991	2001	2011
Population (millions)	9.4	11.6	15.0	18.5	23.2	26.5
Annual Growth Rate	1.65	2.07	2.66	2.09	2.24	1.35

Source: National census data of relevant years, Central Bureau of Statistics

Public Health: Nepal has made significant progress in the health sector over the past decades. Health indicators such as life expectancy, maternal mortality, and infant and child mortality have shown gradual improvement (Table 1-3). Life expectancy at birth is estimated at 67.5 years as of 2009. Infant mortality ratio (IMR) per 1000 live births has declined from 108 in 1990 to 41 in 2009. Similarly, under 5 child mortality has also reduced from 162 in 1990 to 50 in 2009 (NPC 2010). Maternal mortality ratio (MMR) has also significantly decreased; a MMR of 850 per 100 thousand live births in 1990 has reduced to a ratio of 229 per one thousand live births in 2009.

Table 1-3: Basic health indicators of Nepal

Health indicator	1951	1990	2009
Life expectancy (year)	28		67.5

Health indicator	1951	1990	2009
Under 5 yr. child mortality		162	50
IMR/1000 LB	255	108	41
MMR/100,000 LB		850	229

Source: NDH (2011), NPC (2010), Dixit (1999)

Health care system in Nepal is based on primary health care (PHC) which was adopted after Alma Ata Declaration (WHO, 1978). The government has set a target to provide health service to 100% citizens within 30 minutes of walking distance against the present figure of about 62%. This health accessibility pattern is varied remarkably among the three ecological regions (Table 1-4).

Table 1-4: Distribution of households by time taken to reach the nearest health post

Ecological Regions	% of households				
	Up to 30 minutes	30 minute to 1 hour	1-2 hours	2-3 hours	3 hours+
Mountain	37.3	26.6	25.8	7.8	2.8
Hill	50.9	21.2	17.7	6.1	4.2
Terai	76.2	15.0	7.8	0.9	0.2
Nepal	61.8	18.6	13.6	3.7	2.2

Source: NLSS (2004)

The average health service density at the national level is 1 in 33 square km. The coverage is relatively better in the Terai region than other two regions (Table 1-5). Due to rugged topography, the health service coverage in the mountain region is only 1 in 57 square km.

Table 1-5: Distribution of health services by ecological regions

Regions	Distribution of Health Services		Area covered by one health service (km^2)
	Number	%	
Mountain	620	13.9	57
Hill	2,323	52.3	31
Terai	1,503	33.8	27
Nepal	4,446	100	33

Source: NLSS (2004)

The most common diseases in Nepal defined in terms of total new outpatient department (OPD) visits as a percentage of the total population are as follows: i) intestinal worms; ii) ARI/lower respiratory tract infection; iii) pyrexia of unknown origin (PUO); iv) gastritis; v) headache (migraine); vi) upper respiratory tract infection; vii) amoebic dysentery; viii) diarrhea; ix) falls/injuries/fractures; and x) pneumonia (DOHS, 2010). However, the position of the major diseases among the three physiographic regions is not the same. For instance, worm infestation has occupied top position in the mountain, while ARI and gastritis have occupied top position in hill. In Terai, pyrexia of unknown origin is among the top ten diseases.

Human settlement and infrastructure: Though Nepal has done relatively well in providing safe drinking water and sanitation services to the public, only about 80% of the population has received basic drinking water service with only about 10.5% medium to high level of the service (NPC, 2011). Frequent interruption in the water supply and a large deficit of the drinking water, particularly in the cities, are quite common.

Out of the total irrigable land of Nepal (i.e. 1766000 ha), only about 70% has been irrigated (including both seasonal and year round) so far. Likewise, although the total length of the road in

Nepal has reached about 20,000 km, only about 8000 km can be used year round. There is no policy in place yet for proper planning of sustainable solid waste management in Nepal to address rapidly growing urbanization. New settlements are being developed even in highly vulnerable flood plains, landslide prone areas and along river banks. Generally, low income groups and poorer families are migrating from hills to these highly vulnerable areas in search of economic opportunities, better life and modern facilities without proper consideration of potential risks of natural disasters.

Nepal has around 46,000 MW of commercially viable hydropower potential, but it has so far developed only about 700 MW. Only about 56% of the households have access to electricity (NPC, 2011). Due to the monsoon dominated river runoff and majority of the hydropower plants being run-of-river type, only about one third of the total installed capacity of the hydropower can be generated during dry seasons. There is no integrated electrification plan of the country. The number of new households connected to the grid has been increasing at about 10% annually (NEA, 2011) without having significant additional generation input into the grid system.

1.1.4 Economic Condition

Agriculture is the mainstay of the country's economy, which contributes nearly one-third to the Gross Domestic Product (GDP). Nepal has adopted liberal economic policy since 1990 and poverty reduction has been the main objective since the Ninth Five-year Plan (1997-2002). The recently completed Three-Year Plan (2010-2013) also aimed to reduce existing poverty, unemployment and inequality in the country (NPC, 2010). Public, cooperative and private sectors are considered as three pillars of the economy.

Table 1-6 provides time-series data on key economic indicators. The country's economy is characterized by low economic growth which stands about 3% on an average for a decade and has been a major challenge in the economic development of the country. The recently completed Three-year Plan envisaged attaining an economic growth of 5.5% per annum. The GDP of the country for the year 2010/11 was estimated at NRs 10751 million and annual per capita GDP estimated at NRs 41851 (US$ 568) (MOF, 2010). The country has enormous potential for raising GDP through tapping opportunities available in the areas of agro-processing and high value herbs processing industries, tourism, hydropower, education and health.

Table 1-6: Economic indicators

Indicators	1990/91	1995/96	2000/01	2005/06	2009/10
GDP (Current) (Million US$)	3063	4773	5354	9060	15761
Population (Million)	18.5	20.7	23.2	25.88	28.04
Exchange Rate (NRs/US$)	37.9	50.45	74	72.26	74.46
GDP Per Capita (Current) US$	166	230	231	350	562

Source: Economic Survey, FY 2009/10, Ministry of Finance.

Nepal has made significant progress in reducing poverty in the last decade. The share of population below poverty line (with income less than 1$/day) has dropped from 42% in 1995/96 to 31% in 2003/04, and to 25.4% in 2008/09 (NPC, 2010). However, population living under poverty line is estimated to be approximately 55% if calculated on the basis of the international poverty line (US$ 1.25/day).

Table 1-7: Poverty measures for Nepal

Region	Headcount Poverty Index (%)			Poverty Gap Index (%)		
	1995/1996	2003/04	2008/09	1995/1996	2003/04	2008/09
Nepal	41.76	30.85	25.39	11.75	7.55	6.10
Urban Area	21.55	9.55	7.63	6.54	2.18	1.70

Region	Headcount Poverty Index (%)			Poverty Gap Index (%)		
	1995/1996	2003/04	2008/09	1995/1996	2003/04	2008/09
Rural Area	43.27	34.62	28.54	12.14	8.50	6.89

Source: Poverty Measure Exercise and Number of Poor in Nepal, NPC, 2010

Nepal Labor Force Survey, 2008 reveals that a total of 253 thousand persons aged 15 years and above are estimated to be currently unemployed in Nepal (at an unemployment rate of 2.1%), an increase of 42% over the decade (CBS, 2009). Every year a workforce of four hundred thousand enters into labor market that seeks foreign employment as there is less employment opportunities in the country. Remittance has been a major source of foreign currency and amounts to almost 21% of GDP. About 30% of the households have received remittances. Nepal has been receiving foreign aid since the launching of first five year plan (1956-61). The share of foreign aid in GDP was 3.58% in 2007/2008, whereas its share in total government expenditure and development expenditure was 18.16% and 54.75% in 2007/2008 respectively. Nepal's external debt stock was estimated at 30.5% of GDP in 2008 (NPC/UNDP 2010).

1.1.5 Energy

Nepalese economy heavily relies on traditional source of energy. The share of traditional (conventional) source is 87% whereas the share of electricity and renewable energy is insignificant. Of the total traditional energy consumption, firewood still remains as the main source of fuel for cooking for a little over two thirds of the households (68.4%), followed by LPG (12.3%), cow-dung (10.7%), leaves/straw (4.3%), bio-gas (2.4%), kerosene (1.4%) and other sources (0.5%). In rural areas 75% household use firewood in contrast to 36% household in urban areas in 2007 (CBS 2009). LPG is the main source of cooking in urban areas.

Table 1-8: Consumption of energy

(in thousand ton of oil equivalent)

Source	1990/91	1995/96	2000/01	2005/06	2008/09
Conventional:	5576	6185	6824	7698	8185
Firewood	4980	5525	6068	6862	7301
Agricultural residues	224	248	299	329	344
Cow dung	372	412	457	507	540
Commercial:	349	651	1016	1093	1147
Coal	42	72	174	243	181
Petroleum Product	257	507	734	686	775
Electricity	50	72	108	164	191
Renewable	4	10	29	53	64
Total	5929	6846	7869	8844	9396

Source: Economic Survey, MOF, 2010

The consumption of energy is increasing every year due to increased economic activities and population growth. A little more than half (56.1%) of households have access to electricity for lighting and 33% of households still use gas/oil/kerosene for lighting. Out of 3915 Village Development Committees (VDCs), only 2100 VDCs are connected to the national electricity grid. The country is facing acute power shortage in recent years, particularly in winter season when load shedding may stretch up to 14 hours a day.

Nepal has high potential in terms of availability of untapped renewable energy such as hydropower and solar power and high availability of biomass for use as fuel. There are opportunities to Nepal for switching of fossil fuel based generation to renewable energy, and fossil fuels to biomass based power generation (Joshi, 2012). Nepal can pursue the sustainable and low-carbon energy path as a meaningful effort towards reducing emissions, though its share to global emission is insignificant.

1.1.6 Agriculture

Agriculture is the most important sector in Nepal's economy in terms of income generation, employment and food security. It contributes about 35% to the GDP and employs about two-thirds of the economically active population (NPC, 2010c). Moreover, rice, wheat and maize account for about 35% of agricultural GDP (AGDP) and other crops contribute 15%, livestock 26%, horticulture 17% (including fruits and vegetables) and fisheries 2% (NARC, 2010) and rest by the forests and other minor products.

Rice is the main staple food in Nepal. The area under cereal crops in different physiographic regions are presented in Table 1-9. Terai, the southern plain, is the main area for growing rice and wheat. Maize is planted less in Terai region partly due to preference for rice consumption and the favorable production system.

Table 1-9: Area under major crops by physiographic regions (1000 ha)

Region	Paddy	Wheat	Maize	Millet	Buckwheat	Barley
Mountain	66.71(4.46)	52.12 (6.79)	98.53 (10.87)	53.88 (19.99)	3.12 (30.29)	14.15 (49.72)
Hills	407.04 (27.20)	265.44 (34.58)	623.18 (68.76)	206.34 (76.47)	4.91 (47.67)	13.06 (45.89)
Terai	1022.73 (68.34)	449.95 (58.62)	184.55 (20.36)	9.60 (3.56)	2.27 (22.04)	1.25 (4.39)
Nepal	1496.48 (100)	767.51 (100)	906.26 (100)	269.82 (100)	10.3 (100)	28.46 (100)

Source: MOAC, 2011. Note: Figures in parentheses are percent to the total.

Agriculture land is second to the forest in land use category that occupies about 21% of the total land, of which only 59% of the agriculture land (1.766 million ha) is irrigable and less than one-third has round-the-year irrigation. About 40% of the arable land is still rain-fed; hence, the agriculture production is largely dependent on weather condition.

Agriculture is the major source of income and employment (65%). Agriculture productivity has not kept pace with population growth; the country is experiencing the situation of food deficit more frequently. About 41, out of 75 districts of Nepal are considered food deficit districts estimating about 300,000 MT of food deficit in the year 2008/09 (MOAC, 2009). Nepal is at the 16th position out of 31 highly food deficit countries in the world, which require emergency assistance (FAO, 2009). There is hardly any scope to expand the agricultural land to meet the food requirements of the growing population except intensification of agriculture and increasing productivity of cereal crops.

With low productive traditional agriculture, mainly for subsistence agriculture, diversification and commercialization have drawn attention of the planners and policy makers in terms of generating more income, employment opportunities, and biodiversity conservation. The Government of Nepal has been implementing a 20-year Agriculture Perspective Plan (APP) since 1997 with a view to commercialize agriculture, develop overall economy and alleviate poverty. This plan has identified priority inputs and outputs for consolidated investment in order to commercialize agricultural sector. High value horticultural commodities and agriculture business are priority outputs of APP. It has also proposed to establish strong forward and backward linkages of agricultural production. As focused by the APP, commercialization of agriculture and thereby increasing production and income of farmers is the main strategy of Three Year Plan (2011-2013).

1.1.7 Transport

Being a landlocked country, Nepal's transport sector is dominated by road, followed by air transport. The number of vehicles has reached 924,000 as of FY 2009/10, and is increasing rapidly. The quality of public transportation is very weak because of which the number of private vehicles is on the rise. On the other hand, vehicular emissions are also rising because of which air pollution is becoming a critical environmental problem in cities.

1.1.8 Industry

Nepal is still at low level of industrialization. The share of this sector in national GDP is only around 7%. Industrial sector is dominated by cottage, small and medium-sized industries. There are very few large industries in the country. The major industries that are in operation in the country are sugar, cigarette, beer, cement, jute, shoes etc. Many of these industries are using old technologies, and are not very energy efficient. It is very difficult and challenging for Nepalese products to compete with Indian and Chinese products in terms of price and quality. Hence, most of the essential goods are imported from other countries. The disposal of industrial wastes into rivers without treatment is emerging as a major environmental problem.

1.1.9 Forestry

Nepal has 4.27 million ha (29%) of forests, 1.56 million ha (10.6%) of shrub land and degraded forest, 1.7 million ha (7%) of grassland, 3 million ha of agricultural land (21%) and about one million ha (7%) of uncultivated land. There are 17685 community forest users groups managing almost 1.65 million hectares of total forest area (Ministry of Forest 2012). Likewise, a total of 4,194 leasehold forest user groups are managing 23,423 hectares of leasehold forest (MOF, 2010).

Using district-level data (e.g. forest area, shrub area) and crosschecking with national level statistics, Nepal's forests can be classified into the following types: (a) tropical wet, (b) tropical moist with long dry season, (c) tropical dry, (d) montane moist, and (e) montane dry (see Figure 1-7).

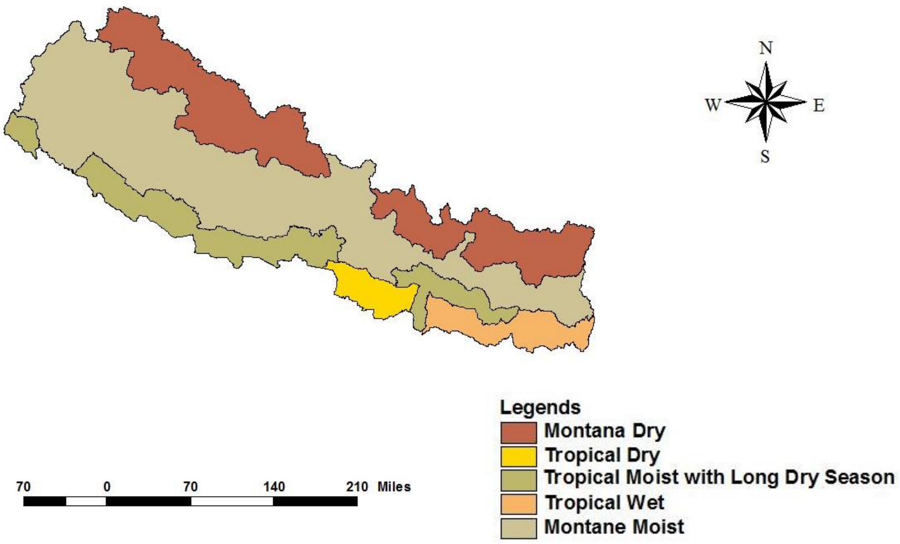


Figure 1-7: Forest types of Nepal according to IPCC (1996) defined criterion

Forest is one of the most important resources and occupies the largest part of the total land area (39.6%) of the country and is still a major source of fuel wood (over 80% of the energy consumption).

Comparing Forest Resources Information Survey Inventory (DFRS 1999) with forest area inventory conducted by Land Resource Mapping Project in 1978/79, the forest area has decreased at an annual rate of 1.3% in terai and 2.3% in the hills. On the contrary, the shrub area has increased during that time. In total, the forest/shrub area has decreased at an annual rate of 0.2% from 1978/79 to 1994 (DFRS 1999).

Table 1-10: Status of forest and shrub lands

Cover Type	Unit	Years		
		1978	1986	1994
Forest	Area (000 ha)	5616.8	5504.0	4268.0
	Percentage	38.0	37.4	29.0
Shrub	Area (000 ha)	689.9	706.0	1560.0
	Percentage	4.7	4.8	10.6
Total	Area	6306.7	6210.0	5828.0
	Percentage	42.7	42.2	39.6

Source: Synthesis Report: Forest and Biodiversity, 2010

1.1.10 Biodiversity

Although Nepal is a very small country, it has significant share of the total global biodiversity due to its unique geographical and altitudinal variations resulting in a great diversity in climate within a short distance of 193 km in average from south to north. Nepal has 118 ecosystems, 75 vegetation types and 35 forest types and is characterized by a high number of floral and faunal diversity (Table 1-11). Majority of the ecosystem are reported to be found in the mid mountains (52 ecosystems) and in the high mountains (38 ecosystems) (MOEST, 2008). Out of these ecosystems, 80 ecosystems exist in the present protected area system. About 23.23% of the country's land is assigned as protected areas which include 10 national parks, three wildlife reserves, one hunting reserve, six conservation areas and 12 buffer zones contributing a lot in biodiversity conservation.

Of the total species of floras and faunas, 350 species of floras and 160 species of faunas are endemic to Nepal, 18 plant species and 39 animal species (mammals-27, bird species-9 and reptile species-3) have been identified as protected species and a number of species have been listed as endangered species.

Table 1-11: Species diversity of main fauna and flora in Nepal

Faunal Diversity		Floral Diversity	
Group	Number of Species	Group	Number of Species
Mammals	181	Angiosperm	5856
Birds	852	Gymnosperm	28
Reptiles	100	Bryophyte	853
Amphibians	43	Pteridophyte	380
Fish	182	Fungi	1822
Butterflies	640	Lichens	465
Moths	2253	Algae	687
Spiders	144		
Total	4395		10091

Source: Synthesis Report: Forest and Biodiversity, MOE, 2010

Nepal has also high agro-biodiversity. Crops such as rice, rice bean, egg plant, buckwheat, soybean, fox-tail millet, citrus and mango have genetic-diversity compared to other food crops. Crop species in Nepal owe their variability to the presence of about 120 wild relatives of the commonly cultivated food plants. A great diversity of indigenous livestock breeds in Nepal has also been found. Breeding of aquatic animals is also gaining ground.

The contribution of forest to national GDP is about 9%. Forest Act, 1993 classifies forests into government managed forests, protected forests, community forests, leasehold forests, religious forests and collaborative forests. Out of 39 life zones categorized by Holdridge (1967), Nepal has 15 types of life zones under existing condition. These life zones are: tropical moist, tropical dry, tropical wet, sub-tropical 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.

1.1.11 Water Resources

Water is regarded as the key strategic natural resources having the potential to be the catalyst for all round development and economic growth of the country. Nepal is endowed with abundant water resources from the availability point of view. There are about 6000 rivers and rivulets draining from north to south towards Ganges (Figure 1-8). There are 33 rivers having their drainage areas exceeding 1000 sq km. Drainage density expressing the closeness of spacing of channels is about 0.3 km per sq km.

Rivers in Nepal can be typically classified into three types depending on their source and discharge. The first type of rivers is large rivers that originate in the Himalayas and carries snow-fed flows with significant discharge even in the dry season. The second type of rivers are Babai, West Rapti, Bagmati, Kamala, Kankai and Mechi rivers, which are the medium type that originate in the Midlands or the Mahabharat range.

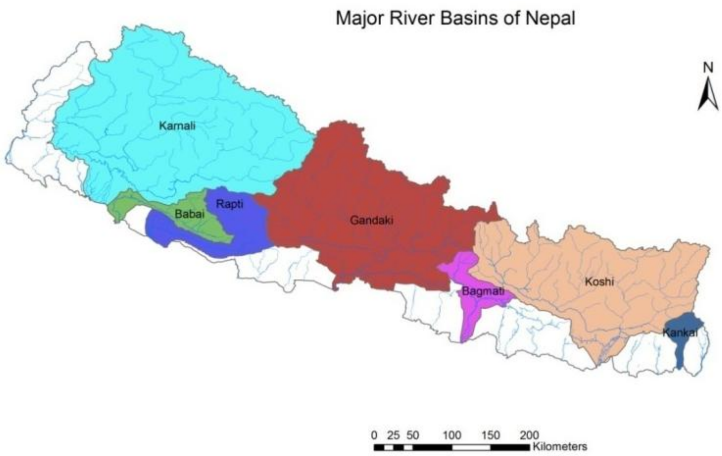


Figure 1-8: Major river basins of Nepal

The total average annual surface runoff from all these river systems is estimated at about 225 billion cubic metres (BCM) or equivalent to an average flow of 7,125 m^3/ s, only about 15 BCM has so far been utilized for economic and social purposes (WECS, 2005). Of which, 95.9% has been used for agriculture, about 3.8% for domestic purpose, and only 0.3% for industry (ADB/ICIMOD, 2006). Although, steep topography and high speed run-off offer great opportunities to generate hydropower, only about 700 MW of electricity has been generated out of 46,000 MW as economically/commercially feasible.

It is seen that around 78% of the average flow of the country is available in the four major basins, 9% in the medium basins and 13% in the numerous small southern rivers of the Terai (Table 1-12). As the southern slopes of the Mahabharata, Himalayan range and the eastern two-third of the country receive the maximum precipitation, there is more contribution of flow from these catchments. About 74% of the total annual surface flow occurs in the four months of June – September. In comparison, 42% of the population resides in the major basins, 18% in the medium and 40% in the Terai region covered by the Southern rivers (WECS, 2011).

Table 1-12: Estimated runoff from the rivers of Nepal

S.N.	River	Length (km)	Drainage Area (km^2)		Estimated Runoff (m^3/sec)	
			Total	Nepal	From all Basins	From Nepal
1	Mahakali	223	15,260	5,410	730	260
2	Karnali	507	44,000	41,550	1440	1360
3	Babai	190	3,270	3,270	95	95
4	West Rapti	257	6,500	6,500	160	160
5	Narayani	332	34,690	30,090	1820	1570
6	Bagmati	163	3,610	3,610	180	180
7	Sapta Kosi	513	60,400	28,140	1670	780
8	Kankai	108	1,575	1,575	83	83
9	Other River		21,432	21,432	851	851
	Total		1,91,007	1,41,577	7029	5339

Source: WECS, 2002

Existing water use: Although Nepal has 225 billion cubic metres (BCM) of water available annually, only a small part of it (estimated at 15 BCM) has so far been utilized for economic and social purposes. Out of which 95.9% has been used for agriculture, 3.8% for domestic purpose and only about 0.3% for industry (ADB/ICIMOD, 2006). Until now, Nepal has utilized mainly medium and small rivers for different uses such as drinking water, irrigation and hydropower. The larger and perennial Himalayan Rivers, except for a few run-of- the-river schemes, have been virtually left untapped. Since there is extreme seasonal variation in water availability in the Nepalese rivers, all future programs will have to focus on storage of water during the rainy season and its utilization during dry periods.

Irrigation potential and development: Irrigation is the largest water use sub-sector affecting the life of many people involved in agriculture. Irrigation has been given due importance in yearly and five year national development plans. Given the importance of irrigation and large investments already made and planned for the future, the effectiveness of water delivery and its ultimate sustainability are of major concern.

Hydro-power development: Hydropower is one of the main sources of energy in Nepal. It accounts for nearly 90% of installed capacity and 95% of total generation of energy. Except for firewood, biomass fuel and hydropower, Nepal has to import all other types of energy paying hard currencies while being extremely rich in water resources. The estimated hydropower potential of Nepal is 83,000 MW of which 114 projects having 45,610 MW have been identified as commercially feasible.

The Integrated Nepal Power System (INPS) is primarily managed by Nepal Electricity Authority (NEA). At present, NEA has a total installed electricity generation capacity of about 689 MW, of which the hydropower capacity is 632 MW. In addition, some hydro-power projects are scheduled to be commissioned. These include the 309-MW Upper Tamakoshi, 60-MW Upper Trishuli A, 37-MW Upper Trishuli B, 128-MW Upper Trishuli and 14-MW Kulekhani III among others.

The country hopes to bring about hydropower development through three strategic considerations, which include building large-scale storage projects envisaged primarily for exporting energy, medium scale projects for meeting national needs and small-scale projects for serving local communities. In this connection, four major storage projects are proposed as Indo-Nepal cooperative initiatives. These are Chisapani Karnali (10,800 MW), the Pancheswor (6480 MW), Budhi Gandaki (600 MW) and the Sapta Koshi high dam (3600 MW) which in total, would provide 22,200 MW installed capacity.

Snow and Glacier: The Himalayan glaciers are receding faster than any other glaciers in the world (IPCC, 2007). According to the 2010 Glacier Inventory of Nepal (Bajracharya et al., 2010, Bajracharya and Maharjan, 2010), there are 3808 glaciers covering an area of 4212 sq km (Table 1-13). Previous study shows a total of 3252 glaciers in Nepal covering a total area of 5312 sq km (ICIMOD, 2001). The recent increase in number of glaciers is mainly due to disintegration of large glaciers mainly due to loss of ice on those glaciers.

Table 1-13: Distribution of glaciers in the river basins of Nepal

Basin	No. of Glaciers	Total Area (sq. km)	Highest Elevation (m asl)	Lowest Elevation (m asl)
Koshi	843	1,180	8,437	3,962
Gandaki	1,337	1,800	8,093	3,273
Karnali	1,461	1,120	7,515	3,631
Mahakali	167	112	6,850	3,695
Total	3,808	4,212		

Source: Bajracharya et al., 2010, Bajracharya and Maharjan, 2010

1.1.12 Waste

Solid waste is not properly managed in Nepal. Land-fill sites have not been selected by many of the municipalities. Wastes are simply collected, transported and dumped on to public land. The municipalities generate over 1350 tons of solid waste daily (ADB/ICIMOD 2006). Kathmandu alone produces 383 tons of solid waste per day. In many municipalities hazardous wastes are mixed and dumped along with municipal waste. Similarly, industrial waste is either burned, dumped or drained in a river or mixed with municipal waste.

1.1.13 Mineral Resources

The country has not been seen rich in mineral resources based on the result of the survey conducted so far. The mineral deposits found so far in the country are often small, scattered, and in areas far from domestic market and are consumed locally. The exploration of minerals lacks commercial viability as a result of high cost for accessing and marketing minerals in the country. The most important minerals that have been exploited are limestone for cement, clay, garnet, magnetite, and talc. Mineral surveys of Nepal have found small deposits of cobalt, copper, iron ore, lead, limestone, magnesite, mica and zinc. A lead and zinc deposit is located near Lari in the Ganesh Himal region. A reserve of 310 million cubic meters of natural gas has been found within 26 square kilometer of Kathmandu valley. Medium grade coal deposits have been found in Dang, Salyan, Rolpa and Palpa, about 50,000 MT of coal is produced from these factories (MOF, 2010). Through explorations carried out so far, no petroleum product has been found that could be exploited commercially.

1.2 Environmental Management

1.2.1 Water Quality and Quantity Management

Legal Aspects: Several legal measures are enforced to manage the quality and quantity of water such as Environment Protection Act (EPA) 1997; Environment Protection Rules (EPR) 1997; Water Resources Act 1992; Nepal Water Supply Corporation Act 1989, Water Resource Regulation 1993, Drinking Water Regulation 1998, Irrigation Regulation 2000; Generic Industrial Effluent Standards 2003; National Drinking Water Quality Standard 2006 and Nepal Water Quality Guidelines 2008 for

Irrigation, Aquaculture, Livestock Watering, Recreation, Industries, Aquatic ecosystem and Recreation. Similarly, High Powered Committee for the Integrated Development of Bagmati Civilization and National Trust for Nature Conservation (NTNC) have endorsed Bagmati Action Plan (2009-2014) for the conservation of the Bagmati River and its tributaries.

1.2.2 Air Quality Management

Legal Aspects: Nepal does not have a separate policy or act on air quality management, however some existing legislation do address this issue. The legal measures enforced in order to manage the air quality are EPA 1997; EPR 1997; National Ambient Air Quality Standards 2003; Vehicle and Transport Management Act1993; Industrial Enterprises Act 1992; Nepal Vehicle Mass Emission Standard 2000 (for new vehicles) and In-use Vehicle Emission Standards and Emission testing of vehicles since 1995. The import of new two-stroke three wheelers is banned since 1999 and two-stroke three wheelers were removed from Kathmandu in 2004. Similarly, MOSTE has endorsed Air Quality Monitoring Action Plan (2010-2013) for the monitoring and improvement of air quality.

1.2.3 Solid Waste Management

Legal aspects: There are different legal measures that have been enforced in order to manage solid waste of the country such as Solid Waste Management Act 2011; Local Self Governance Act 1999, Local Self Governance Regulation 1999, Industrial Enterprises Act 1992; National Health Care Waste Management Guidelines 2002 by NHRC and WHO and Health Care Waste Management Guidelines 2008 by Department of Health Service, Ministry of Health and Population.

Chapter 2

National Greenhouse Gas Inventory

2.1 Introduction

Since pre-industrial times, the measured concentrations of some anthropogenic greenhouse gases (GHGs) in the atmosphere have been rising. While the presence of such gases is essential for maintaining habitable atmosphere, the enhanced effect on the climate system of these increasing levels is of serious concern. As per the IPCC Guidelines, the national inventory takes into account the emission of following GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and indirect gases such as nitrogen oxide (NOx), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulfur dioxide (SO_2), emitted from the anthropogenic activities in the sectors of (a) energy, (b) industry, (c) agriculture, (d) land use, land use change and forestry (LULUCF), and (e) waste.

Naturally occurring GHGs include water vapor, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are accounted for in the national GHG inventory. Some fluorine-containing halogenated substances – hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) – do not deplete stratospheric ozone but are potent GHGs; these substances are also addressed by the UNFCCC. However, stratospheric ozone depleting substances, viz. chlorofluorocarbons (CFCs), hydro chlorofluorocarbons (HCFCs), and halons are covered under the Montreal Protocol on Substances that Deplete the Ozone Layer, and Parties to the UNFCCC are not required to include these gases in their national GHG inventory. Chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromo fluorocarbons (i.e., halons).

There are also several gases that do not have a direct global warming effect but indirectly affect terrestrial and/or solar radiation absorption by influencing the formation or destruction of GHGs, including tropospheric and stratospheric ozone. These gases include carbon monoxide (CO), oxides of nitrogen (NO_x), and non-methane volatile organic compounds (NMVOCs). Aerosols, which are extremely small particles or liquid droplets – such as those produced by sulfur dioxide (SO_2) or elemental carbon emission, can also affect the absorptive characteristics of the atmosphere.

Estimation of anthropogenic GHG emission in Nepal began officially in 1994, and the first national GHG inventory report (with 1990 as the base year) was published in 1997 by the Department of Hydrology and Meteorology (DHM) under the US Country Study Program implemented between 1994 and 1997. The second GHG inventory (with 1994 as the base year) was prepared by Climate Change Study Group, and reported in Nepal's Initial National Communication (INC). Nepal's Second National Communication (SNC) includes the national GHG inventory with 2000/01 as the base year.

The official calendar in Nepal starts from middle of July. Therefore, the base year data for 1990 includes data pertaining to the year 1990/91. Likewise, data collected for 1994/95 and 2000/01 are used as the base year data for 1994 and 2000, respectively.

2.2 Methodology

The estimates presented in the national GHG inventory (for various base years) have been calculated using standard methodologies given in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997), the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000), and the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2003). The emission of a specific GHG (mainly CO_2, CH_4, and N_2O) from each source category (viz. energy; industry; agriculture; land use, land use change, and forestry (LULUCF), and waste) is estimated by multiplying the activity data for the source category by the respective emission factor. The emission factors used in this report are the default emission factors suggested in IPCC publications (1997, 2000, 2003, and 2006). As far as possible, emission factors given for the Indian subcontinent are chosen. Conversion of GHG emission into CO_2 equivalents is made on the basis of the decision FCCC/CP/2002/8. The Global Warming Potential (GWP) values used in this report are adopted from the Second Assessment Report (SAR) (see Table 2-1).

Table 2-1: Global warming potential (GWP)

Greenhouse Gas	CO_2	CH_4	N_2O
GWP (IPCC 1995)	1	21	310

The SNC includes GHG inventory for the base year 2000. The relevant activity data is derived from the following documents published by the government agencies: Energy Synopsis Report (Energy Profile of Nepal), 1996-97, 2006, 2010, WECS; A Compendium of Environment Statistics of Nepal, 1994-1998, 2008, CBS; Industrial Statistics (various volumes), DOI; Statistical Information on Nepalese Agriculture, 1999/2000, 2010; Statistical Information on Nepalese Forestry, 1999/2000, Department of Forest Research and Survey; Remote Sensing and Satellite Imagery Data for Land Use Change Monitoring; State of Environment Nepal, 2001, MOPE/UNEP/SACEP/ICIMOD; Industrial Pollution Inventory, 1994/95, MOI; Population Census, 1991, 2001, CBS; and Land System and Land Utilization Report of Land Resources Mapping Project, 1986, among others.

2.3 Overview of National GHG Inventory

Base Year 1990: The national GHG inventory (base year 1990) includes estimation of CO_2 emission from energy consumption and cement production, CH_4 emission from flooded rice cultivation, livestock farming and biomass burning and N_2O emission from fertilizer. However, the inventory does not specify GHG contribution from the LULUCF and waste sector. The GHG emission by different end-use sectors as estimated in the 1990 inventory is summarized in Table 2-2.

Table 2-2: GHG emission by different end-use sectors in 1990/91

S.N.	GHG Source and Sink Categories	CO_2		CH_4 (Gg)	N_2O (Gg)
		Emission (Gg)	Removal (Gg)		
1	Fuel combustion	912.96			
2	Agriculture			920.82	0.803
3	Biomass burning			85.00	0.590
	Net emission	912.96		1005.82	1.393

Source: DHM, 1997

It is observed that fossil fuel consumption dominated the CO_2 emission. The CH_4 emission from agricultural sector was much higher than that from the burning of biomass (mainly wood and dung cake). The N_2O emission from the agriculture sector resulted particularly from the use of fertilizers.

Base Year 1994: Nepal's Initial National Communication (INC) Report provides information on GHG (CO_2, CH_4, and N_2O) sources and sinks, and estimates of emission and removals for the base year 1994/95. Emission is reported under five categories: energy, industrial processes, agriculture, land use change and forestry (LUCF), and waste (Table 2-3).

Table 2-3: GHG emission by different end-use sectors in 1994/95

S.N.	Greenhouse Gas Source and Sink Categories	CO_2 Emission (Gg)	CO_2 Removal (Gg)	CH_4 (Gg)	N_2O (Gg)
1	Energy	1465	-	71	1
2	Industrial processes	165	-		
3	Agriculture	-	-	867	29
4	Land-use change and forestry	22895	-14778		
5	Waste	-	-	10	1
	Total emission and removals	24525	-14778	948	31
	Net emission	9747	-	948	31

Source: INC (MOPE, 2004)

In the 1994 inventory, using the GWP factors (see Table 2-1), the total emission of the main GHGs was estimated at 39265 Gg of CO_2 equivalent. Of this, CO_2, CH_4, and N_2O constituted 25, 51, and 24% respectively. Of the five categories included in the inventory, the LULUCF sector was the largest contributor of CO_2 followed by the energy sector. The LULUCF sector also sequestered about 64.5% equivalent of its CO_2 emission. As expected, agriculture and solid waste sectors were found to be the main contributors to the emission of CH_4 and N_2O respectively.

Base Year 2000: The 2000 inventory provides information on Nepal's anthropogenic emission of direct GHGs (CO_2, CH_4, and N_2O) and indirect GHGs (NO_x, CO, NMVOC, and SO_2) by sources and removals by sinks from the sectors of energy, industrial process, agriculture, LULUCF, and waste. Consistent with UNFCCC reporting guidelines (UNFCCC, 2006), indirect GHGs are not included in the total GHG emission.

Table 2-4: Direct and Indirect GHG emission and removal by different end-use sectors in 2000

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 (Gg) Emissions	CO_2 (Gg) Removals	CH_4 (Gg)	N_2O	CO2-eq (Gg)
Total National Emissions and Removals	2,894	-12775	668	30	13447
1 Energy	2,763		164	2	6827 (27.8%)
Energy Industries	821				821
Transport	818				818
Other Sectors	1,124		164	2	5188
2 Industrial Processes	131				131 (0.5%)
A. Mineral Products	131				131
3 Agriculture			470	27	18240 (68.9%)
A. Enteric Fermentation			430		9030
B. Manure Management			38	8	3278
C. Rice Cultivation			2		42

GREENHOUSE GAS SOURCE AND SINK	CO_2 (Gg)	CO_2 (Gg)	CH_4 (Gg)	N_2O	CO2-eq (Gg)
D. Agricultural Soils				19	**5890**
4 Land-Use Change & Forestry		**-12775**	**17**		**-12418**
A. Changes in Forest and Other Woody Biomass Stocks		-29562			
B. Forest and Grassland Conversion	12,561		17		
C. Abandonment of Managed Lands		-122			**-122**
D. CO_2 Emissions and Removals from Soil	4,348				**4348**
5 Waste			**17**	**1**	**667 (2.7%)**
A Solid Waste Disposal on Land			12		**252**
B Wastewater Handling			5	1	**415**
6 Memo items					
International Bunkers	**162**				
Aviation	162				
CO_2 emission from Biomass	**30,294**				

GREENHOUSE GAS SOURCE AND SINK	NOx	CO	NMVOC	SO2
CATEGORIES				
Total National Emissions and Removals	67	2,903	333	76
1 Energy	67	2,755	332	76
Energy Industries	3	3		5
Transport	9	25	5	1
Other Sectors	55	2,727	327	70
2 Industrial Processes			1	
Other production			1	
3 Land-Use Change & Forestry		147		
B Forest and Grassland Conversion		147		
4 Memo items				
International Bunkers		1		
Aviation		1		

(A) Direct GHGs: The direct GHG emission by sector and removal by sinks is summarized in Table 2-5 (see Table 2-1 for GWP values). Excluding emission and removal from the LULUCF sector, the total CO_2 equivalent emission in 2000/01 is estimated at 24,541 Gg (Table 2-6). However, including contribution from the LULUCF sector, the net GHG emission is 12,080 Gg of CO_2 eq. This shows that the LULUCF as a whole acts as CO_2 sink. The key contributors to the GHG emission (excluding LULUCF sector) are agricultural sector accounting for 68.9% and energy sector accounting for 27.8% of the total CO_2 eq. emission. Waste and industrial process sectors emitted 2.7% and 0.5% of the total CO_2 eq. emission respectively.

Table 2-5: GHG emission and removal by different end-use sectors in base year 2000/01

S.N.	Categories	CO_2 emission (Gg)	CO_2 removal (Gg)	CH_4 (Gg)	N_2O (Gg)
	Total national emission and removal	2894.24	-12776.38	667.53	30.55
1	Energy	2763.28	-	163.96	2.22
2	Industrial processes	130.96	-	-	-
3	Agriculture	-	-	470.08	27.14
4	LULUCF	-	-12776.38	16.75	-
5	Waste	-	-	16.74	1.19

The general trend in sector GHG emission (by sectors) showed both increasing and decreasing trend since 1994 (Table 2-6). Accordingly, over the period of six years, the total emission from energy and waste sectors increased by 5362 Gg and 147 Gg respectively. The compounded annual growth rate of GHG emission from the energy and waste sectors during this period shows an overall increase of 29.24% and 4.2% per annum, respectively. These increments are attributable to the increase in the economic activities leading to more energy consumption and more waste production.

Table 2-6: Sector emission trend and compounded annual growth rate since 1994

S.N.	Sectors	1994 (CO_2e Gg)		2000(CO_2 e Gg)		CAGR*% (1994-2000)	2008 (CO_2 e Gg)	
		Total Emission	% of Total	Total Emission	% of Total		Total Emission	% of Total
1	Energy	1465	5	6827	27.8	29.24	7959	26.5
2	Industrial processes	165	0.6	131	0.5	-3.77	632	2.1
3	Agriculture	27197	92.6	16916	68.9	-7.58	20662	68.8
4	Waste	520	1.8	667	2.7	4.23	758	2.5
	Total (without LULCF)	29347	100.0	24541	100.0	-2.92	30011	100.0

Note: Methodologies, definitions of activity data and emission factors adopted in the 1994 and 2000 base year studies differ from those used for the base year 2008. * CAGR: compounded annual growth rate.

Agriculture and industrial process sectors showed significant decrease in the compounded annual growth rate of GHG emission: an overall decrease of 7.58% and 3.77% per annum, respectively. Some discrepancy in the emission reporting can be attributed to changes in the definition of activity data. In earlier studies (DHM, 1997; MOPE, 2004), for e.g., whole of the paddy area in the country was taken as if it were under continuous flooding. But later, it was realized that paddy crops in most parts of the country are grown under water stress, and multiple aeration is very common. Moreover, inclusion of activities in the estimation also affected the estimates. For e.g., emission from the manure management is excluded in the 1990 inventory. Selection of emission factors also affects the estimates. For the 2000 inventory, the most suitable emission factors are selected from the IPCC database. The most suitable emission factors for agriculture in Nepal are those recommended for the Indian sub-continent. On the other hand, the general sector-wise trend in the GHG emission showed an increasing trend between the years 2000 and 2008 using same emission factors for both years.

Table 2-7 shows emission from the LULUCF sector in 1994 and 2000. The depicted figures have to be interpreted with caution. The wide difference between the GHG emission estimated in 1994 and 2000 from the LULUCF sector can be attributed to the activity data and choice of different default values. The SNC (2000 estimates) uses a higher default growth rate value for forestry growth than that used in the INC (1994 estimates). A same default value of 2.1 kt dm was used as growth rate for shrub and grassland. On the other hand, grassland conversion rate of zero k ha per year was used for calculation in the SNC against the INC used rate of 29 k ha per year. This resulted into the

reporting of a lower estimation of carbon released in the SNC (3699 k-ton) than that reported in the INC (5058 k-ton).

Table 2-7: Emission from LULUCF sector in the year 1994 and 2000

Base Year	CO_2 Emission (Gg)	CO_2 Removals (Gg)	CH_4 (Gg)
1994	22895	-14778	
2000	16909	-29684	17

(B) Indirect GHGs: Although not included in the total GHG emission, the estimate of indirect GHG emission is presented later in relevant sections. Emission of NOx, CO and NMVOC is mainly attributable to the energy sector, particularly to the biomass combustion. In 2000, emission of NOx from the residential sector comprised of 82% of the total NOx emission. Similarly, emission of CO from the residential sector comprised 94% of the total CO emission. The residential sector is seen to be the largest producer of NMVOCs, producing 98.2% of NMVOC emission in 2000.

Key category analysis: The IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) identifies a key category as "one that is prioritized within the national inventory system because its estimation has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emission, the trend in emission, or both". In other words, key categories refer to the most significant emission sources in the country. Table 2-8 shows key category analysis using 2000/01 emission estimates. The top six emission sources in Nepal, together accounting for 90.2% of the total GHG emission, are as follows: (1) enteric fermentation, (2) agricultural soils, (3) residential CH_4 energy use, (4) road vehicles, (5) residential CO_2 energy use and (6) manure management.

Table 2-8: Key category analysis without LULUCF

IPCC Source Category	Sector and Source Categories to be Assessed in Key Source Category Analysis	Applicable GHG	Emission Estimate (2000/01, non-LULUCF) (Gg CO_2 eq)	Level Assessment Excluding LULUCF (%)	Cumulative-level Excluding LULUCF (%)
4.A	Agriculture: CH_4 emission from enteric fermentation in domestic livestock	CH_4	9,016.3	37.9	37.9
4.D	Agriculture: N_2O (direct and indirect) emission from agricultural soils	N_2O	6,724.7	28.2	66.1
1.A.4	Energy: Other sectors – residential CH_4	CH_4	3,428.4	14.4	80.5
1.A.3	Energy: CO_2 mobile combustion – road vehicles	CO_2	817.6	3.4	83.9
1.A.4	Energy: Other sectors – residential CO_2	CO_2	750.5	3.2	87.1
4.B	Agriculture: CH_4 emission from manure management	CH_4	746.6	3.1	90.2
1.A.4	Energy: Other sectors – residential N_2O	N_2O	676.3	2.8	93.0
4.B	Agriculture: N_2O emission from manure management	N_2O	375.5	1.6	94.6
6.B	Waste: N_2O emission from wastewater handling	N_2O	368.9	1.5	96.1
6.A	Waste: CH_4 emission from solid waste disposal sites	CH_4	255.3	1.1	97.2
1.A.4	Energy: Other sectors: agriculture/ forestry/ fishing CO_2	CO_2	223.6	0.9	98.1
1.A.4	Energy: Other sectors – commercial CO_2	CO_2	150.7	0.6	98.7
2.A	Industrial Processes: CO_2 emission from cement production	CO_2	118.5	0.5	99.2

2.4 GHG Emission from Energy Sector

2.4.1 Energy Resource Base

Energy in Nepal is derived from traditional, commercial and alternative resources. Traditional energy sources include biomass fuels– particularly fuel wood, agriculture residue and animal dung. Commercial sources of energy are fossil fuels and electricity. Alternative energy sources include micro-hydro, solar power, wind power, biogas, briquettes, etc. But the huge demand for energy is largely being met with biomass fuels. It has been noticed that burning biomass has significant negative effects on the well-being of human, eco-systems and environment. In order to attain sustainable development, dependency on the biomass must be reduced gradually in favor of renewable energy sources.

Biomass, hydropower and solar power are the major energy resource base in the country. Also, there exist some sporadic deposits of natural gases and coal reserves, which are very small in quantity and still not exploited commercially. The potential of known indigenous energy resources in Nepal is estimated at 1970 million gigajoule (GJ) per annum on a sustainable basis (WECS, 2006), which would be 15 times the estimated total consumption. Of the total sustainable potential, water resources represent the largest fraction (75%), with forests contributing 12% and the rest coming from other sources (WECS, 2006). Though Nepal has a huge hydropower potential, its exploitation has been very minimal.

Traditional energy sources: Nepal relies mainly on biomass fuels due to the lack of development of other energy alternatives. Forest resources are under increasing threat from burgeoning human and livestock population to meet their requirements for fuel wood, fodder, and timber. Forest area in the country decreased by 1.7% per year from 1978/79 to 1998/99 (WECS, 2006). The annual loss of forest in terai region was reported slightly lower at 1.3% as compared to the national annual rate which indicates higher level of deforestation rate in the hill and mountain regions.

Hydropower: The theoretical hydropower potential in Nepal is estimated at about 83 GW, whereas the technically and economically feasible potential is about 45 GW and 42 GW, respectively (WECS, 2010). Hydropower utilization is currently about 1.5% of the proven potential. The total installed electricity generation is about 689.3 MW out of which hydroelectric generation capacity is around 635.9 MW.

Petroleum products Nepal imports petroleum products to meet its fossil fuel demand. The amount of petroleum products imported during the years 1995 and 2005 are given in Table 2-9. It shows that between 1995 and 2005, there was a considerable increase in the supply of liquefied petroleum gas (LPG) because of the recent trend to use LPG in place of kerosene, electricity and fuel wood in urban and semi urban areas.

Table 2-9: Import of petroleum products in Nepal

Fuel type	Unit	1995	2005	Increase%
Motor sprit	kL	41,736	78,463	1.9
Diesel	kL	254,323	310,535	1.2
Kerosene	kL	213,830	233,310	1.1
Air turbine fuel	kL	40,776	76,887	1.9
LPG	MT	18,600	89,045	4.5

Source: WECS, 2006

Coal: There are some small deposits of coal and lignite in Nepal, which are not commercially attractive. The occurrences of coal can be classified into four major categories: quaternary lignite of Kathmandu Valley, coal from Dang (Eocene coal from Mid-Western Nepal), Siwalik coal, and

Gondwana coal. Out of these four types identified, the quaternary lignite deposit of the Kathmandu Valley and coal from Mid-Western Nepal are of some economic significance. The Siwalik coal deposits, though widely distributed throughout the Siwalik range of the country, are small and sporadic, and have not been commercially exploited. Likewise, the Gondwana coal from the east of Nepal is of low quality, small in size, and of no economic significance.

Solar energy: Nepal receives good amounts of solar radiation. The sun shines for about 300 days a year. The average insolation varies from 3.6 to 6.2 $kWh/m^2/day$ (WECS, 2006). Recent measurements show that at high altitudes, the average insolation is about $6.5kWh/m^2/day$ and in low altitudes; it is $5.3kWh/m^2/day$ (Poudel et al., 2011). The mountains and hills have great solar energy potential, accounting for almost 94% of the total solar energy output. There are two methods of utilizing solar energy– solar thermal and solar photovoltaic systems. The use of solar photovoltaic is increasing rapidly in the country after the provision of subsidy by the government. So far, around 22,000 household solar photovoltaic systems have been installed in different parts of the country (MOPE, 2003).

Biogas: Biogas is a methane rich gas produced by the digestion of animal, human and bio-solid waste. In Nepal, it is the animal waste that is mainly used for biogas production. Nepal has a suitable climate to produce enough biogas. The estimated potential for biogas production in Nepal is around 1200 million cubic meters per year (WECS, 1999). By 2005, more than 140,519 plants had been installed in Nepal with the support from the Biogas Support Program (BSP, 2005). Till date, the number of biogas plant installed in Nepal has exceeded 250,000. The biogas energy is the first project under Clean Development Mechanism (CDM) in Nepal.

2.4.2 Energy Consumption Pattern

As shown in Table 2-10, the total energy consumption in the year 2000/01 was estimated to be 335.2 million GJ, dominated largely by the use of traditional non-commercial forms of energy such as fuel wood, agricultural residue and animal waste (WECS, 2006). About 87% of the demanded energy is fulfilled by traditional sources (fuel wood, agricultural residue and animal waste) and remaining 13% by commercial sources (electricity and fossil fuels).

Table 2-10: Energy consumption in 2000/01 (in '000 GJ)

Fuel Type	Sector						
	Residential	Industrial	Commercial	Transport	Agriculture	Other	Total
<u>Traditional</u>:							
Agricultural residue	11482.3	1249.8					12732.1
Animal dung	19491.8						19491.8
Fuel wood	256416.3	644.1	1575.3				258635.7
Total	287390.4	1893.9	1575.3				290859.6
<u>Commercial:</u>							
ATF				2283.4			2283.4
Coal	31.4	7415.0					7446.4
Electricity	1866.1	1874.3	339.0	21.2	103.0	408.5	4612.1
Fuel oil		588.1					588.1
Gasoline				1984.1			1984.1
HS Diesel		206.8		9145.3	3015.3		12367.4
Kerosene	9534.7	536.1	1401.2				11472.0
L Diesel		2.0		98.0	33.7		133.7
LPG	1102.9		812.2	59.5			1974.6
Other petroleum		482.1					482.1
Total	12535.1	11104.4	2552.4	13591.5	3152.0	408.5	43343.9

Fuel Type	Sector						
	Residential	Industrial	Commercial	Transport	Agriculture	Other	Total
Renewable:							
Biogas	1179.2						1179.2
Micro-hydro	38.1						38.1
Solar	0.3						0.3
Total	1217.6						1217.6
Grand Total	301143.1	12998.3	4127.7	13591.5	3152.0	408.5	335421.1

Source: WECS (2006)

Figure 2-1 depicts share of each fuel type in the total energy consumption in 2000/01. Fuel wood – used mostly for domestic purposes – accounts for 77.1% of the total energy consumption in 2000/01. Forests are the main source of fuel wood; however, some fuel wood also comes from non-cultivated inclusions and farmland. On the other hand, agricultural residue and animal waste account for about 10% of total energy consumption in the year 2000/01. Its use in Nepal is increasing, especially in the Terai belt, due to the increasing scarcity of fuel wood from forest areas.

At present, only about 12% of the total population has access to electricity. About 90% of the total population is from rural areas and only 2% of rural population has access to electricity (WECS, 2011). In 2000/01, electricity accounted for 1.4% of energy consumption. On the other hand, petroleum products met 9.3% of total energy demand of the country in 2000/01. Petroleum products are mainly consumed in the transport sector, and also in the industrial, agricultural and commercial sectors.

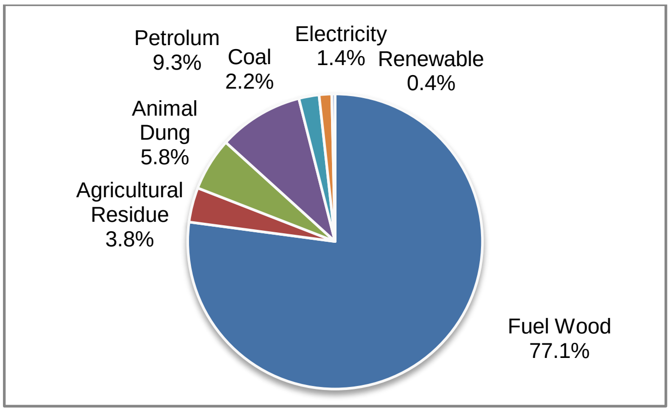


Figure 2-1: Energy consumption by fuel type in 2000/01

Nepal also imports coal to meet its energy demand, mainly in the industrial sector. Coal is imported from Assam, West Bengal and Bihar of India. Industries, such as cement, lime and brick manufacturing depend upon imported coal. In addition, steel rolling mills are another major consumer of coal. Coal consumption in the overall energy scenario of Nepal in 2000/01 was about 2%. Kathmandu alone consumes 40% of the coal imported into the country (WECS, 2010). Scattered deposits of mud coal, lignite, and peat occur in Nepal.

The Energy Synopsis Report of WECS shows that there is a distinct change (both in amount and type of fuel) in energy consumption over time. The total energy consumption data in the country reveals an increase of about 2.4% annually, which almost commensurate with the present growth of GDP to some extent. However, commercial fuel consumption is known to increase only by about 1.6% annually. Moreover, within the commercial energy system, electricity consumption is growing with an annual rate of about 10%. Coal consumption is almost similar in different years within the last decades. Its growth is just about 0.5% annually. The average annual change in the petroleum consumption is also very low that is just about 0.7% in 2000/01 to 2008/09. Especially the

consumption of kerosene, furnace oil and light diesel is decreasing whereas LPG is increasing even more than 25% annually replacing kerosene, fuel wood and electricity as well.

The historical trend of energy consumption pattern by fuel types shows that even though progressing at a slow pace, there is a shift in energy consumption from the traditional to commercial and renewable sources (WECS, 2010). The share of commercial energy has increased from about 9% in 1995 to about 12% in 2008/09. Similarly, there is a growing trend in the renewable energy consumption. Within the commercial sources, electricity is dominant which has substituted other fuels.

2.4.3 GHG Emission from Energy Sector in Base Year 2000/01

The energy systems of most economies are largely driven by the combustion of fossil fuels, namely, coal, oil and natural gas. Fossil fuel combustion oxidizes carbon present in the fuel, which is emitted as CO_2. Some carbon is also released in the form of CO, CH_4, and non-methane hydrocarbons, which is oxidized to CO_2 in 10-11 years. Also emitted are N_2O, SO_2, and black carbon. The national GHG inventory 2000 includes estimates of CO_2, CH_4, N_2O, NOx, CO, NMVOC and SO_2 emitted from fossil fuel combustion in the following sub-sectors of the energy sector: industries for heat production, transportation, commercial and residential use, and agriculture. Note that Following the IPCC methodology, the CO_2 emission from biomass burning is not included in the inventory due to the fact that the rate of regeneration of agricultural residues and other traditional bio-mass energy sources equals the rate of their use.

In 2000/01, the energy sector emitted 6827 Gg of CO_2-eq of which 5189 Gg of CO_2 eq. is emitted from the residential sub-sector. The energy sector comprises emission estimates from the combustion of fossil fuel in stationary and mobile sources. Stationary sources include fossil fuel combustion in energy industries, residential, commercial/institutional and agricultural sectors. Mobile sources include road transport, civil aviation and railways.

Methodology and choice of emission factors: Methodology recommended in the IPCC 1996 revised guidelines (IPCC, 1997) is used for estimating GHG emission from various types of fossil fuel combusted in the energy sector. Steps involved in the CO_2 estimation following the IPCC reference approach are as follows: (1) Apparent consumption = Production + Imports – Exports – International bunkers – stock change (2) Conversion of data to energy unit (TJ) (3) Estimation of carbon content from carbon emission factor (4) Estimation of carbon stored (5) Estimation of net carbon emission = Carbon content – Carbon stored (6) Actual carbon emission = Net carbon emission x Fraction of carbon oxidized (6) Estimation of CO_2= (44/12) x Actual carbon emission.

The CO_2 emission is calculated by two methods: Reference approach (top-down) and sectoral approach (bottom-up). Reference approach uses apparent fuel consumption accounting for the carbon flows into and out of the country. Sectoral approach (bottom-up) accounts for the fuel consumption by sectors. According to the IPCC methodology, the emission in the sectoral approach are categorized into energy industries, manufacturing industries and construction, transport, commercial, institutional and residential use, and agriculture, forestry, fishing, and others.

Tier 1 sectoral approach is used in accordance with the decision tree of the Good Practice Guidance (2000) to calculate emission. Accordingly, the general equation to calculate carbon emission from different end use sectors is as follows (IPCC, 1996):

$$\text{Carbon emission} = \sum \text{fuel consumption for each sector x carbon emission factor} - \text{carbon stored x fraction oxidized}$$

The general equation to calculate emission of non-CO_2 gases is as follows (IPCC, 1996):

$$\text{Emission} = \sum (EF_{ab} \times Activity_{ab})$$

where, EF_{ab} denotes emission factor (kg/TJ) and $Activity_{ab}$ denotes energy input (TJ) using fuel type 'a' in sector type 'b'.

The emission factors used in this report are default emission factors available in IPCC publications (1997, 2000, 2003 and 2006). The values of NCV (net calorific value), CO_2 emission factor and fractions of carbon oxidized for different fossil fuels are given in Table 2-11.

Table 2-11: Factors used in estimation of CO_2 from fossil fuels

Description	Fuel Types						
	Gasoline	Diesel	Jet Kerosene	Other Kerosene	LPG	Fuel Oil	Coal
NCV (TJ/kt)	44.80	43.33	44.59	44.75	47.31	40.19	25.12
Carbon emission factor (tC/TJ)	18.9	20.2	19.5	19.6	17.2	21.1	25.8
Fraction of carbon oxidized	0.99	0.99	0.99	0.99	0.995	0.99	0.98

Emission factors: Selection of emission factors (EFs) significantly affects the estimates of emission. For 2000 inventory, the most suitable EFs have been selected from the IPCC database for the year 1996 (available online at http://www.ipcc-nggip.iges.or.jp/EFDB). Accordingly, for this report, the emission factors based on the IPCC 1996 data have been used for GHG projections. Where relevant data is unavailable, EFs reported for other years, or for the Indian subcontinent (or India) have been adopted. The following table shows EFs used in the projection of energy-sector GHG emission.

Table 2-12: Emission factors for fuels

Sector	Fuels	CO_2 (Kg/Tj)	CH_4 (Kg/Tj)	N_2O (Kg/Tj)
Residential	Fuel wood	112	300	4
	Animal dung		4190	27
	Agricultural residue		230	9.7
	Coal		300	1.4
	Kerosene	71900	10	0.6
	LPG	63100	5	0.1
	Biogas	54600	5	0.1
Industrial	Fuel wood	112000	30	4
	Agricultural residue		2210	9.7
	Animal dung		281	27
	Coal	92600	10	1.4
	Fuel oil	77400	3	0.6
	H S diesel	74100	3	0.6
	Kerosene	71900	3	0.6
	Other petroleum		0.5	2
	L diesel	74100	3	0.6
Transportation	H S diesel	3.18 (Mt/Toe)	5	0.6
	Gasoline	20		11
	L diesel	3.18 (Mt/Toe)	5	0.6
	LPG		62	0.2
Agriculture	L Diesel	74100	0.16	0.6
	H S diesel	74100	0.16	0.6
Commercial	Wood	91.01	300	4
	Kerosene	71900	10	0.6
	LPG	63100	5	0.1

Source - IPCC (1996, 2001, 2006), Ramachandra and Shwetmala (2009)

Overview of GHG emission: Energy-related activities are one of the major sources of GHG emission in Nepal. The energy consuming sector is categorized as per the economic sector of the country into residential, commercial, transport, industrial, and agriculture sector (WECS, 2010). Table 2-13 sums up CO_2 emission from the consumption of various types of fossil fuels from these end-use sectors in 2000/01.

Table 2-13: CO_2 emission by different end-use sectors in 2000/01 (in Gg)

Sectors	Gasoline	Kerosene	Diesel	Residual Fuel	Add Fuels	LPG	Coal	Total
Industrial		38.14	15.31	45.04	35.0		687.43	820.92
Transport	136.12		677.77			3.73		817.62
Residential		678.37				69.21	2.91	750.49
Agricultural			223.57					223.57
Commercial		99.69				50.97		150.66
Total	136.12	816.20	916.65	45.04	35.0	123.91	690.34	2763.26

Source: WECS (2010)

Emission of GHG from fuel combustion and fuel supply activities are calculated by multiplying levels of activity by emission factors usually expressed as mass pollutant per energy unit of activity. The emission from the use of fuels for international bunkers is excluded from the national emission totals. CO_2 emission from burning of aviation fuel is not counted in the total national emission and is reported in the memo-section.

While there is CO_2 emission from the combustion of biomass used to produce energy, such emission is not included in the energy sector totals. It is accounted for in the LULUCF sector, and is recorded as a loss of biomass (forest) stocks. Other GHGs (CH_4 and N_2O) from biomass fuel combustion are reported in the energy sector. In 2000/01, the energy sector in Nepal emitted 6894.64 Gg of CO_2 equivalent. Out of this, 2763.28 Gg was emitted as CO_2, 163.96 Gg as CH_4 and 2.22 Gg as N_2O. Table 2-14 gives the result of the GHG emission estimated using the sectoral approach.

Table 2-14: GHG emission from the energy sector in 2000/01 (in Gg)

Energy Sector	CO_2	CH_4	N_2O	CO_2 equivalent
Industrial	820.93	0.09	0.02	829.02
Transport	817.63	0.09	0.01	822.62
Residential	750.49	163.26	2.18	4854.75
Agricultural	223.57	0.03		224.20
Commercial	150.66	0.49	0.01	164.05
Total	2763.28	163.96	2.22	6894.64
Memo items:				
Aviation bunker*	162			
CO_2 emission from biomass**	30294			

*Bunkers are neither added to the total emission from the energy sector nor to the national totals. ** CO_2 emission from biomass is excluded from the totals.

About 71% of the total CO_2 equivalent emission from the energy sector in 2000/01 was from the fuel combusted in the residential sector for heating and lighting purposes. This sub-sector has rural and urban spread and therefore includes combustion of both fossil fuel and biomass, which together emitted high amount of GHG. The transport and industrial sectors each emitted about 12% of the total CO_2 eq. emission in 2000/01. Rest 5% GHG emission was from the fuel combusted in the commercial and agricultural sector. Figure 2-2 shows the GHG emission distribution (CO_2 eq.) from the energy sector.

In 2000/01, the energy sector emitted 67 Gg of NO_x, 2755 Gg of CO, 332 Gg of NMVOC, and 76 Gg of SO_2 (Table 2-15). About 82% of the total NO_x, 98.6% of the total CO, 98.1% of the total NMVOC emission from the energy sector was from the fuels combusted in the residential sector.

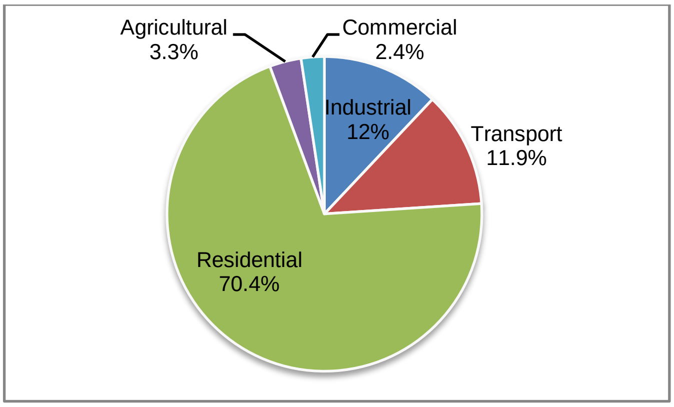


Figure 2-2: GHG emission distribution from the energy sector (CO_2 eq.)

On the other hand, SO_2 emission is related to the composition of fuels, not to the combustion technology. So, SO_2 emission is estimated assuming low sulfur content in the fuel, and that no SO_2 abatement technology is used.

Table 2-15: Emission of indirect GHG from energy sector in 2000/01 (in Gg)

Sector	NOx	CO	NMVOC	SO_2
Total	67	2755	332	76
Industrial	3	3		5
Transport	9	25	5	1
Residential	55	2719	326	
Agricultural				
Commercial		8	1	70

(A) GHG Emission from Industrial Sector

Energy use in industrial sector: Industries in Nepal still rely on biomass fuels like fuel wood and agriculture residue. Fuel wood accounts for almost 50% of the energy consumed followed by electricity and petroleum products. It is estimated that about 13 million GJ of energy is consumed in the industrial sector in 2000/01 (WECS, 2010). The distribution of the emission by fuel type is shown in Figure 2-3. The industrial energy consumption has increased only by 0.4% annually in last 8 years (WECS, 2010).

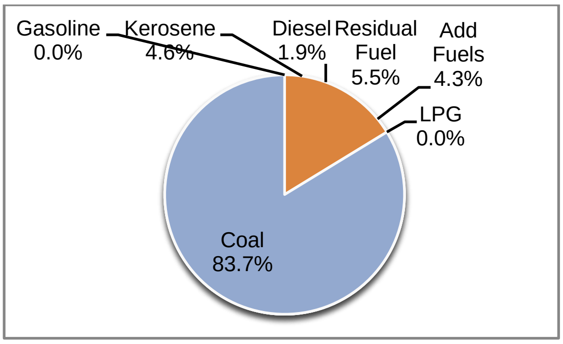


Figure 2-3: Distribution of emission by fuel type in industrial sector (2000/01)

The main end uses in the industrial sector are process heating, motive power, boiling in the boilers and lighting. In 2000/01, the industrial sector in Nepal emitted 829.02 Gg of CO_2 equivalents. Out of this 820.93 Gg was emitted as CO_2, 0.09 Gg as CH_4 and as 0.02 Gg as N_2O. It is clear that 84%of the emission of CO_2, CH_4 and N_2O was due to coal combusted in this activity. The industrial sector also emitted 3 Gg of NOx, 3 Gg of CO and 5 Gg of SO_2.

Energy use in transport sector: Transport is the second largest energy consuming sector after the domestic sector. Due to economic growth in Nepal over the last two decades, the demand for all transport services, particularly road transport and aviation has increased substantially. The total number of registered vehicles in the country has increased from 95.7 thousand in 1990/91 to 1.015 million in 2009/10 (WECS, 2000). Motorcycles and cars/jeeps constitute nearly 85% of the total vehicles. It is very unusual that within ten years, growth of motorcycles' population has been twenty fold.

The transport sector can be divided into five categories while assessing the energy consumption which are, namely, road transport, railway transport, trolley transport, ropeway transport and aviation transport. Energy consumption by sub-sector of the transport sector is heavily dominated by road because it consumes about 86.5% of the total sectoral consumption whereas; the aviation subsector consumes about 13.4%. Energy consumption in the railway, trolleybus, and ropeway subsector is very minimal at even less than 0.5%.

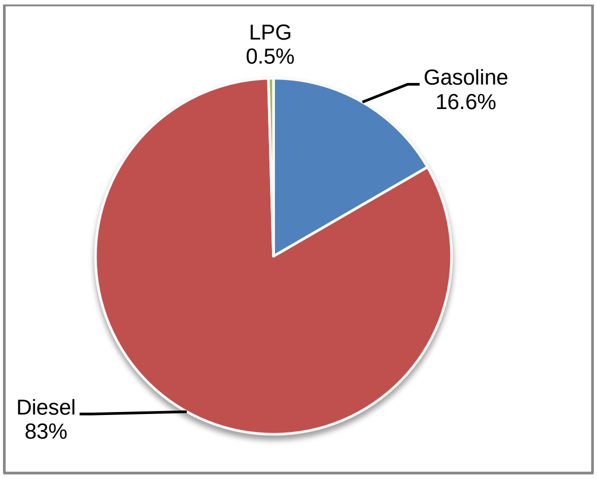


Figure 2-4: Distribution of emission by fuel type in transport sector (2000/01)

The total commercial energy consumption in the transport sector in 2000/01 is estimated to be 13.6 million GJ that includes an array of fuels, such as diesel, petrol, air turbine fuel (ATF), kerosene, electricity and LPG. The distribution of the emission by fuel type is shown in Fig. 2-4. Diesel comprises 67% of total energy used in the road transport sector, followed by ATF (16.7%) and petrol (14.5%) respectively. The rest (1.8%) includes electricity and LPG. Consequently, it is estimated that the transport sector emitted 822.62Gg of CO_2 eq in 2000/01, of which 817.63Gg was emitted as CO_2, 0.09 Gg as CH_4 and 0.01Gg as N_2O. About 83%of the emission of CO_2 was due to diesel combusted in this activity. The transport sector emitted 9 Gg, 25 Gg, 5 Gg and 1 Gg of NOx, CO, NMVOC and SO_2 respectively.

It is well known that CO_2 emission result from the release of carbon in the fuel during combustion and the quantity of emission depends not only on the quantity of the fuel combusted, but also on the carbon content of the fuel, type of the combustion technology, age of equipment, operation and maintenance practices. Most of the carbon is emitted as CO_2 immediately during the combustion process. However, some carbon is released as CH_4, carbon monoxide or non-Methane volatile organic carbon (NMVOC), which oxidizes to CO_2 in the atmosphere within the period of a few days to about 12 years. The quantity of these GHG depends on the technology used in mobile combusting source. GHG emission estimation on the basis of the vehicle specific emission factors called the bottom up approach will provide a true picture of the emission from this sector. An attempt has been made to use the bottom up approach to estimate GHG from the road transport sector. The results are given in the following section.

Methodological issues: In order to use higher-tier levels for calculating road transportation emission, a better understanding of fuel sold and vehicle kilometers travelled is needed for the entire vehicle fleet. The IPCC 2006 Guidelines suggest that, in general, the fuel approach (top-down) is appropriate for CO_2 whereas the kilometer approach (distance travelled by vehicle type and road type), is appropriate for CH_4 and N_2O. A Tier 2 approach (bottom-up) based on fuel consumption and default emission factors is used to estimate the road transport emission for this inventory.

Activity data: In Nepal, vehicle fleet is registered in 12 different Zonal Transport Management Offices (ZTMOs) under Department of Transport Management (DOTM). The fleet consists of all categories of motor vehicles. The vehicle population data published by ZTMO comprises of the cumulative vehicle registration only by vehicle categories. Such figures do not take into account the number of scrapped vehicles. In reality, the later figures are high as compared to actual vehicle operation on the road.

For the first time in 1986, the number of effective vehicles on the road based on the traffic police records of 12 zones were documented (WECS, 1989). The operational factors (ratio of effective vehicles on the road to the cumulative number of registered vehicles) of the cumulative fleet for the year 1986 were then estimated. Again, in 2000, ZTMO reregistered vehicles for changing the registration numbers in Bagmati Zone. This record was used to estimate the operational factors of the cumulative fleet for the year 2000 by WECS (WECS, 2000). The operational factors for the years in between two index years 1986 and 2000 were calculated by varying linearly the difference of operational factors of those two index years (Prajapati, 2000). In 2012, vehicles are being re-registered but the result has not yet been published. The activity data was estimated by using the distance traveled and fuel efficiency approach which was published in WECS report (WECS, 2000). Table 2-16 gives the annual vehicle kilometer travelled and energy intensity data used in this report.

Table 2-16: Average annual kilometer travelled and energy intensity

Fuel	Vehicle	Average Annual km	Energy Intensity, km/l
Diesel	Truck	50336	5.695
Diesel	Bus	50336	5.695
Diesel	Mini bus	50336	5.695
Diesel	Jeep/van	31143	8.942
Diesel	Tractor	17791	5.356
Diesel	Three wheeler	37270	12.187
Motor spirit	car	23097.5	11.238
Motor spirit	motor cycle	10550	44.448
Motor spirit	Three wheeler	15989	6.463
LPG	Three wheeler	7100	2.94
Electricity	Three wheeler	8448	1.167

Source: WECS, 2000

Emission factors: The emission factor is defined as the estimated average emission rate for a given pollutant for a given class of vehicles. The emission factors for in use vehicles vary depending on the vehicle characteristics, operating conditions, level of maintenance fuel characteristics and ambient condition. These factors have to be determined locally. In Nepal, there is no facility to determine emission factors of the in use vehicles. Therefore, IPCC (IPCC, 1998) default values have been used in estimating the pollutant. These values are listed in Table 2-17.

Table 2-17: Emission factors used for Nepal (based on IPCC 1996 guidelines)

Vehicle	Fuel	Gaseous Pollutant (tons/TJ)					
		CO	CH_4	NOx	N_2O	NMVOC	CO_2
Car	Gasoline	13	0.02	0.6	0.001	1.5	73
Motor cycle	Gasoline	13	0.1	0.06	0.001	8.3	73
Truck	Diesel	0.9	0.006	1	0.003	0.2	74
Bus	Diesel	0.9	0.006	1	0.003	0.2	74
Minibus	Diesel	0.4	0.001	0.4	0.004	0.1	74
Jeep/van	Diesel	0.3	0.002	0.3	0.004	0.07	74
Tractor	Diesel	0.3	0.002	0.3	0.004	0.07	74
3 Wheeler	Diesel	0.4	0.001	0.4	0.004	0.1	74
	Gasoline	8.3	0.02	0.07	0.001	1.4	73
	LPG	2.6	0.02	0.9		0.6	65
	Electricity	0	0	0	0	0	
Railways	Diesel	0.61	0.006	1.8	0.002	0.13	75

Source: WECS, 2000

GHG emission: The emission inventory for road transportation in Nepal has been estimated from bottom-up approach. Table 2-18 gives detailed estimates of GHG emission for 2000/01. It is seen that in 2000/01, road transport emitted 914.4 Gg of CO_2, 0.14 Gg of CH_4 and 0.038 Gg of N_2O.

Table 2-18: GHG emission from Transport sector

Fuel: Gasoline

Vehicles	Fuel	Vehicle Population (Thousand)	Total Fuel consumed (TJ)	GHG emission (Tons/year)					
				CO_2	CH_4	N_2O	CO	NMVOC	NOx
Truck/tanker	Diesel	11.872	3979.744	294501	23.88	11.94	1092.2	795.95	3979.74
Bus	Diesel	5.6407	1890.806	139919.6	11.34	5.67	440.82	378.16	1890.81
Minibus	Diesel	1.5123	506.897	37510.37	0.51	2.03	115.19	50.69	202.76
Jeep/van	Diesel	19.244	2542.166	188120.3	5.08	10.17	317.2	177.95	762.65
Tractor	Diesel	11.2	1410.983	104412.8	2.82	5.64	233.06	98.77	423.29
3 Wheeler	Diesel	1.9405	190.003	14060.19	0.19	0.76	38.047	19	76
Car	M.S	12.829	883.047	64462.44	17.66	0.88	4774.7	1324.57	529.83
Motor cycle	M.S	94.166	748.522	54642.15	74.85	0.75	2984.7	6212.74	44.91
3 Wheeler	M.S	3.3041	228.505	16680.9	4.57	0.23	959.99	319.91	16
Total				914309.8	140.9	38.07	29855.2	9377.74	7925.99

A comparison of the GHG emission estimated by the top-down and bottom-up methods is given in Table 2-19. It shows that the bottom-up approach gives a higher value. This might be due to different assumptions made to estimate the GHG emission and default values chosen.

Table 2-19: Comparison of the GHG emission estimated by top down and bottom up methods

Gases	Method		Ratio
	Top down (Gg)	Bottom-up (Gg)	
CO_2	817.63	914.31	1.11
CH_4	0.09	0.14	1.55
N_2O	0.01	0.038	3.80
CO	25	29.85	1.19
NMVOC	5	9.37	1.87
NOx	9	7.9	0.87

Figure 2-5 shows the share of pollutant emission from the following category of vehicles: Heavy Duty Vehicles (HDV) and Low Duty Vehicles (LDV). The HDVs include bus, truck/ tanker, and minibus while LDVs include car, van, pickup, and jeep powered by both gasoline and diesel.

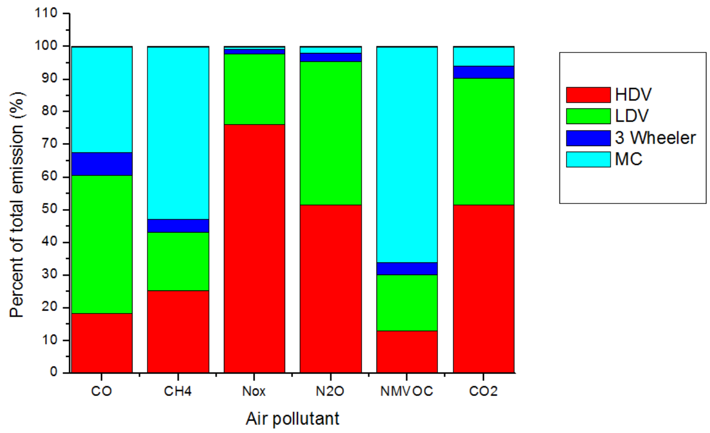


Figure 2-5: Share of pollutant emission from different types of vehicles (2000)

In 2000, HDVs accounted for about 76% of total NO_x emission, 51.5% of total N_2O emission and 51% of total CO_2 emission. The high amount of emission of these pollutants may be attributed to higher diesel consumptions. Low duty vehicles (LDVs) accounted for about 44% of total N_2O, 42% of total CO emission, and 39% of total CO_2 emission. A high share of N_2O may be attributed to higher number of gasoline–operated vehicles. Motorcycles accounted for about 66% of the total NMVOC emission, 52% of total CH_4 emission and 32% of the total CO emission. The higher share of motorcycles in terms of emission is expected as these represent over half of the total vehicular population and also have low average fuel efficiency. The contribution from 3-wheelers is relatively small since these constitute only about 3% of the total vehicles.

(B) GHG Emission from Energy Use in Residential Sector

Energy use in residential sector: The residential sector accounts almost 89% (about 301.1 million GJ) of the total energy consumption of Nepal in 2000/01. The consumption is primarily for cooking, lighting, heating and other household purposes. Usage of LPG as the primary source of cooking by households in urban Nepal exceeded consumption of the same by rural households. Biomass fuels such as fuel wood, crop residues, and animal dung continue to be the dominant fuels used by rural households.

GHG emission: In 2000/01, the residential sector emitted 4854.75Gg of CO_2 equivalent, of which 750.49 Gg was in the form of CO_2 emission, mainly from fossil fuel use in the residential sector. The CH_4 and N_2O emission was 163.26 Gg and 2.18 Gg respectively. The CH_4 emission is found to be driven by the biomass consumption in the residential sector. The residential sector emitted 55 Gg, 2719 Gg and 326 Gg of NO_X, CO and NMVOC respectively. The high amount of emission of the pollutants is attributed to the heavy biomass burning in this sector.

(C) GHG Emission from Energy Use in Commercial Sector

Energy use in commercial sector: The commercial sector accounts almost 1.2% (about 4.128 million GJ) of the total energy consumption of Nepal in 2000/01. In the commercial sector, key activities include lighting, cooking, space heating/cooling, pumping, running of equipments and appliances. Sources of energy for the sector are grid based electricity, LPG, kerosene, diesel, agricultural residue and fuel wood. The commercial and institutional sectors also seek extensive use of captive power generation across the country due to frequent power shortages in various seasons. These

power generation units generally run on diesel. In the urban sector, the important sources of energy are kerosene and LPG.

GHG emission: In 2000/01, the commercial sector emitted 164.05 Gg of CO_2 equivalent, of which 150.66 Gg was emitted as CO_2, 0.49 Gg as CH_4 and 0.01 Gg as N_2O. It also emitted 8 Gg of CO and 1 Gg of NMVOC.

(D) GHG Emission from Energy Use in Agriculture Sector

Energy use in agricultural sector: The energy for agricultural sector came from two types of sources - electricity and petroleum. In the year 2000/01, the agricultural sector consumed about 3.152 million GJ of energy. About 96% of the total energy used in agricultural sector came from petroleum products especially diesel fuel. Only 4% was derived from electricity.

GHG emission: In 2000/01, the agricultural sector emitted 224.2 Gg of CO_2 equivalent, of which 223.57 Gg was in the form of CO_2 emission, mainly from high speed diesel use (refer Table 2-5).

2.5 Trend in GHG Emission from Energy Sector

In 1995/96, Nepal's greenhouse gas emission from the energy sector was 5460 Gg carbon dioxide equivalent (CO_2 eq.) of which 1732 Gg as CO_2, 148 Gg as CH_4 and 2 Gg as N_2O. In 2008/09, the total greenhouse gas emission reached to 7959 Gg CO_2 eq., which is 45.8% higher than the previous level. Table 2-20 gives the GHG emission estimated for the period 1995/96 to 2008/09.

Table 2-20: Trend of GHG emission from energy sector (in Gg)

Emission	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
CO_2(Gg)	1732	1804	2013	2143	2989	2763	2770	2679	2754	2558	2862	2531	2548	2871
CH_4(Gg)	148	151	154	157	161	164	171	174	178	182	185	189	193	198
N_2O (Gg)	2	2	2	2	2	2	2	2	2	2	3	3	3	3
CO_2eq.(Gg)	5460	5595	5867	6060	6990	6827	6990	6953	7112	7000	7677	7430	7537	7959

The compound annual growth rate (CAGR) of CO_2 emission from the energy sector between 1995/96 and 2008/09 was 2.94% (Table 2-21). On a subsector basis, the maximum growth in emission is from the transport sector (7.34%) followed by the industrial sector (2.38%) and other sectors (2.29%).

Table 2-21: Trend of GHG emission from fuel combustion

Sectors	GHG emission in Gg CO_2 eq.			CAGR** in% (1995/96-2008/09)
	1995/96	2000/01	2008/09	
Industrial	552	821	750	2.38
Transport	527	818	1325	7.34
Others*	4380	5189	5884	2.29
Total	5459	6828	7959	2.94

*Commercial, residential, agricultural. ** CAGR: compounded annual growth rate.

Inventory reporting under the Climate Change Convention covers three more direct GHGs besides CO_2, CH_4, and N_2O, which are: sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). But, energy sector does not emit SF_6, PFCs and HFCs. Figure 2-6 shows the estimated values of GHGs for the period 1995/96 to 2008/09.

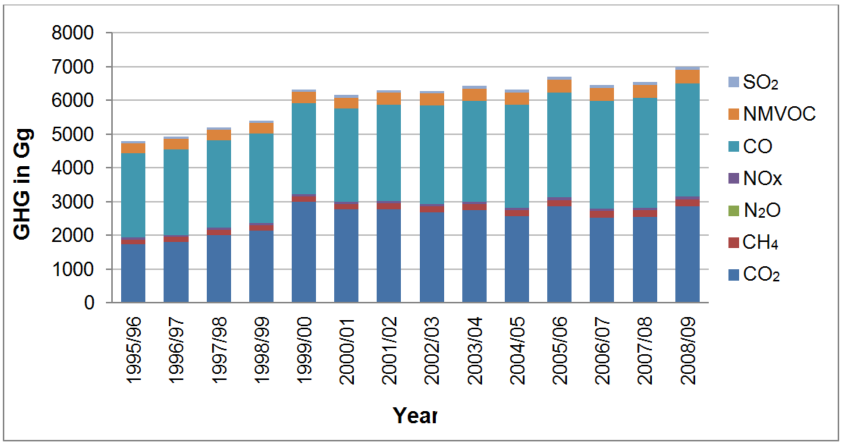


Figure 2-6: Nepal's GHG emission by gas from energy sector between 1995/96 to 2008/09

Carbon dioxide emission in 1995/96 was 1732 Gg accounting for 31.7% of total GHGs emission. CO_2 emission increased at a steady pace and reached a maximum value of 2989 Gg in 1999/2000. In the latter years, the values of CO_2 emission decreased slowly. This can be attributed to the decrease in fossil fuel consumption due to the unusual situation of the country. Methane emission in 1995/96 was 3108 Gg (in CO_2 eq.), accounting for 56.9% of the total GHG emission. In 2008/09, CH_4 emission increased by 1050 Gg in CO_2 eq. (33.78%) to 4158 Gg (CO_2 eq.). Likewise, nitrous oxide emission in 1995/96 was 620 Gg (in CO_2 eq.), accounting for 11.3% of the total GHG emission. In 2008, N_2O emission increased by 310 Gg in CO_2eq. (33.3%) to 930 Gg (in CO_2eq.). Likewise, the indirect GHG emission of NOx, CO, NMVOC and SO_2 is also reported in the inventory (Table 2-22). Following UNFCCC reporting guidelines (UNFCCC, 2006), indirect GHGs are not included in Nepal's GHG emission total.

Table 2-22: Emission of GHGs in 1995/96, 2000/01, and 2008/09

Gases	GHG Emission in Gg CO_2eq.			Change from 1995/96 (Gg)	Change from 2000/01	CAGR* in% (1995/96-2008/09)
	1995/96	2000/01	2008/09			
NOx	58	67	83	+25 (43.1%)	+16 (23.8%)	2.79
CO	2487	2755	3340	+853 (34.3%)	+585 (21.23%)	2.29
NMVOC	299	332	404	+105 (35.1%)	+72 (21.7%)	2.34
SO_2	66	76	90	+24 (36.36%)	+14 (18.42%)	2.41

* CAGR: compounded annual growth rate.

Emission of NOx and CO is largely from the residential sector due to biomass combustion. In 2008/09, emission of NOx from the residential sector comprised 80.2% of total NOx emission. Other sources of NOx emission were the transport (16.86%) and industrial sector (3.6%). The CAGR of NOx emission between 1995/96 and 2008/09 was 2.79%. Similarly, emission of CO from the residential sector comprised 98.5% of the total CO emission. In 2008/2009, the emission of CO increased by 34.3% from the emission values of 1995/96 with the CAGR of 2.29%.

The residential sector was also the largest producer of NMVOCs, producing 97.7% of NMVOC emission in 2008/9. Emission from road transportation comprised 2.22% of total NMVOC emission. In 2008/9, NMVOC emission increased by 21.7% from the 1995/96 value. The CAGR of NMVOC emission between 1995/96 and 2008/09 was 2.34%. In 2008/09, emission of SO_2 from the residential sector comprised 93.3% of the total SO_2 emission. The industrial sector contributed 3.33% and the transport sector 2.22% of total SO_2 emission. The CAGR of SO_2 emission between 1995/96 and 2008/09 was 2.41%.

2.6 GHG Emission from Industrial Processes

GHG emission occurs from a variety of industrial activities which are not related to energy. The main emission sources are industrial production processes which transform the materials chemically or physically. During these processes, many different greenhouse gases, including CO_2, CH_4, N_2O, and PFCs, are released. Nepal is not an industrial country as such. There are very few industries which are important from the perspective of GHG inventory. These are mineral production, food and beverage and paper industries. In this inventory, CO_2 and SO_2 have been estimated from cement production while CO_2 has been estimated from lime production industries. Emission of NMVOC from food and drink industries has been estimated by using the IPCC method. Paper industries emit NOx, NMVOC, CO and SO_2 but reliable data on the production of paper are not available. The limited available data shows that their contribution to indirect GHG is negligible, hence it is not considered in this report.

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) are used as alternatives to ozone depleting substances. Current and expected applications of these compounds include refrigeration and air-conditioning, fire extinguishing, aerosols, solvents, and foam production. These chemicals are either emitted instantaneously or slowly being leaked out over time. In Nepal, halocarbons or high global warming potential gases are also consumed in very small quantities. However, due to lack of reliable data, emission of these gases is not recorded in this report.

Methodology and choice of emission factors: For estimating the GHG emission from the industrial processes, the IPCC 1996 revised guidelines (IPCC, 1997) have been used for each of the categories. The activity data for the various industries are sourced from the Central Bureau of statistics, and the annual reports of the various ministries of the Government of Nepal. The emission factors used in this inventory are presented in Table 2-23.

Table 2-23: Emission factors used for industrial processes

Category	Gas	Emission Factor	Source
Cement production	CO_2 SO_2	0.4985 t CO_2/t cement produced 0.3 kg SO_2/t cement produced	IPCC (1996)
Lime production	CO_2	0.79 t CO_2/t quicklime produced	IPCC (1996)
Food and drink	NMVOC	0.035 kg NMVOC/hL beverage produced 10 kg NMVOC/t sugar produced 1 kg NMVOC/t animal feed produced 1 kg NMVOC/t biscuits produced	IPCC (1996)

GHG Emission for the base year 2000: In 1994, the industrial processes sector was the smallest source of emission in Nepal's GHG inventory (INC, 2004). In this inventory also, this sector is again the smallest source of emission. This reflects the country's poor industrial activities. The summary of GHG emission from the industrial processes sector is given in Table 2-24.

Table 2-24: GHG emission from the Industrial process (Gg)

Industry	CO_2	SO_2	NMVOC
Minerals Products	130.86	0.07	
Cement production	118.55	0.07	
Lime production	12.31		
Metal production	0.1		
Iron and steel production	0.1		
Other production			1.06
Food and drink			1.06

In 2000/01, the total CO_2 emission from this sector was 130.96 Gg. It emitted 0.07 Gg of SO_2 and 1.06 Gg of NMVOC.

According to the IPCC (1996) guidelines, the emission is grouped into the following sub-categories: mineral production, metal production and other production. GHG emission from these categories is given in the following sections.

(A) Mineral Production: Emission from mineral products is mainly process-related carbon dioxide emission resulting from the use of carbonate raw materials. For the 2000/01 inventory, this source sub-category included cement production, and lime production. The most significant emission came from cement production (contributing 90.7% of emission for mineral) followed by lime stone production. The trend in this category is shown in Table 2-25. It can be seen that there is no fixed trend in the GHG emission from cement and lime production. This might be due to many factors including the unavailability of raw material, fuel, labor etc.

Table 2-25: CO_2 emission from mineral production and NMVOC from food and drink production

Year	Cement Production CO_2 in Gg	Lime Production CO_2 in Gg	Food and drink NMVOC in Gg
1995/96	225	0	0.69
1996/97	134	0	0.69
1997/98	160	0	0.69
1998/99	148	0	0.70
1999/00	122	15	1.17
2000/01	119	12	1.05
2001/02	178	19	0.95
2002/03	134	10	1.03
2003/04	193	307	1.01
2004/05	131	208	NA
2005/06	200	318	NA
2006/07	220	1	1.04
2007/08	208	555	NA
2008/09	171	461	NA

Note: NA: Activity data are not available

Sulphur dioxide (SO_2) is emitted in small quantities from the cement-making process. The amount of SO_2 is determined by the sulphur content of the limestone. 75 to 95% of the SO_2 emission is absorbed by the alkaline clinker product (IPCC, 1996). The emission factor for SO_2 used in this report is the IPCC default value. In 2000/01, SO_2 emission was 0.07 Gg which did not appear in the summary report because it is less than 0.5 Gg. It is well known that the IPCC software takes any value less than 0.5 as zero and any value greater than 0.5 as one. In other years also, SO_2 emission values are less than 0.5 Gg. Hence, these are not tabulated.

(B) Food and Drinks Production: Emission of NMVOCs is produced during the fermentation of cereals and fruits in the manufacture of alcoholic beverages. Such emission is also produced during all processes in the food chain that follow after slaughtering of animals or harvesting of crops. Estimates of NMVOC emission for the period 1995–2008 have been calculated using Nepal's production figures from the Central Bureau of Statistics and default IPCC emission factors (IPCC, 1996). In 2000/01, NMVOC emission was estimated to be 1.05 Gg, an increase of 0.32Gg from the 1995/96 level of 0.69 Gg.

(C) Consumption of Halocarbons and Sulphur Hexafluoride: Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) are used in a wide range of equipment and products from refrigeration systems to foam blowing. No HFCs or PFCs are manufactured within Nepal. The use of synthetic gases, especially HFCs, has increased since the mid-1990s when

chlorofluorocarbons (CFCs) and hydro-chlorofluorocarbons (HCFCs) began to be phased out under the Montreal Protocol. In Nepal, the Ozone Depleting Substance (ODS) Consumption Act 2001 sets out a program for phasing out the use of ozone-depleting substances by 2010. In 1999, Nepal consumed 30 tons of CFC and 23 tons of HFC (NBSM, 2004). Nepal does not export HFCs. Therefore, the total emission of HFC in 1999 can be taken as 23 tons. But for the base year 2000, data are not available, and hence not reported.

2.7 GHG Emission from Agricultural Sector

2.7.1 Overview

Nepal is an agrarian country with 79% of 4.25 million households involved in agricultural production which contributed 35% to the gross domestic production. However, being a central Himalayan country, only about 21% of land area is under agricultural activities (ABPSD, 2010). With mostly smallholder farmers of average farm size 0.7 ha, agriculture contributes only 50% to their household income. Nevertheless, it is a major source of employment supporting the livelihood of 65% of the labor force that is higher in rural areas (ABTRACO, 2008). With the limited affordability and availability of chemical fertilizers, 80% of the farmers integrate livestock and poultry in their crop farming to meet milk and meat requirements and to supply manure in lieu of chemical fertilizers. The livestock are also used for draft power instead of machines thus reducing the need for fossil fuel in agriculture.

In Nepal, the practice of agriculture is traditional. Draft power is based on human labor and bullocks. Use of machineries and fossil fuels is very limited, and the emission of CO_2, though included in the energy-related emission, is negligible. However, agriculture is one of the major sources of CH_4 and N_2O emission through livestock production, farm yard manure management, rice cultivation and soil management. The GHG inventory for agriculture is developed using the following scoping framework: CH_4 emission is attributed to enteric fermentation, manure management, rice cultivation, and soil management whereas N_2O and NOx emissions are attributed to manure management, and soil management.

Other sources of GHGs such as savannas burning are not relevant for Nepal and excluded from the inventory. In agricultural burning, the CO_2 released is not considered to be the net emission and the long term net emission of CO_2 from the burning of crop residues are considered to be zero (IPCC 1997). Though other GHG emission from residue burning comes under the net emission, necessary data are not available in Nepal.

2.7.2 Method and Choice of Emission Factors

The quantification of the emission was done by multiplying the eligible activity data for agriculture obtained from published government sources by the respective emission factors obtained from the source category for a specified gas as the Emission Factor Database (EFDB) default value of the revised 1996 IPCC guidelines (IPCC, 2006). Annex A of the Kyoto Protocol identifies agricultural emission sources such as enteric fermentation, manure management, rice cultivation, and field burning and soil management. The estimates from the entire source are aggregated to find the annual emission figures. The time series emission data was obtained by estimating the annual emission from the year 1996 to 2009 in addition to the base year 2000. As the annual data in Nepal are available according to the Nepalese fiscal year (16 July to 15th July of the next year), the reported data for the year are the data for the fiscal year beginning in that calendar year. For example, the data for the fiscal year 2000/01 is taken as the data for the calendar year 2000.

The standard methodologies recommended by the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) were used. IPCC Good Practice Guidance and uncertainty management in the national greenhouse gas inventories (IPCC 2000) was referred. More specifically, the reference manual of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories was followed to quantify the level of GHG emission from agriculture. Module 4 of the software recommended by the IPCC was used for estimation purpose using the national data on activity levels reported by the Government of Nepal and emission factors reported by the EFDB. The EFDB released at the 8^{th} session of the Conference of the Parties to the UNFCCC in October 2002 (with amendments) was used. The future projections of GHG emission show that methane emission in Nepal will reach to 614 Gg by 2015, 730 Gg by 2025 and 796 Gg by 2030. Similarly, the N_2O emission is feared to reach to 40 Gg by 2030. As a result, the total emission from Nepal is likely to reach to 835 Gg in the year 2030. Though national level emission factors were preferred, such emission factors are not available from the published sources. While selecting the emission factors reported by IPCC, preference is given to those reported for the Indian sub-continent to the extent that such figures are available.

2.7.3 GHG Emission for Base Year 2000

(A) Emission from enteric fermentation and manure management: Cattle are the most important livestock in Nepal which is integrated with crops/horticulture for the livelihood of the smallholder farmers. Commercial dairy farms are very limited. Cattle farming is a major source of methane emission from enteric fermentation. Cattle farming in Nepal is mainly fodder based rather than feed based and expected to have a lower level of methane emission per head than that from feed based intensive livestock farming. Methane emission from manure management is reported to be usually smaller than that from enteric fermentation emission, and is principally associated with confined animal management facilities where manure is handled as a liquid (IPCC, 1997). However, manure is handled as a dry lot in Nepal.

As a cattle farming in Nepal is generally semi-range-based, the emission from manure management per capita is expected to be lower than the coefficient reported by the IPCC database. A national level emission factor is, however, not available. Methane is produced when the organic dung is decomposed in an anaerobic environment, but the smallholder farmers manage the dung in small heaps exposing most part of it and reducing the chance of anaerobic action on it. As the manure in the country is stored in small heaps or pits and not generally stored as a liquid in ponds or lagoons, methane emission is expected to be low. Sub-module 1 is used for estimating methane and nitrous oxide emission from livestock and manure management. The activity data was obtained from the publications of Ministry of Agriculture and Cooperatives and the emission factors from the IPCC database.

Methane emission from domestic livestock from enteric fermentation and manure management was 468.52 Gg in the year 2000. Similarly, nitrous oxide emission from animal waste management systems (AWMS) was 7.65 Gg.

(B) Emission from flooded rice field: Rice cultivation in Nepal is practiced under flooded conditions. As flooding limits the supply of oxygen at the deeper layers, anaerobic decomposition of organic material in flooded rice field produces methane. Though rice production in some part of the country, particularly under low lying conditions is flooded, rice farming in most of the hill slopes is practiced under small terraces with limited water supply. Continuous flooding is neither possible due to limited water nor feasible under the hilly terrains. Some portion of the rice is even grown under upland conditions without any irrigation. Therefore, methane emission from such rice fields in Nepal is expected to be much lower than that from rice cultivation under continuous flooding. The activity data such as area under the rice crop was obtained from the publications of the Ministry of Agriculture and Cooperatives and the emission factors for respective water management regimes from the IPCC database. The emission coefficients were selected to fit the country situation of rice farming.

It should be noted that in Nepal, rice area disaggregation is available only by irrigated and un-irrigated categories. Thus, the classification of paddy land by the national system does not match with the system adopted by the Module 4 of the IPCC guideline. So, taking guidance from the Initial National Communication (INC) and also from the IPCC, the area under different water management regimes was apportioned using the judgment of agronomists working in the country. Using emission factors defined in the IPCC database, methane emission from the rice field is estimated at 1.57 Gg per year.

(C) Emission from savanna burning: Savanna burning is not recorded in Nepal.

(D) Emission from field burning of agricultural residues: A few case studies report that agricultural residues are burnt in the field but such data are not available at the national level. Emission factors such as carbon fraction and nitrogen fraction from burning agricultural residues are also not available in Nepal. Moreover, there are limited practices of field burning of agricultural residues; so, emission from this activity is negligible. Moreover, as the biomass burned is generally replaced by re-growth over the subsequent year, the CO_2 released is not considered to be the net emission. An equivalent amount of carbon is removed from the atmosphere during this re-growth to offset the total carbon released from combustion. Therefore, the long term net emission of CO_2 is considered to be zero (IPCC 1997). Hence, emission from this activity is not included in the estimation.

(E) Emission from agricultural soils: Use of synthetic fertilizer, nitrogen from animal wastes, nitrogen from increased biological N-fixation, and nitrogen derived from cultivation of mineral and organic soils through enhanced organic matter mineralization are sources of nitrous oxide emission from the soil (IPCC 1997). As the application of synthetic fertilizers is very low (25 kg of nutrients/ha), the emission is also low. The farming technologies and soil management practices followed in Nepal do not perfectly match with those reported by the EFDB of the IPCC. The nearest possible technologies and practices were identified to match them with the emission factors reported by the IPCC. As no emission factor is found reported in Nepal for such activities, the IPCC EF is used for inventorying GHG from the agriculture sector as a whole.

Table 2-26 summarized emissions from the agricultural sector. The direct nitrous oxide emission from agricultural fields, excluding cultivation of histosols was found to be 13.26 Gg per year. As the histosols are not reported from Nepal, the direct nitrous oxide emission from cultivation of histosols is considered to be zero. Nitrous oxide soil emission from grazing animals from pasture range and paddock was estimated to be 3.37 Gg per year. Similarly, indirect nitrous oxide emission from atmospheric deposition of NH_3 and NO_X are found to be 0.78 Gg per year. Likewise, indirect nitrous oxide emission from leaching was 2.08 Gg per year. In aggregate, methane emission from Nepalese agriculture during the year 2000 was found to be 470 Gg. Similarly, nitrous oxide emission was 27 Gg for the same year.

Table 2-26: Summary of emissions from agriculture sector in base year 2000

Sub-module	Source	Gases	Emission Gg/year		
			Methane	Nitrous oxide	Total
4-1s1	Domestic livestock	Methane emission from domestic livestock enteric fermentation and manure management	468.52	0	468.52
4-1s2	Domestic livestock	Nitrous oxide emission from animal production emission from animal waste management systems (AWMS)	0	7.65	7.65

Sub-module	Source	Gases	Emission Gg/year		
			Methane	Nitrous oxide	Total
4-2s1	Rice field	Methane emission from flooded rice fields	1.57	0	1.57
4-5s1	Agricultural soils	Direct nitrous oxide emission from agricultural fields, excluding cultivation of histosols	0	13.26	13.26
4-5s3	Agricultural soils	Nitrous oxide soil emission from grazing animals - pasture range and paddock	0	3.37	3.37
4-5s4	Agricultural soils	Indirect nitrous oxide emission from atmospheric deposition of NH_3 and NO_X	0	0.78	0.78
4-5s5	Agricultural soils	Indirect nitrous oxide emission from leaching	0	2.08	2.08
		Total emission	470.08	27.14	497.22

2.7.4 Trend in GHG Emission

The time series estimates of GHG emission from Nepalese agriculture are prepared using Module 4 of the IPCC Guidelines, and the results are presented in Table 2-27. The methane emission, which was 450 Gg in the year 1996, reached 564 Gg in the year 2009. Similarly, the nitrous oxide emission which was 25 Gg in the year 1996, reached 30 Gg in the year 2009. Though the emission of these gases is increasing over the years, the growth is very slow, corresponding to the slow growth in the agricultural economy.

Table 2-27: Change in emission of methane and nitrous oxide over the years

GHG	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4 (Gg)	450.83	456.16	459.71	464.01	470.08	475.35	484.38	492.91	502.66	511.77	525.11	535.91	551.53	564.30
N_2O (Gg)	24.96	25.12	26.10	26.52	27.14	27.35	27.97	28.26	28.39	28.49	28.73	29.11	29.29	30.14

The methane emission estimated for the year 1996 is nearly half of the methane emission in 1990 reported by DHM (1997). But, the estimated nitrous oxide emission is 31 times more than the emission reported in 1990 from the same study. The methane emission reported by MOPE (2004) for the year 1994 was smaller than that reported by DHM (1997). However, N_2O emission reported by MOPE (2004) is closer to the present estimate. Such discrepancies in emission reporting can be attributed to changes in the definitions of activity data. In earlier studies (DHM, 1997; MOPE, 2004), for e.g., whole of the paddy area in the country was taken as if it were under the continuous flooding. But, later on, it was realized that paddy crops in most parts of the country is grown under water stress and multiple aerations are very common. In addition, the inclusion of the activities in the estimation and selection of the emission factor also affected the estimates. For example, emission from manure management was not included in the 1990 inventory. For the 2000 inventory, the most suitable emission factors (EFs) are selected from the IPCC database. The most suitable EFs for agriculture in Nepal are those reported for the Indian sub-continent. Other international EFs are used only when more suitable EFs are unavailable.

2.8 GHG Emission from Land Use, Land Use Change and Forestry

2.8.1 Overview

It is estimated that 18-25% of global GHG emission results from deforestation (Stern, 2006), which is more than the emission from the entire transportation system. The world's forest vegetation and soils contain twice as much carbon as exists in the Earth's atmosphere. Forest acts as both sink and source. Forest clearing for agriculture and other purposes has been a dominant factor in determining the extent and condition of the world's forests (IUFRO, 2007). This loss accounts for about 20% of the global carbon emission, making land cover change the second largest contributor to global warming (IPCC, 2007). Forests, therefore, play a vital role in any initiative to combat climate change: by altering, balancing, and storing the carbon flux. Different land use types of Nepal are depicted in Table 2-28. The data reveal that out of the total land area of the country, forest comprises around 4.27 million hectares (29%), 1.56 million hectares of shrub land (10.6%). 12% of grassland, 21% of farm land, and about 7% of uncultivated inclusions.

Table 2-28: Land use in Nepal

Categories	Area (Million ha)	Area (%)
Forest	4.27	29.0
Shrub land	1.56	10.6
Grass land	1.77	12.0
Farm land	3.09	21.0
Uncultivated inclusions	1.03	7.0
Water, streams and river beds	0.38	2.6
Urban and industrial area	2.62	17.8
Total	14.72	100.0

Source: DFRS 1999 and MPFS 1989

Land use classes other than forest and shrub cover 60.4% of the total land area of Nepal. This report uses the data collected from the National Forest Inventory (NFI, 1999), which refers to the year 1994 although the results were published in 1999. While comparing the NFI results with the Land Resource Mapping Project (LRMP) results from 1987/1989, the following points encapsulate the forest and shrub cover change:

- In the Terai plain, forest area decreased at an annual rate of 1.3% from 1987/89 to 1990/91.
- In the hills, forest area decreased at an annual rate of 2.3% from 1987/89 to 1994, but there is an increase in shrub area. Forest and shrub together have decreased at an annual rate of 0.2%
- In the whole country, from1987/89 to 1994, 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%

The historical inventory data of Nepal shows a change in the area covered by forest and shrub (Table 2-29). This trend has prevailed from 1954 to the latest NFI study (1994). However, Only HMG/USAID data of 1965, LRMP data of 1978-79 and NFI (1994) data are comparable because these assessments include techniques of aerial photo interpretation (NFI, 1999; Oli and Shrestha, 2009). It is evident that the total forest and shrub cover has been dwindling.

Table 2-29: Forest and shrub cover change

Forest Area Including Shrub		Source
(K ha)	%	
4857	33	E. Robbe, FAO 1954
6697	45.5	Forest Resource Survey HMG/N, USAID 1965
4268	29	Nelson Report 1975
6285	42.7	Land Resources Mapping Project (LRMP), 1987-89
6211	42.2	Master Plan for Forestry Sector (MPFS), 1985-86
5828	39.6	National Forest Inventory (NFI), 1994

Macro-level studies reveal that Nepal's forest coverage and condition has significantly improved due to the Community Forestry (CF) intervention. Several publications show that the abrupt change in the context inside and outside the forest is due to people centered forest resource management approach. The Forest Resources Assessment supported by the Government of Finland is ongoing which is expected to update the status of forests in Nepal. The NFI results are more appropriate to use for base year 2000 with necessary correction, wherever possible and whenever required.

Change in forest and other woody biomass stock: Forest land use and forest management and utilization are dynamic and interacting. Firewood is the main source of energy used for household consumption. Besides, firewood is also used for the preparation of agricultural implements. The MPFS (1989) projection of forest products use for the year 2000 shows that the demand figure is greater than supply (Table 2-30). The deficit in supply hinted that demand is supplemented by over cutting of the products, mainly from the national forest. Nepal's forest, however, is not free from heavy lopping, open grazing and illicit cutting.

Table 2-30: Supply and balance status of forest products

Forest Products	Supply and Balance	Year 2000	Balance
Firewood (million ton)	Supply	13.8	-1.6
	Demand	15.2	
Timber (million ton)	Supply	1.6	-0.9
	Demand	2.5	

Furthermore, rural households consumed all forms of biomass fuel, which includes fuel wood from stems, branches, and twigs, agricultural residues and dung. Urban households and industries such as the brick industry consume mainly fuel wood. Since the intervention of the CF program and Leasehold forest program which are community based participatory forest management programs, forest quality and quantity is believed to be on the increase. DOF (2002) estimated that the Leasehold forestry program planted 23,771 number of saplings/seedlings over a ten years period. FAO (2010) reported that 133,000 ha area is planted forest, which is used in this report. A total of 3,251,000 seedlings were planted through the CF Program (DOF, 2002). The report further documented that an area of 2,527 ha is planted under the community plantation program.

2.8.2 Methodology of Estimation

The steps involved to estimate carbon sink in the country are as follows:

- Estimation of the forest area
- Categorization of the forests area into forest types according to IPCC guidelines
- Estimation of number of trees increased in private farms.
- Calculation of biomass growth from forests in terms of dry matter
- Conversion of the biomass growth into carbon and finally to carbon dioxide in terms of weight.

To calculate changes (emission or removal) in the forest and other woody biomass stocks, total plantation area, forest and shrub area, and trees outside the forest were considered. The annual growth rate for plantation forest was taken as 6.8 tones dm/ha/yr (refer IPCC, 1996: Workbook pp 5.5) assuming planted area of Nepal falls under tropical mixed category form. Total consumption of firewood data given in WECS (2010) report is utilized to estimate GHG emission.

The growth rate of vegetation has a significant contribution to the country's GHG sink. However, at present, the growth rate of Nepal's forest as per the IPCC defined criteria is not available. The growth rate of Nepal's forest estimated by different agencies varies widely (see Table 2-31). The growth rates given in IPCC (2003) are lower while the values in the WECS (2010) report are comparatively higher. However, WECS's estimation does not represent the natural growth condition of forest – the growth rate was presented only for forest below 25 years.

Table 2-31: Growth rate by vegetation type

S.N.	Physiographic Zone	Equivalent vegetation zone	Growth rate kt dm/ha/year by sources		
			MPFS (1998)	WECS (2010)	IPCC (2003)
1	High Himal	Montane dry	3.872	5.8	1.5
2	High mountains	Montane moist	4.635	5.8	1.0
3	Mid mountains	Dry	3.086	7.9	1.0
4	Siwalik	Tropical moist with long dry season	5.389	9.6	3.0
5	Terai	Tropical wet/very moist	7.418	9.6	3.4
		Average	4.880		

On the other hand, the estimations of growth rate by MPFS are based on field based research. Therefore, the MPFS growth rates are adopted in the SNC. Furthermore, although vegetation of Nepal has been classified using the IPCC (1996) criteria, there is a lack of corresponding forest inventory data. To overcome this shortcoming, the five physiographic zones are considered to be the close representatives of the five vegetation zones.

Table 2-32 shows that the Terai forest i.e. tropical wet forest has the highest growth rate of biomass (7.418 kt dm/ha/yr) whereas dry forest (3.086 kt dm/ha/yr) has the lowest growth rate. On an average, the forests' growth rate of biomass is 4.880 kt dm/ha/yr. The annual growth rate for trees outside the forest per thousand trees was calculated by considering the average biomass increment for Nepal, i.e. 5.7 kg/year/tree. This was then converted into per thousand trees assuming stocking 2500 trees per ha. The default value of carbon fraction of dry matter adopted is 0.5. The total annual carbon uptake from woody biomass increment including trees outside forest was found to be 14,194.35 kt C.

Table 2-32: Total carbon uptake through increment in forest, plantation and trees outside forest

Forest category	Area of Forest/ Biomass Stocks (k ha)	Annual Growth Rate (t dm/ha)	Annual Biomass Increment (kt dm)	Carbon Fraction of Dry Matter	Total Carbon Uptake Increment (kt C)
Mixed hardwood plantation	135.5	6.81	922.76	0.5	461.38
Wet/Very moist	99.86	7.14	713.00	0.5	356.50
Moist, long dry season	863.43	5.389	4,653.02	0.5	2,326.51
Dry	83.16	3.086	256.63	0.5	128.32
Montane moist	2211.47	4.635	10,250.16	0.5	5,125.08
Montane dry	642.07	3.872	2,486.10	0.5	1,243.05
Shrub	1753.00	2.1	3,681.30	0.5	1,840.65
Grassland	1769.4	2.1	3,715.74	0.5	1,857.87
Number of trees (1000s of trees): 300000 Annual growth rate (kt dm/1000 trees): 0.0057			1,710.00	0.5	855.00
				Total	14,194.35

Moreover, the total biomass consumed for the base year 2000/01 was about 15445.72 kt dm, which is the sum total of biomass consumption from commercial harvest, total traditional fuel wood used, and total other wood use (Table 2-33). The total harvest of round wood was 47269.8 m^3 (DOF, 2002). The total traditional and other wood statistics for the base year 2000/01 were taken from WECS (2010).

Table 2-33: Total biomass consumption

Total Biomass Removed in Commercial Harvest (kt dm)	Total Traditional Fuel wood Consumed (kt dm)	Total Other Wood Use (kt dm)	Total Biomass Consumption (kt dm)	Wood Removed From Forest Clearing (kt dm)
4.80	15,308.42	132.50	15,445.72	3,181.71

As shown in Table 2-34, the total biomass consumption from stock was about 12264.01 kt dm. Similarly, the total net carbon uptake from forest and other wood biomass stocks was 8062.25 kt dm. This total net carbon uptake from forest was obtained from the total carbon uptake from the increment minus annual carbon release. Upon multiplying the total net carbon uptake (8,062.35 kt dm) by carbon factor, i.e., 44/12 we obtain 29561.96 Gg of CO_2, which was removed from the atmosphere due to biomass increment of forest and other woody biomass stocks of Nepal. In summary, the forestry sector of Nepal including grassland uptake 29561.96 Gg of CO_2 annually.

Table 2-34: Annual CO_2 emission/removal from changes in forest and other woody biomass stocks

Total Biomass Consumption From Stocks	Annual Carbon Release (kt C)	Net Annual Carbon Uptake (+) or Release (-)	Convert to CO_2 Annual removal (Gg CO_2)
12,264.01	6,132.00	8,062.35	29,561.96

It should be noticed that the net carbon uptake estimated by using different growth rates given in Table 2-6 yields significantly different carbon uptake values. For example, using IPCC (2003), the default growth rate values, we obtained carbon uptake values as 1735 Gg, which is the lowest.

2.8.3 GHG Emission

(A) Carbon dioxide emission from forest land conversion: Forest clearing is one of the major problems of Nepal and is usually accomplished by cutting the undergrowth and felling trees followed by burning the biomass onsite and offsite as fuel wood. The average biomass stock of Nepal ranges from 184 to 234.4 tons/ha (DFRS, 1999; Oli and Shrestha, 2009). For Nepal commercial harvesting of tracts of forest land is not practiced yet. However, extraction by the Timber Corporation of Nepal (TCN), District Forest Products Supply Committee and external consumption of timber from the CFs and District Forest Office are considered as commercial harvesting of forest. Generally, forest clearance happens in double steps: (1) forest to shrub land, (2) shrub land to cultivated land. These double step statistics were hardly updated annually. Consequently, for this report, the statistics of NFI (1999) and FAO (1993) were taken as reference statistics based on which the rates of loss were calculated, and finally the area of land converted annually for all category of forests calculated. As there is a direct correlation between forest loss and increase in shrub cover, the till date reported forest clearance data was used for the loss of shrub cover as reported in DOF (2002).

The statistics of forest and shrub cover of Nepal shows typical fluctuation from 1954 to 1994. It is witnessed that forest loss of Nepal is constantly increasing, which also had significant effect in changes of growing stocks and biomass. Nevertheless, biomass on the land is not fully cleared as the re-growth in agricultural use is also accounted in the process. Although the default value is 10 tons of dry matter per hectare (IPCC, 1996), a value of 16.1 tons of dry matter per hectare is adopted in this report, as recommended by WECS (2001), considering that the land contains woody perennials. The same value was also used in the Initial National Communication (INC). Table 2-35 depicts the biomass lost from forest conversion, which shows that 10,605.71 kt dm of biomass is lost annually.

Table 2-35: Biomass lost from forest clearing

Vegetation types	Area Converted Annually (kha)	Biomass Before Conversion (t dm/ha)	Biomass After Conversion (t dm/ha)	Net Change in Biomass Density (t dm/ha)	Annual Loss of Biomass (kt dm)
Wet/ very moist	1.958	225	16.1	208.90	408.94
Moist, long dry season	16.925	100	16.1	83.90	1,420.04
Dry	1.630	75	16.1	58.90	96.02
Montane moist	43.350	190	16.1	173.90	7,538.62
Montane dry	12.586	40	16.1	23.90	300.81
Shrub	70.25	16	10.0	6.10	428.53
Plantation	3.25	137	10.0	127.00	412.75
Subtotal	149.949			682.60	10,605.71

Area conversion rate is found to be higher in montane moist category of forest and least is found in the tropical wet category. Likewise, loss of plantation area per annum was adapted from MoPE (2004). Biomass-before-conversion values adopted are IPCC-defined default values. However, for montane dry forest, the lowest value under the tropical forest category has been adopted.

The quantity of biomass burned on site was computed by multiplying the annual loss of biomass (see Table 2-35) and the fraction of biomass burned on site (see Table 2-36). The fraction of biomass oxidized on site and the carbon fraction of the above ground biomass (AGB) are default values. Similarly, on multiplication of the quantity of biomass oxidized on site and carbon fraction yields the quantity of carbon released from the biomass burned on site in kilotons of carbon, i.e. 954.51 kt C (see Table 2-36 last column).

Table 2-36: Carbon released from onsite burning of biomass

Vegetation types	Fraction of Biomass Burned on Site	Biomass Burned on Site (kt dm)	Fraction of Biomass Oxidized on Site	Biomass Oxidized on Site (kt dm)	Carbon Fraction AGB* (Burned on Site)(kt C)	Carbon Released (from Burned Biomass) (kt C)
Wet/ very moist	0.2	81.79	0.9	73.61	0.5	36.80
Moist, long dry season	0.2	284.01	0.9	255.61	0.5	127.80
Dry	0.2	19.20	0.9	17.28	0.5	8.64
Montane moist	0.2	1,507.72	0.9	1,356.95	0.5	678.48
Montane dry	0.2	60.16	0.9	54.15	0.5	27.07
Shrub	0.2	85.70	0.9	77.13	0.5	38.57
Plantation	0.2	82.55	0.9	74.30	0.5	37.15
Subtotal						954.51

*AGB: above ground biomass

Following the same calculation procedure as applied in Table 2-36 to obtain the total carbon released from on-site burning, the total carbon released from off-site burning was calculated, and the result (Table 2-37) shows that about 3182 kt of biomass was burned off-site. As a result of this, 1432 kt C was released into the atmosphere.

Table 2-37: Carbon released from biomass burned offsite

Vegetation types	Fraction of Biomass Burned off Site	Biomass Burned off Site (kt dm)	Fraction of Biomass Oxidized off Site	Biomass Oxidized off Site (kt dm)	Carbon Fraction of AGB* (Burned off Site) (kt C)	Carbon Released (from Biomass Burned off Site) (kt C)	Total Carbon Released (from on and off Site Burning) (kt C)*
Wet/ very moist	0.3	122.68	0.9	110.41	0.5	55.21	92.01
Moist, long dry season	0.3	426.01	0.9	383.41	0.5	191.71	319.51
Dry	0.3	28.80	0.9	25.92	0.5	12.96	21.60
Montane moist	0.3	2,261.59	0.9	2,035.43	0.5	1,017.71	1,696.19
Montane dry	0.3	90.24	0.9	81.22	0.5	40.61	67.68
Shrub	0.3	128.56	0.9	115.70	0.5	57.85	96.42
Plantation	0.3	123.83	0.9	111.44	0.5	55.72	92.87
	Subtotal	3,181.71				1,431.77	2,386.28

Note: The total is obtained by adding together 7th column of Table 2-36 and 7th column of Table 2-37. *AGB: above ground biomass

Upon adjustment of the forest area for the new category of forest, FAO (1993) and FAO (2000 in FAO, 2010) data was used to find the converted average area. Values from biomass before conversion were taken from (IPCC, 1996). The net change in biomass density was obtained by subtracting the biomass after conversion from the biomass before conversion.

The average annual loss of biomass was calculated by multiplying the 10-year average annual converted area by the net change in biomass density. The average annual loss of biomass when multiplied by the fraction left to decay results in the quantity of biomass left to decay. This value then multiplied by 0.5 – the carbon fraction of above ground biomass – gives the quantity of carbon released from the decay of biomass (see Table 2-38). In total, 1193 tons of carbon has been assessed to have been released from offsite burning.

Table 2-38: Carbon released by decay of biomass

Vegetation Types	Average Area Converted (10 Year Average) (kha)	Biomass Before Conversion (tdm/ha)	Biomass After Conversion (tdm/ha)	Net Change in Biomass Density (t dm/ha)	Average Annual Loss of Biomass (kt dm)	Fraction Left to Decay	Quantity of Biomass Left to Decay (kt dm)	Carbon Released from Decay of AGB* (kt C)
Wet/very moist	1.042	225	16.1	208.90	217.67	0.4	87.07	43.53
Moist, long dry season	9.01	100	16.1	83.90	755.94	0.4	302.38	151.19
Dry	0.87	75	16.1	58.90	51.24	0.4	20.50	10.25
Montane moist	23.073	190	16.1	173.90	4,012.39	0.4	1,604.96	802.48
Montane dry	6.7	40	16.1	23.90	160.13	0.4	64.05	32.03
Subtotal								1039.48

*AGB: above ground biomass

It is found that 2386.28 kt C released from immediate release from burning (see Table 2-37) and 1,039.48 kt C is the 10-year average delayed emission from decay (see Table 2-38). Summing these two values (3,425.76 kt C) is equivalent to 12,561.12 Gg CO_2, which is obtained multiplying by the carbon fraction i.e. 44/12.

(B) Emission of Non-CO_2 trace gas: Besides CO_2, several other gases such as methane (CH_4), nitrous oxide (N_2O), ozone-depleting substances (ODSs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF6) and perfluorocarbons (PFCs) also affect climate after being emitted. Unless substantial efforts are undertaken to reduce them, these non-CO_2 GHGs, being linked with society's fundamental needs for food and energy, will continue to increase and further warm the climate (Burkett et al., 2005; Denman et al., 2007; Velders et al., 2010).

However, reliable emission data are not available for Nepal. For this reason, we have to rely upon the IPCC (1996) provided default values for trace gases emission ratios, namely 0.012 for methane (CH_4), 0.06 for carbon monoxide (CO), 0.007 for nitrous oxide (N_2O), and 0.12 for nitrogen mono-oxides (NOx). These trace gases can be categorized into carbon compounds and nitrogen compounds.

As shown in Table 2-39, the quantity of carbon released is used to quantify the carbon and nitrogen compounds emission. The nitrogen-carbon ratio (N/C) of biomass burned is 0.001, which results into 1.05 tons of nitrogen released. This nitrogen value is then used to calculate the trace gas emission in relation to the trace gas emission ratio. In total, among these traces gases, 16.75 Gg of methane and 146.56 Gg of carbon monoxide are released from the burning of cleared forest. Likewise, 0.01 Gg of nitrous oxide and 0.42 Gg of nitrogen monoxide are also released.

Table 2-39: Emission of trace gases from burning of cleared forest

Quantity of Carbon Released (kt C)	Total Nitrogen released (kt N)	Traces Gases	Traces Gas Emission ratio	Trace Gas Emission (kt C)	Conversion Ratios	Trace Gas from Burning of Cleared Forests (Gg CH_4, CO)
1,046.85	1.05	CH_4	0.012	12.56	16/12	16.75
		CO	0.06	62.81	28/12	146.56
				(kt N)		(Gg N_2O NO_x)
		N_2O	0.007	0.01	44/28	0.01
		NO_x	0.121	0.13	46/14	0.42

(C) Carbon uptake from abandoned land: CO_2 removal from biomass accumulation also occurs as a result of the abandonment of managed land i.e. cultivated land and pasture (used for grazing animals). Though shrub land is increasing, it is not basically due to the abandonment of managed land but caused by degradation and deforestation. However, there are small patches of such lands particularly in the hills and mountainous regions abandoned due to low productivity and lack of other facilities to manipulate the land. The land utilization maps prepared by the LRMP project categorized such lands. The carbon uptake results from abandoned land are presented in Table 2-40. Accordingly, 33.34 kt of C is accumulated from 13.4 k ha area of abandoned and re-growing land, which is equivalent to 122.55 Gg of CO_2.

Table 2-40: Carbon uptake from abandoned land

Vegetation Types	20-Year total Area Abandoned and Regrowing (kha)[1]	Annual Rate of Aboveground Biomass Growth (t dm/ha)	Annual Aboveground Biomass Growth (kt dm)	Carbon Fraction of Aboveground Biomass	Annual Carbon Uptake in Aboveground Biomass (kt C)
Montane moist	13.3	5	66.50	0.5	33.25
Montane dry	0.1	1.8	0.18	0.5	0.09
Subtotal					33.34

Source: Land Utilization Map, 1986

(D) Changes in the soil carbon from mineral soils: Forest soils have high organic matter content than any other land use category. Therefore, the conversion of forest land to any other land use affects the soil carbon content. The carbon stocks in any land use are also affected by the agricultural management practices. Therefore, the soil carbon stock is a function of the changes in land use and agricultural management practices. To estimate the changes in the soil carbon stock, a 20-year inventory period is used. However, there is no detailed information of the soil carbon content according to its type. Nevertheless, the land system map prepared by the LRMP has estimated the organic matter content. The data sets for this calculation were adapted from MoPE (2004).

Table 2-41 provides net changes in soil carbon loss from changes in land use, which shows that 23.7 Terra gram of C has been lost between 1974 and 1994; the negative sign indicates land use change from high carbon content to low carbon content. About 1186 Gg of carbon has been lost per annum, which is equivalent to 4347 Gg of CO_2 per annum.

Table 2-41: Net changes in soil carbon

Land use system	Carbon content (t/ha)	Area in 1994 (million ha)	Soil carbon in 1974 (Tg)	Area in 1974 (million ha)	Soil carbon in 1994 (Tg)	Changes in soil carbon from 1974-1994 (Tg)
Terai forest	102.00	0.487	49.67	0.622	63.44	-13.77
Terai cultivation	45.00	1.34	60.30	1.205	54.23	6.08
Warm temperate forest	68.00	3.386	230.25	3.756	255.41	-25.16
Warm temperate cultivation	34.00	1.78	60.52	1.410	47.94	12.58
Cold temperate forest	124.00	1.954	242.30	2.055	254.82	-12.52
Cold temperate cultivation	90.00	0.334	30.06	0.233	20.97	9.09
Total				9.281	696.81	-23.7

(E) Carbon emission from liming: Limestone is partially soluble, especially in acid, and therefore forms many erosional landforms. $CaCO_3$ can be added to neutralize the effects of acid rain in river ecosystems. Currently, calcium carbonate is used to neutralize acidic conditions in both soil and water. Table 2-42 depicts the annual amount of lime used and annual CO_2 emission per year by using 2074 mega gram (Mg) of limestone (Nepal Agriculturual Limestone Industry, 2002).

Table 2-42: Annual CO_2 emission from lime use

Type of Lime	Total Amount (Mg)	Carbon Conversion Factor	Carbon Emission from Liming (Mg C)	Unit Conversion Factor	Total Annual Carbon Emission (Gg)	Annual CO_2 Emission (Gg/yr)
Limestone ($CaCO_3$)	2074	0.12	248.88	0.001	0.25	0.91
Total			248.88			0.91

Source: Nepal Agriculturual Limestone Industry, 2002

2.9 GHG Emission from Waste Sector

2.9.1 Overview

The GHG emission in the waste sector is largely influenced by the domestic and commercial solid waste management system as well as domestic and industrial wastewater handling practices. In respect to solid waste management and wastewater handling practices in Nepal, the conspicuous GHG emission is Methane (CH_4). Nevertheless, the indirect Nitrous oxide (N_2O) emission due to nitrification and de-nitrification of ammonium-nitrogen (NH_4-N) present in human sewage is also accounted for.

Solid waste disposal in Nepal takes place in two different ways. In the rural areas and small towns, there is no systematic collection of waste, and it is haphazard. As anaerobic conditions do not develop, no methane is generated in these areas. However, in the urban areas, solid waste is disposed in open dumps, river banks and, in some towns, by land filling in low-land areas located in and around the urban centers. Due to stacking of the waste over years, anaerobic conditions develop, and hence these solid waste disposal sites generate large quantities of biogas containing a sizeable proportion of methane. In this study, all sites are assumed to fall into the category of uncategorized solid waste disposal sites, which can closely approximate the solid waste disposal scenario of the country. The methane correction factor (MCF) is applied for the estimation of GHG.

Wastewater handling also contributes to methane emission since methane is generated under anaerobic conditions. The method of handling of wastewater is an important factor to decide methane emission. In Nepal, domestic and commercial wastewater is usually discharged into the open pits/latrines, aerobic shallow ponds, and streams and rivers with few exception of discharging in septic tanks and deep lagoons. Similarly, industrial wastewater handling practice is also not much different. Both domestic and industrial wastewater can be significantly important in terms of GHG emission in Nepal.

For the base year 2000/01, total methane emission from solid waste and wastewater handling system is 16.74 Gg in which the contribution from domestic and commercial solid waste disposal is 12.16 Gg (73%), methane emission from domestic and commercial wastewater handling is about 3.33 Gg (20%) and methane emission from industrial wastewater handling is 1.25 Gg (7%). The share of methane emission from these sectors is shown in Figure 2-7. The emission details are presented in the next section.

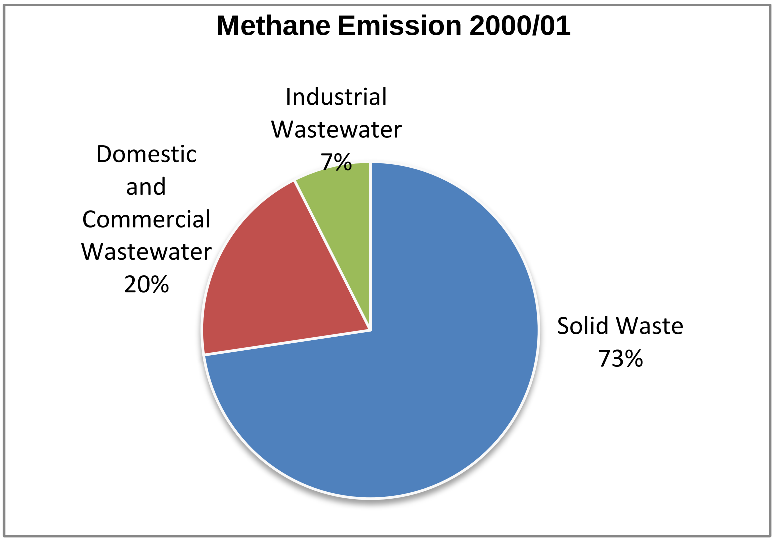


Figure 2-7: Methane emission from solid waste and wastewater management in 2000/01.

2.9.2 Methodology and Choice of Emission Factors

The GHG contribution from the solid waste sector was calculated by using the IPCC tier I methodology. This is a mass balance approach that involves estimating the degradable organic carbon (DOC) content of the solid waste (IPCC, 1996). Using this estimate, the amount of CH_4 that can be generated by the solid waste was calculated. Similarly, the emission contribution from wastewater handling was calculated by using the IPCC tier I methodology. In this approach, the biological oxygen demand (BOD) and chemical oxygen demand (COD) of the wastewater are used to estimate the amount of CH_4 generated by wastewater (IPCC, 1996). The choice of emission factors was based on the revised IPCC 1996 guidelines default values for the particular context of solid waste management and wastewater handling practices in Nepal. The GHG estimation procedure, emission factors used, and assumptions made, if any, are discussed in the following sections.

2.9.3 Greenhouse Gas Emission for Base Year 2000

(A) Solid waste: The biochemical reaction of biodegradable solid waste under anaerobic condition produces methane, carbon dioxide, hydrogen sulphide (H_2S) and other trace elements. The GHG emission depends on the waste volume that goes into the solid waste disposal (SWD) sites, degradable organic compounds (DOC) in the waste, waste management practices, and methane recovering facilities of SWD sites.

The estimation of the GHG emission takes into account of only the urban solid waste generation and emission from solid waste. In the rural communities the emission has been assumed to be negligible as a big portion of the waste decomposes aerobically in the agricultural field and/or is used for food stuff for animals. Moreover, there are no solid waste disposal sites in the rural communities. The urban population for the year 2000 is estimated from the available urban population data for the year 1991 and 2001 (CBS, 2001). In addition to the population data, different studies have shown that solid waste generation in the urban areas varies from one municipality to another in the range of 0.11 kg/capita/day to 0.93 kg/capita/day with an average of 0.34 kg/day (SWMRMC, 2004) and 0.25 kg/capita/day to 0.5 kg/capita/day with an average of 0.37 kg/capita/day (SOE, Nepal, 2001). With reference to these studies, the average urban solid waste generation is taken as 0.37 kg/capita/day (estimation data for the year 2000) for estimating the GHG emission from the solid waste sector in Nepal.

In addition, a few assumptions (based on personal observation, related literature and discussion with other stakeholders) and default values have been used to estimate the methane emission from solid waste: (1) All solid waste disposal sites are treated as uncategorized solid waste disposal sites (SWDs). (2) About 60% of the total generated waste goes into the SWDs (Alam et al., 2008, SWMRMC, 2004). (3) Degradable organic carbon (DOC) for the year 2000 is estimated at 0.16 (from Revised 1996 IPCC guidelines). (4) The methane conversion factor (MCF) is 0.6 (Revised IPCC 1996 default value). (5) Fraction of DOC which actually degrades is estimated to be 0.77(Revised 1996 IPCC default value). (6) Fraction of carbon released as methane is 0.5 (Revised 1996 IPCC default value). It is to be noted that there are no methane-recovering facilities in the solid waste disposal sites in the country. The estimated amount of methane (CH_4) emission from solid waste handling in the country is shown in Table 2-43.

Table 2-43: Methane emission from solid waste handling in year 2000

Year	Urban Population '000	Waste Generation (Kg/Capita/Day)	Total Annual Waste Production ('000 ton)	CH_4 Emission (Gg)
2000	3044.4	0.37	411.14	12.16

(B) Domestic and Commercial Wastewater: The GHG emission from wastewater handling takes into account of urban wastewater only. One of the reasons for this is that sewage systems and septic tanks are limited only in the urban areas. In the Kathmandu Valley, there are some wastewater treatment facilities, some of which are partially operated and others are non-operating. Therefore, the treatment condition for the fraction of wastewater is assumed to be of non-aerated lagoons. So, it is assumed that 10% of the total wastewater that is discharged into the treatment facilities is under anaerobic condition. Moreover, in Kathmandu Valley alone, about 70,000 households have septic tanks (ADB, 2006) and in the urban areas (based on personal observation and communication with other stakeholders), it is assumed that 50% of households have septic tanks.

In addition, a few assumptions have been made to estimate the Methane emission from the domestic and commercial wastewater handling system: (1) Urban population for the year 2000 is estimated from the available urban population for the year 1991 and 2001 (CBS, 2001). (2) The Biological Oxygen Demand (BOD) value is taken as 14600 kg/ 1000 person/year (Revised 1996 IPCC default value for Asia). (3) The Methane Conversion Factor (MCF) for the domestic and commercial wastewater handling system is taken as 0.75 (Revised 1996 IPCC default value for Asia). The estimated amount of Methane (CH_4) emission from domestic and commercial wastewater handling is shown in Table 2-44.

Table 2-44: Methane emission from wastewater handling in year 2000

Year	Urban Population '000	Total Organic Wastewater (kg/BOD/yr)	Wastewater Under Anaerobic Condition%	CH_4 Emission (Gg)
2000	3044.4	44,442,400	40	3.33

(C) Industrial Wastewater: The industrial effluents responsible for greenhouse gas emission in the country are mainly wastewater generation from sugar, paper and pulp, leather tanning, beer, soft drinks and modern liquor, and vegetable oils and ghee industries (Devkota et al., 1994). The total wastewater generation and biological oxygen demand (BOD) load for the year 2000 is estimated by considering the total production of those industrial products in the year 2000/01(Industrial Statistics, 2004/05) and by using the emission factors for wastewater generation per ton of those products and the BOD load per unit volume of wastewater generation for those products (INC, 2004).

Because of the inadequateness of any study on industrial wastewater handling in Nepal and the absence of any industrial effluent discharge standard before 2001, the assumption made in the

Initial National Communication of 80% of industrial untreated effluents in 1994/95 has been maintained for the year 2000/01 as well. A few assumptions are made to estimate the methane emission from the industrial wastewater handling system: (1) 20% of industrial wastewater is under anaerobic condition with no methane recovery facility. (2) The ratio of biological oxygen demand (BOD) and chemical oxygen demand (COD) is taken as 1.7 (Revised 1996 IPCC Guidelines). (3) The methane conversion factor (MCF) for the industrial wastewater handling system is taken as 0.9 (Revised 1996 IPCC default value for Asia).

The total amount of annual production of major products in the year 2000/01, wastewater generation volume, and the total BOD load production from industrial wastewater handling is shown in Table 2-45.

Table 2-45: Industrial production, wastewater generation and BOD load in year 2000

Industrial Products Type	Production	Unit (annual)	Wastewater Generation (m3/ton)	COD (kg/m^3 wastewater)
Sugar	114247	tons	22	6.46
Vegetable oil	112617	tons	11	2.89
Beer	23223	'000 liters	61.3	0.85
Paper and pulp	17079	tons	36	9.86
Soft drinks	34462	'000 liters	4.3	0.85
Liquor	7464	'000 liters	5	7.48
Leather and tanning	3010	'000 sq ft	57	1.87

Source: Industrial Statistics 2004/05, Devkota et al. 1994, INC 2004

The estimated amount of methane emission form industrial wastewater handling system is shown in Table 2-46.

Table 2-46: Methane emission from industrial wastewater handling in year 2000

Year	Total Organic Wastewater (kg/COD/yr)	Wastewater Under Anaerobic (kg/BOD/yr)	CH_4 Emission (Gg)
2000	27,815,222.40	5563044.48	1.25

(D) Human Sewage: The GHG emission from human sewage is Nitrous oxide (N_2O). The conversion of ammonium-nitrogen (NH_4-N) to N_2O during nitrification and conversion of nitrate nitrogen (NO3-N) to N_2O during de-nitrification result in the presence of Nitrogen in human sewage. The nitrous oxide emission from human sewage is estimated for the total population of the country for the base year 2000.

Also, a few assumptions have been made for the estimation of N_2O from human sewage: (1) Per capita protein consumption (protein in kg/person/yr) is taken as 20.951 (FAO, 2010). (2) Fraction of nitrogen in protein (kg N/kg protein) is taken as 0.16 (Revised 1996 IPCC default value). (3) Emission factor (kg N_2O-N/kg sewage-N produced) is taken as 0.01 (Revised IPCC 1996 default value). The estimated amount of Nitrous oxide (N_2O) emission from human sewage is 1.19 Gg N_2O / yr.

2.9.4 Trend in GHG Emission

Figures 2-8 shows methane emission trend from year 2000 to 2010 due to commercial and domestic solid waste, wastewater handling and industrial wastewater handling practices. A linear growth of methane emission from domestic and commercial solid waste is observed, which is the result of increased population growth. As the population increases, the solid waste generation will also increase; however, due to urbanization, the generated waste composition may vary over the years.

Also, the methane emission from domestic and commercial wastewater shows a linear growth due to increase of population over the years.

However, the methane emission from industrial wastewater seems to be more or less constant indicating no growth in industrial production.

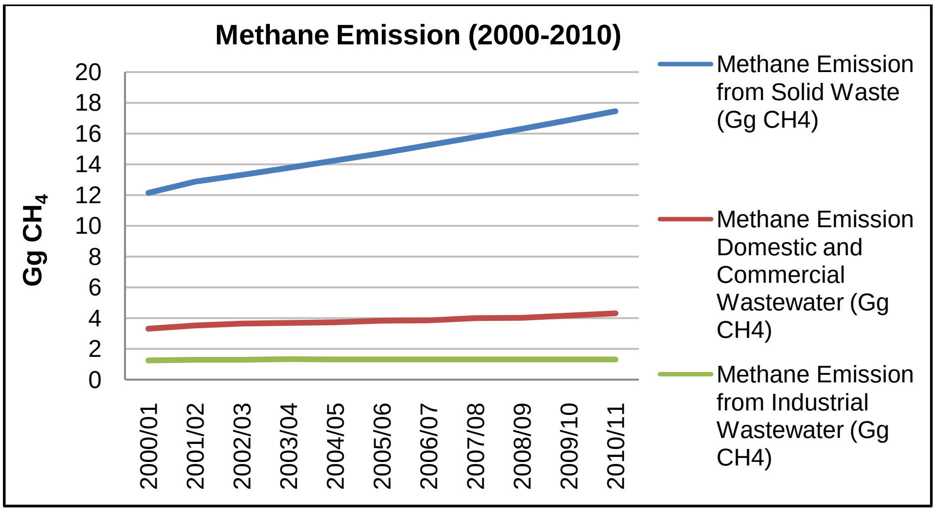


Figure 2-8: Methane emission from waste sector (2000-2010)

Figure 2-9 shows percentage share of methane emission from different subsectors in the waste sector. It is evident from the figure that the share of methane emission from solid waste for the year 2000 -2010 is almost constant and it is about 70% of total emission from waste sector. Similarly, the share of domestic and commercial wastewater handling practice is about 20% and the rest about 10% share from industrial wastewater handling practice. However, the absolute value of methane emission is increasing for each subsector.

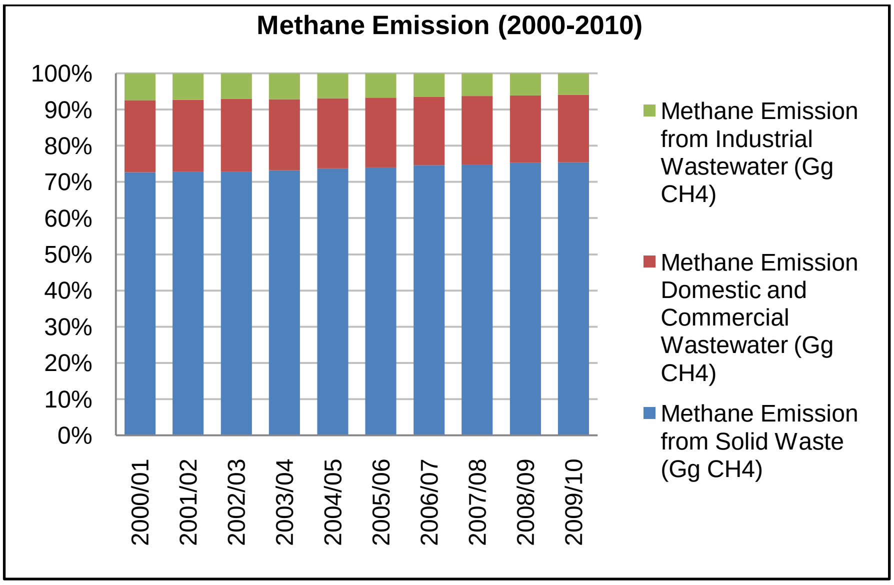


Figure 2-9: Methane emission from waste sector (2000-2010)

Figure 2-10 shows the trend of nitrous oxide emission from human sewage from year 2000 to 2010. It is evident from the figure that the emission is linearly increased over the decade which starts from 1.19 in the year 2000 to 1.38 in the year 2010. The linear growth is because of the increased population of the country which in turn may be attributed to the increased consumption of protein.

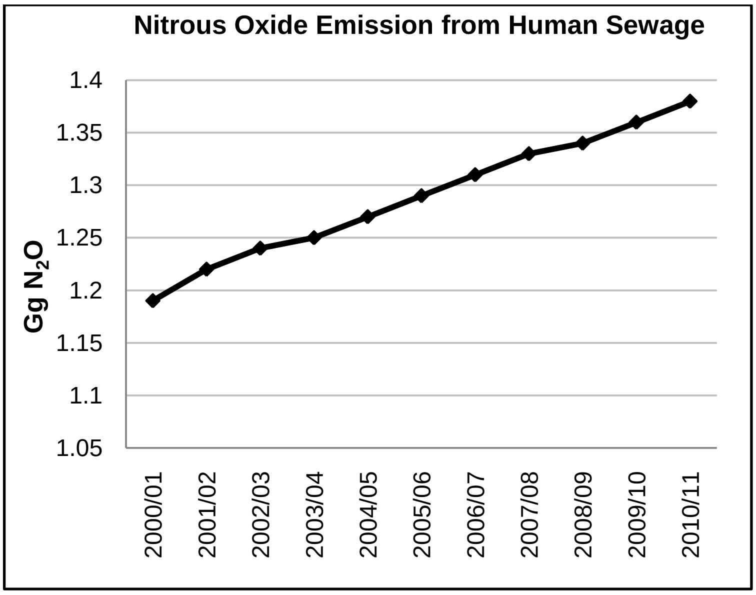


Figure 2-10: Nitrous oxide emission from human sewage (2000-2010)

Chapter 3

GHG Mitigation Assessment

3.1 Energy Sector

3.1.1 Projection of GHG Emission

The total energy consumption in the year 2000/01 is estimated to be 335.2 million GJ, dominated largely by the use of traditional non-commercial forms of energy such as fuel wood, agricultural residue and animal waste. For projection purpose, the following scenarios have been analyzed:

- Business-as-Usual (BAU) Scenario: BAU scenario is based upon the assumption that future household and GDP growth rate will continue to progress as per the current trend. Household growth rate is taken as 3.47% per annum. GDP growth rate is taken as 4.63% from 2011/12.

- Medium Growth (MG) Scenario: It is assumed that the GDP growth rate will be 5% per annum with household growth rate remaining same as in the BAU scenario.

- High Growth (HG) Scenario: It is assumed that the GDP growth rate will be 10% per annum with household growth rate remaining same as in the BAU scenario.

- Mitigation Scenario (MG/HG): Mitigation scenarios for the energy sector under MG and HG emission scenarios have been developed with the following conditions: (1) The energy intensity in the residential sector (energy consumed per household) is changed in proportion to the change in GDP. (2) The share of coal in the industrial sector is reduced by 5% till 2017 and thereafter by 15% till 2030 under the corresponding – MG or HG – emission scenario. (3) The share of fossil fuel in the transport sector is reduced by 3% till 2017 and thereafter by 10% till 2030 under the corresponding – MG or HG – emission scenario. (4) The share of traditional energy sources in the residential sector (e.g., agricultural residue, animal dung, fuel wood) is reduced by 5% till 2017 and thereafter by 15% till 2030 under the corresponding – MG or HG – emission scenario, using improved cooking stoves.

Projected Energy Demands: Using LEAP software, the projected energy demand under different scenarios is calculated and presented in Table 3-1 and depicted in Figure 3-1.

Table 3-1: Projected energy demand (million GJ)

Scenario	2000	2005	2010	2015	2020	2025	2030
BAU Scenario	339.51	383.56	432.37	497.54	569.65	664.15	768.78
HG Scenario	339.51	383.56	432.37	558.56	742.67	1010.97	1376.30
MG Scenario	339.51	383.56	432.37	520.84	630.88	777.61	950.60
MG Mitigation Scenario	339.51	383.56	432.37	509.13	599.82	719.21	854.77
HG Mitigation Scenario	339.51	383.56	432.37	558.56	706.75	937.22	1243.35

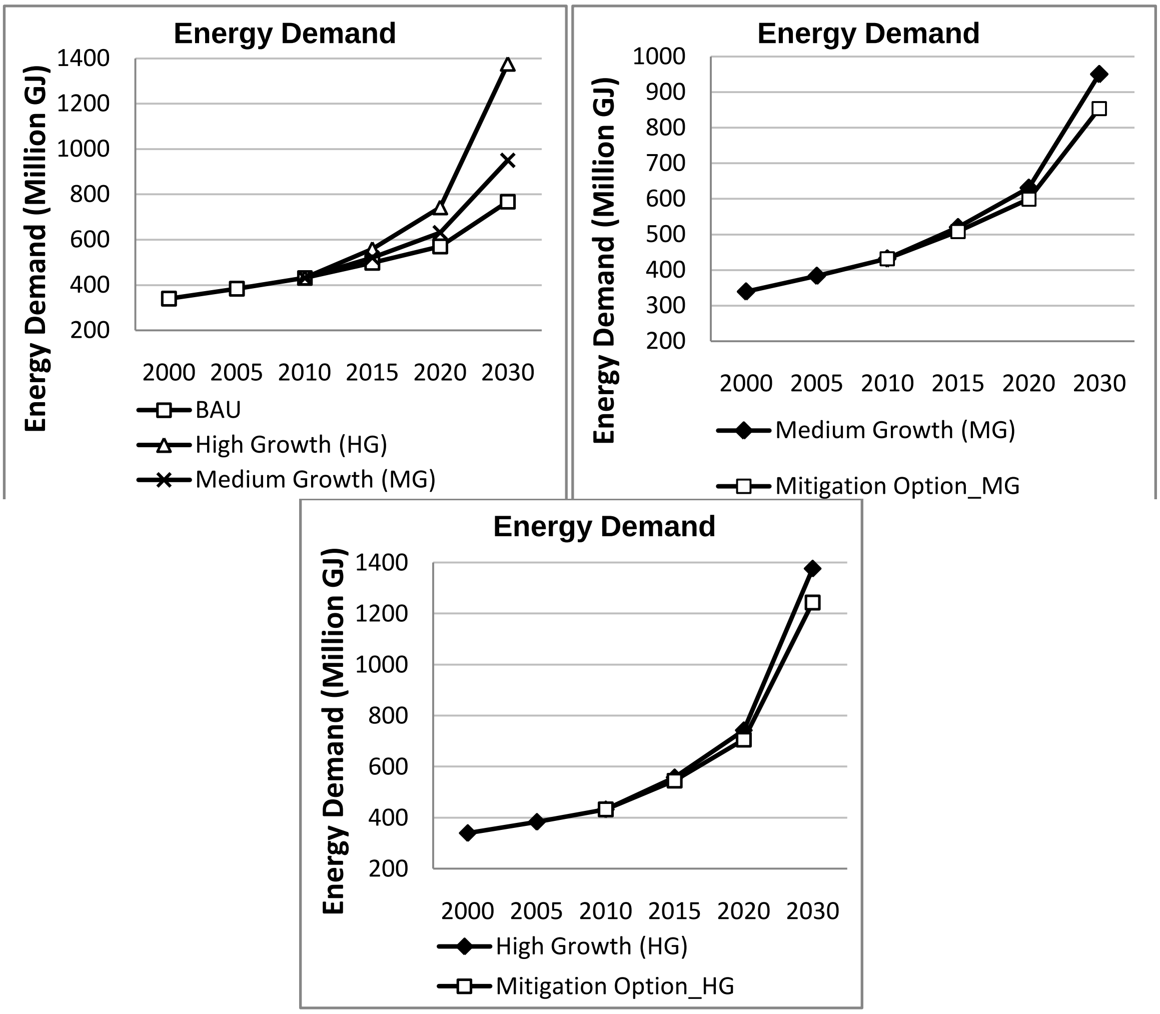
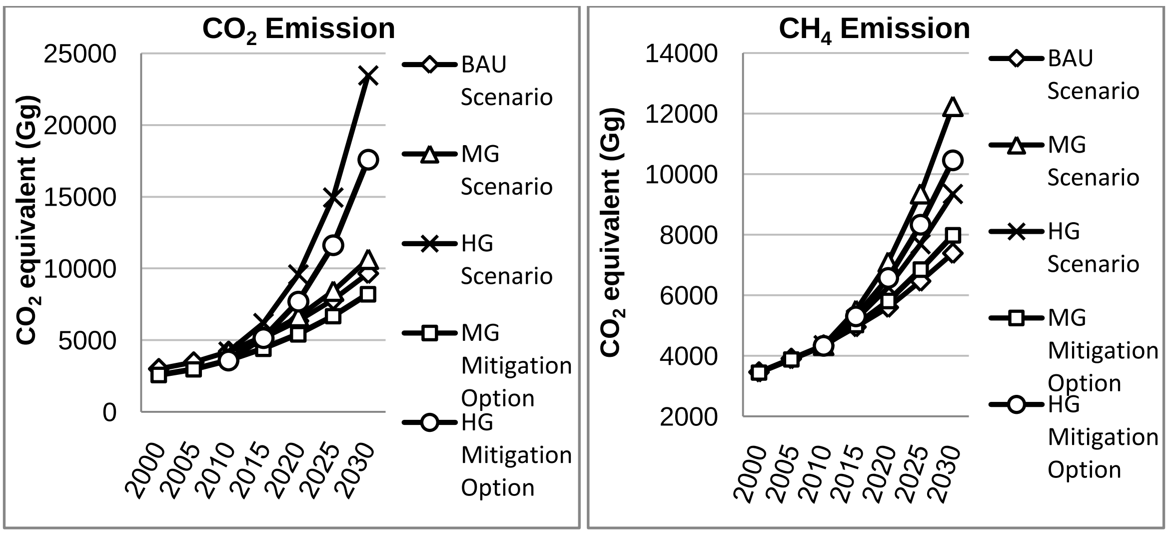


Figure 3-1: Energy demand under different scenarios (top left); under mitigation option for medium growth scenario (top right); and under mitigation option for high growth scenario (bottom)

Projected GHG Emission: GHG emission is projected under different scenarios using LEAP software. The projections for CO_2, CH_4 and N_2O are presented in Figure 3-2.



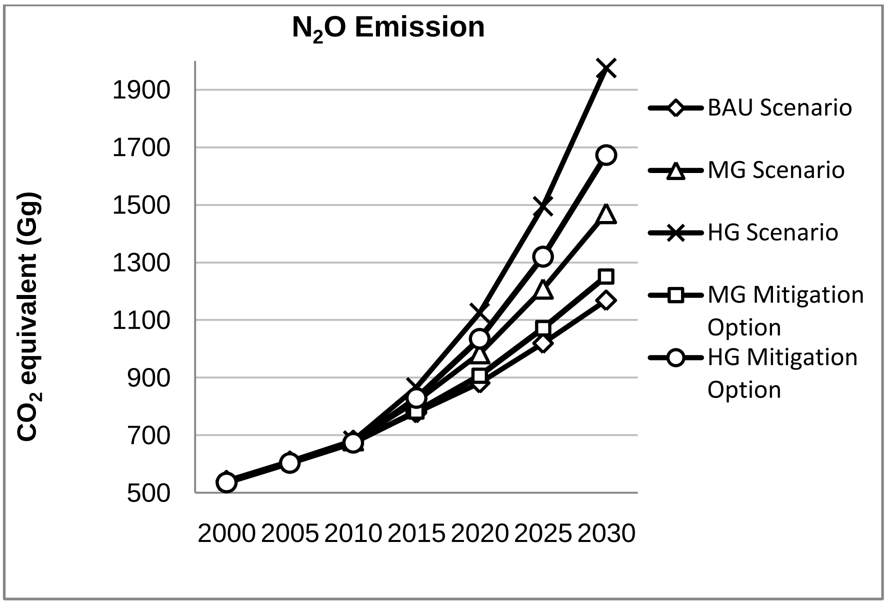
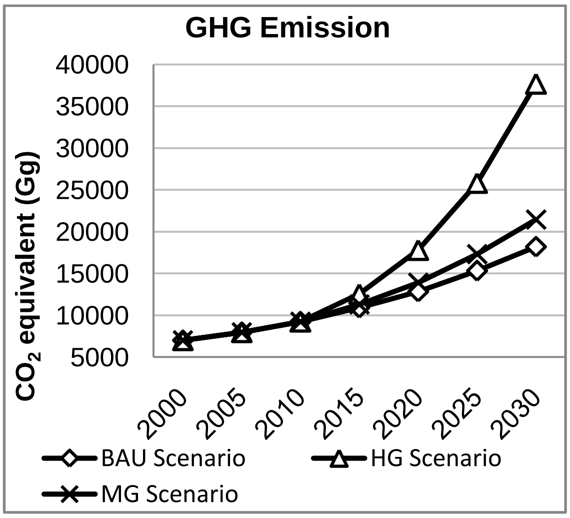
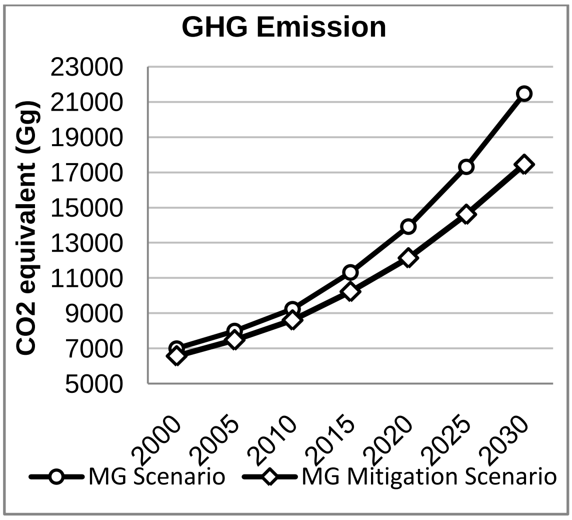


Figure 3-2: Emission of CO_2 (top left), CH_4 (top right), and N_2O (bottom) under different scenarios

The total GHG emission in terms of CO_2-equivalent is presented in Table 3-2 and Figure 3-3.





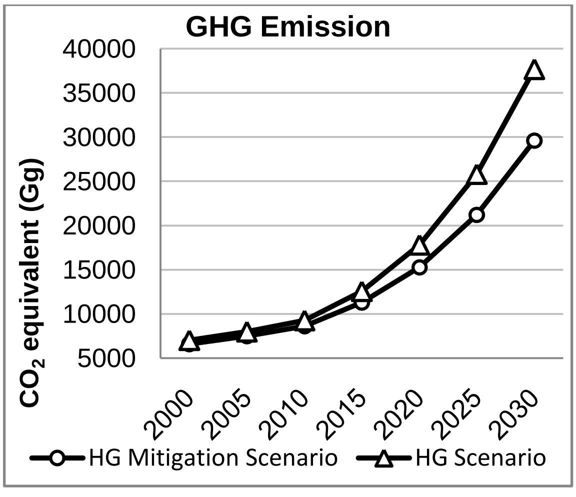


Figure 3-3: GHG emission under different scenarios (top left); under mitigation option for medium growth scenario (top right); and under mitigation option for high growth scenario (bottom)

Table 3-2: GHG emission in the energy sector by scenario

Description	GHG emission (Gg CO_2 equivalent) by year						
	2000	2005	2010	2015	2020	2025	2030
<u>BAU Scenario</u>:	7011.60	7982.80	9246.98	10904.06	12832.89	15314.47	18211.65
Residential	4663.93	5247.14	5830.35	6619.62	7460.41	8577.64	9763.97
Commercial	184.63	215.15	268.70	336.95	422.52	529.82	664.37
Industrial	957.84	1116.14	1393.97	1748.03	2191.95	2748.60	3446.62
Transport	951.33	1108.55	1384.49	1736.14	2177.04	2729.91	3423.17
Agriculture	253.87	295.83	369.47	463.31	580.97	728.50	913.51
<u>MG Scenario</u>:	7011.60	7982.80	9246.98	11310.47	13911.10	17327.56	21466.72
Residential	4663.93	5247.14	5830.35	6965.11	8365.19	10249.42	12433.02
Commercial	184.63	215.15	268.70	341.74	436.16	556.67	710.46
Industrial	957.84	1116.14	1393.97	1772.89	2262.71	2887.85	3685.72
Transport	951.33	1108.55	1384.49	1760.83	2247.32	2868.21	3660.64
Agriculture	253.87	295.83	369.47	469.90	599.72	765.41	976.88
<u>HG Scenario</u>:	7011.60	7982.80	9246.98	12560.88	17803.97	25812.20	37676.99
Residential	4663.93	5247.14	5830.35	7326.80	9374.45	12236.37	15812.97
Commercial	184.63	215.15	268.70	411.64	662.95	1067.68	1719.51
Industrial	957.84	1116.14	1393.97	2135.48	3439.21	5538.89	8920.44
Transport	951.33	1108.55	1384.49	2120.96	3415.82	5501.21	8859.75
Agriculture	253.87	295.83	369.47	566.00	911.55	1468.06	2364.32
<u>MG Mitigation Scenario</u>:	6573.10	7471.83	8608.81	10227.45	12141.79	14607.86	17453.07
Residential	4663.93	5247.14	5830.35	6776.76	7869.28	9322.01	10920.10
Industrial	957.84	1116.14	1393.97	1725.07	2128.91	2627.22	3238.36
Transport	951.33	1108.55	1384.49	1725.62	2143.60	2658.63	3294.61
<u>HG Mitigation Scenario</u>:	6573.10	7471.83	8608.81	11286.46	15316.55	21275.00	29713.54
Residential	4663.93	5247.14	5830.35	7130.04	8822.52	11136.77	13901.96
Industrial	957.84	1116.14	1393.97	2077.88	3235.85	5038.99	7837.72
Transport	951.33	1108.55	1384.49	2078.54	3258.18	5099.24	7973.86

Note: Figures may not sum to the total shown due to rounding.

3.1.2 Mitigation Options and Policies

Mitigation measures in the energy supply sector include:

- Increasing plant efficiency
- Switching to lower-carbon fuels, for e.g., from coal to gas
- Reducing losses in the transmission and distribution of electricity and fuels
- Increasing the use of renewable energy such as solar, hydropower, wind, and biomass energy.
- Early applications of Carbon Capture and Storage (CCS, e.g. storage of removed CO_2 from natural gas).

Policies for GHG mitigation in the energy sector include:

- Market-based instruments include GHG and energy taxes, cap-and-trade systems and subsidies for renewable energy.
- Regulatory measures include use of low carbon fuels, performance and emission standards.

- Hybrid measures include tradable emission permits, and renewable portfolio standards.

Government funded research, development and demonstration programs and activities are also vital in establishing and promoting a low-carbon energy supply sector.

3.1.3 Residential and Commercial Sector Energy Use

3.1.3.1 Current Policies and Mitigation Efforts

Electricity Act 1992: Electricity Act, 1992 adequately address the concern over environment protection through conducting environmental assessment to minimize adverse impact. It states: "A person or a corporate body, who desires to conduct survey, generation, transmission or distribution of electricity, shall be required to submit an application to the prescribed officer along with the economic, technical and environmental study report and with other prescribed particulars on the relevant subject. Provided that such study report shall not be required to be included while applying for the license to conduct the survey relating to electricity. No substantial adverse effect be made on environment: while carrying out electricity generation, transmission or distribution, it shall be carried out in such manner that no substantial adverse effect be made on environment by way of soil erosion, flood, landslide, air pollution etc."

Subsidy Policy for Renewable (Rural) Energy 2009: Government of Nepal established Alternative Energy Promotion Centre (AEPC) with the objective of environment conservation and sustainable development of rural areas by promoting different sources of renewable energy resources and technologies. Considering these facts and to make the Subsidy Arrangement, 2008 equitable, inclusive and effective, Renewable (Rural) Energy Subsidy Arrangement, 2009 has been made. The objectives are as follows:

- To maximize the service delivery and service delivery efficiency in the use of renewable energy resources and technologies in the rural areas and to provide opportunity to low-income rural households to use rural energy technologies (RETs).
- To support rural electrification as well as gradually reduce the growing gap of electricity supply, consumption, etc. between rural and urban areas.
- To make the use of grant assistance provided by donors, existing and forthcoming, in a more effective and objective oriented manner and thereby attract additional donors and other investors in RETs sector.
- To support development and extension of RET market by attracting private sector entrepreneurs.
- To support to the envisaged long-term targets of the Government of Nepal in providing rural electrification and energy services.

Rural Energy Policy 2006: The goal of this policy is to contribute to rural poverty reduction and environmental conservation by ensuring access to clean, reliable and appropriate energy in the rural areas. In order to achieve this goal, the "Rural Energy Policy" has the following objectives:

- To reduce dependency on traditional energy and conserve environment by increasing access to clean and cost effective energy in the rural areas.
- To increase employment and productivity through the development of rural energy resources.

- **To increase the living standards of the rural population by integrating rural energy with social and economic activities.**

Policy for decentralization of energy supply: In the 10th Five-Year Plan (2002-2007) of GoN targeted the electrification rate to be extended from 39% to 55%. Although urban areas are largely electrified, rural-urban migration continues to push for the extension of urban grids. Yet, the electrification goal calls for rural electrification over 5 years of almost 1,000,000 rural households, out of which 70% or 700,000 were assumed to be electrified through extension of the national grid, while the remaining 30% were to get electricity service from individually owned solar photo voltaic systems and isolated micro-hydro grids. To accelerate rural electrification and reduce the cost of rural power, the Government has adopted a decentralized approach to electrification. Since 2003, the expansion of the national grid into rural areas is undertaken in partnership between Nepal Electricity Authority (NEA) and rural electricity user cooperative.

Mitigation Efforts

Promotion of renewable energy: Since it became operational in 1999/2000, the AEPC under the Ministry of Science, Technology and Environment has been implementing ambitious program to promote biogas, solar PV and micro-hydro-projects in the rural Nepal. From mid-2000 to mid-2005, Nepal achieved, on a per rural capita basis, the fastest penetration of renewable energy systems in support of rural electrification:

- **Two third of the increase in the rural electrification rate from 30% in year 2001 to 36% in year 2004/05 came from off-grid solutions in the form of isolated micro-hydropower grids and stand-alone solar home systems.**

- **Annual sales of solar PV-systems (SHS: solar home system) per capita (or un-served rural household) are high with over 65,000 SHS being installed from 2001 to 2006.**

- **Progress in electrification through the implementation of micro-hydropower projects was lower than for SHS in terms of number of served rural households; but compared with progress in other developing countries, Nepal's experience is the international benchmark to beat.**

Clean Development Mechanism (CDM): CDM can accelerate dissemination of renewable energy technologies. Most renewable energy projects are CDM eligible. Furthermore, such projects tend to benefit rural areas in poor countries, and thus promote the distribution of CDM benefits to areas and countries that might otherwise be left out. CDM projects in Nepal are managed by AEPC.

The biogas program, executed by AEPC, is the first project in Nepal to operate under CDM principles. AEPC's biogas program (BSP: Biogas Support Program) began in July 1992. As of July 2011, 241,920 biogas plants have been installed under the BSP alone in over 2800 village development committees (VDCs) and in all 75 districts. Likewise, 2907 biogas plants have been installed under the Gold Standard Voluntary Emission Reduction Project (GSP), and 11,835 plants have been installed before BSP started, thereby making a total of 2,56,662 biogas plants installed (source: http://www.aepc.gov.np).

Decentralised renewable energy technology: AEPC's Renewable Energy Project (REP), co-financed by the European Union and the GoN, is in line with the government policy for organizing energy supply through local based organizations and with government policy to promote renewable energy. REP supplies larger scale PV- system to Community Energy Service Providers (CESP) set up by community-based organizations (CBOs) that are involved in productive activities (functional groups like forest user groups) to provide energy to public administration, schools, clinics, water pumping

and "private productive users of power" on a "fee-for-service" basis. The progress made in the sector of alternative energy is presented below.

Table 3-3: Progress in the alternative energy sector as of 2010/11

S. N	Activities	Unit	2009/10	2010/11 (first 8 months)
1.	Solar dryer/cooker distribution	no.	318	18
2.	*Gobar* * gas plants installed	no.	19511	6774
3.	Improved (iron) cooking stoves installed	no.	8000	1537
4.	Improved (clay) cooking stoves installed	no.	60000	28529
5.	Home solar energy system installed	no.	36135	41884
6.	Improved water mills installed	no.	986	243
7.	Micro-hydro electricity production	kilowatt	867	3660
8.	Research related with Alternative Energy	no.	13	-
9.	Training related with *gobar** gas technology	no.	23106	-
10.	Micro-hydro electricity plant	no.	828	-
11.	Solar lamp	no.	-	4077

Source: Alternative Energy Promotion Center (AEPC). *cow-dung

Carbon mitigation projects: Status of some key ongoing projects on carbon mitigation is summarized below (source: http://www.aepc.gov.np).

- Biogas Support Program–Nepal (BSP–Nepal) Activity-1: The project activity reduces GHG emission by displacing conventionally used fuel sources for cooking, such as fuel wood and kerosene. The project includes a total of 9,708 small biogas digesters installed from the period 1 November 2003 to 15 June 2004. The status is as follows:

Applied methodology: AMS I.C. Estimated annual emission reduction: 46,990 tCO_2e. certified emission reduction (CER) issued during first verification (01/08/2004-31/07/2006) 60,404 tCO2e. *Project status*: Registered with UNFCCC on 27 December 2005 [UNFCCC Ref. No. 0136] (see http://cdm.unfccc.int/Projects/DB/DNV-CUK1132666829.52/view); undergoing second periodic verification for the period 01/08/2006 to 31/07/2009; request for renewal of crediting period for the second crediting period (01/08/2011-31/07/2018) has been submitted to UNFCCC.

- Biogas Support Program–Nepal (BSP-Nepal) Activity-2: The project activity has the same objectives as Biogas Support Program–Nepal Activity-1. The project includes a total of 9,688 small biogas digesters installed from the period 16 June 2004 to 6 April 2005. The status is as follows:

Applied methodology: AMS I.C. *Estimated annual emission reduction*: 46,893 tCO_2e. CER issued during first verification (01/08/2004-31/07/2006) 31,874 tCO2e. *Project Status*: Registered with UNFCCC on 27 December 2005 [UNFCCC Ref. No. 0139] (see http://cdm.unfccc.int/Projects/DB/DNV-CUK1132671435.09/view); undergoing second periodic verification for the period 01/08/2006 to 31/07/2009; renewal of crediting period for the second crediting period (01/08/2012-31/07/2019) is being submitted.

- Micro-hydro Promotion: The project activity is the installation and operation of micro-hydro plants of sizes 5-500 kW in different parts of Nepal with a cumulative capacity of 14.965

MW. The project activity reduces GHG emission through the replacement of diesel fuel used for lighting and milling. The status is as follows:

Applied methodology: AMS I.A. *Estimated annual emission reduction*: 40,535 tCO_2e. *Project status*: Registered with UNFCCC on 18 October 2010 [UNFCCC Ref. No. 3653] (see http://cdm.unfccc.int/Projects/DB/SGS-UKL1271162312.37/view).

- Biogas Support Program–Nepal Activity-3: The project activity is the promotion of household biogas digesters and biogas stoves to households with one or two cattle located in Nepal. The digesters enable households to displace firewood and fossil fuels with biogas from animal waste and human excreta. The generated biogas will feed biogas cook stoves, and replace the firewood used for cooking in wood stoves in the baseline scenario. The replacement of firewood that is non-renewable biomass (NRB) is counted as emission reduction under the CDM. The proposed project activity includes 20,254 digesters which were implemented between 7 April 2005 and 8 May 2006. The status is as follows:

Applied methodology: AMS I.E. Estimated annual emission reduction: 56,919 tCO_2e. *Project status*: Registered with UNFCCC on 13 December 2011 (see http://cdm.unfccc.int/Projects/DB/RWTUV1321009660.45/view).

- Biogas Support Program–Nepal Activity-4: The project activity has the same objectives as Biogas Support Program–Nepal Activity-3. The proposed project activity includes 20,254 digesters which were implemented between 9 May 2006 and 21 June 2007. The satus is as follows:

Applied methodology: AMS I.E. *Estimated annual emission reduction*: 56,487 tCO_2e. *Project status*: Registered with UNFCCC on 13 December 2011 (see http://cdm.unfccc.int/Projects/DB/RWTUV1321020993.82/view).

- Nepal Biogas Support Program-PoA: The project activity is the installation of the household biogas digester. The target groups are households with at least one head of cattle (generally cows or buffalos) who currently use non-renewable biomass (firewood) and/or fossil fuels (kerosene and/or LPG) for cooking purposes. The POA includes biogas digester installed from 22 June 2007. Around 20,000 biogas digesters are expected to be installed in different districts. The status is as follows:

Applied methodology: AMS I.E. *Estimated annual emission reduction per CPA (CDM Program Activity)*: 59,980 tCO2e. *Project status*: Currently under final stage of validation (see http://cdm.unfccc.int/ProgrammeOfActivities/Validation/DB/Z36X1S3M65OLXAHEUE7ELY7571XD4Q/view.html).

- Promotion of Improved Cooking Stove (ICS)–Nepal: The project activity is dissemination of Improved Cooking Stoves (ICS) in different region (Terai and High Hills). The users of the ICS are the households previously using inefficient and traditional firewood stoves. The project will promote 24,000 Mud Improved Cooking Stoves (ICS) in Terai region and 3,000 Metallic Improved Cook Stove (MICS) in high hill region annually starting from February 2011. The status is as follows:

Applied Methodology: **AMS II.G.** ***Estimated annual emission reduction per CPA***: **42,304 tCO2e.** ***Project status***: **Currently under validation.**

- **Promotion of the Solar Home System (SHS) – Nepal: Solar home system (SHS) refers to a solar electricity system having a solar photo voltaic (PV) panel with a capacity of 10 watt peak or more, a battery, a battery charge controller and an appropriate number of lights. The project activity is the installation of 320,000 Solar Home System in the non electrified rural home in the different parts of Nepal. The project will replace the kerosene used for the lighting in these rural household. The status is as follows:**

Applied methodology: **AMS I.A.** ***Estimated annual emission reduction***: **31,037 tCO_2e.** ***Project status***: **The project design document (PDD) is being prepared.**

- **Promotion of Improved Water Mills: The improved water mill (IWM) is a modified version of the traditional water mill which translates into a higher agro-processing capacity (milling capacity often doubles) with possibility of providing a diverse range of services like hulling, oil expelling, saw milling etc. The project (starting on January 2011) supports installation of 8000 IWMs in select districts of Nepal, and discourages installation of diesel mills. The status is follows:**

Applied methodology: **AMS I.B. Estimated annual emission reduction: 38,699 tCO_2e.** ***Project status***: **The project is currently under validation.**

3.1.3.2 Projection of GHG Emission

Residential Sector: The projected GHG emission from the use of energy in the residential sector with breakdown of separate GHG gases is presented in Table 3-4.

Table 3-4: Projected GHG emission from residential sector energy use (CO_2 equivalent Gg)

Description	Projected GHG emission by year (CO_2 equivalent Gg)						
	2000	2005	2010	2015	2020	2025	2030
BAU Scenario:	4663.93	5247.14	5830.35	6619.62	7460.41	8577.63	9763.97
CO_2	758.05	852.84	947.63	1075.91	1212.57	1394.15	1586.98
CH_4	3388.40	3812.10	4235.81	4809.23	5420.07	6231.75	7093.64
N_2O	517.49	582.20	646.91	734.48	827.77	951.73	1083.36
MG Scenario:	4663.93	5247.14	5830.35	6965.11	8365.19	10249.42	12433.02
CO_2	758.05	852.84	947.63	1132.06	1359.63	1665.88	2020.79
CH_4	3388.40	3812.10	4235.81	5060.23	6077.40	7446.32	9032.73
N_2O	517.49	582.20	646.91	772.81	928.16	1137.23	1379.51
HG Scenario:	4663.93	5247.14	5830.35	7326.80	9374.45	12236.37	15812.97
CO_2	758.05	852.84	947.63	1190.85	1523.66	1988.82	2570.14
CH_4	3388.40	3812.10	4235.81	5323.00	6810.64	8889.86	11488.30
N_2O	517.49	582.20	646.91	812.95	1040.14	1357.69	1754.53

Commercial Sector: The projected GHG emission from the energy use in the commercial sector with breakdown of separate gases is presented in Table 3-5.

Table 3-5: Projected GHG emission from commercial sector energy use (CO_2 equivalent Gg)

Description	Year						
	2000	2005	2010	2015	2020	2025	2030
BAU Scenario:	184.63	215.15	268.70	336.95	422.52	529.82	664.37
CO_2	168.43	196.26	245.11	307.37	385.43	483.31	606.05
CH_4	11.96	13.94	17.41	21.83	27.37	34.32	43.04
N_2O	4.25	4.95	6.18	7.75	9.72	12.19	15.29
MG Scenario:	184.63	215.15	268.70	341.74	436.16	556.67	710.46
CO_2	168.43	196.26	245.11	311.74	397.87	507.80	648.09
CH_4	11.96	13.94	17.41	22.14	28.25	36.06	46.02
N_2O	4.25	4.95	6.18	7.86	10.04	12.81	16.35
HG Scenario:	184.63	215.15	268.70	411.64	662.95	1067.68	1719.51
CO_2	168.43	196.26	245.11	375.50	604.75	973.95	1568.56
CH_4	11.96	13.94	17.41	26.67	42.94	69.16	111.39
N_2O	4.25	4.95	6.18	9.47	15.25	24.57	39.57

3.1.3.3 Mitigation Options

There are many cost-effective technologies and measures that have the potential to significantly reduce or control GHG emission from buildings:

- Energy-efficient heating and cooling systems, including using solar energy in active and passive heating and cooling.
- Improved building thermal integrity through insulation and air sealing.
- Efficient lighting and effective use of natural light (“daylighting”).
- More efficient electrical appliances and heating and cooling devices.
- Improved cook stoves with improved insulation.
- Alternative refrigeration fluids.
- Recovery and recycling of fluorinated gases.
- Reduced emission through curbing energy use through greater efficiency
- Adoption of Leadership in Energy & Environmental Design (LEED) building standards for commercial, residential, retrofit and municipal projects
- Implementation of a weatherization program.

Government policies include a combination of market based programs and regulatory measures:

- Market-based programs include incentives for consumers to use new energy-efficient products (in many situations, the fate of less efficient second-hand equipment must also be considered); incentives for manufacturers to develop energy efficient products; and government or large-customer procurement for energy-efficient products.
- Regulatory measures, if well enforced, can be highly effective. Such measures include mandates on energy-efficiency performance standards, building codes, appliance efficiency standards and efficiency labeling.

3.1.4 Industrial Sector Energy Use

3.1.4.1 Current Policies and Mitigation Efforts

The current policies and efforts for the mitigation of GHGs produced by energy use in the industrial sector are focused on reducing use of fuel woods and coals.

3.1.4.2 Projection of GHG Emission

The projected GHG emission from the energy use in the industrial sector with breakdown of separate gases is shown in Table 3-6.

Table 3-6: Projected GHG emission from industrial sector energy use (CO_2 equivalent Gg)

Description	Projected GHG emission by year (CO_2 equivalent Gg)						
	2000	2005	2010	2015	2020	2025	2030
BAU Scenario:	957.84	1116.14	1393.97	1748.03	2191.95	2748.60	3446.62
CO_2	881.23	1026.87	1282.47	1608.22	2016.63	2528.76	3170.94
CH_4	67.29	78.41	97.93	122.80	153.99	193.09	242.13
N_2O	9.32	10.87	13.57	17.02	21.34	26.76	33.55
MG Scenario:	957.84	1116.14	1393.97	1772.89	2262.71	2887.85	3685.72
CO_2	881.23	1026.87	1282.47	1631.09	2081.73	2656.87	3390.91
CH_4	67.29	78.41	97.93	124.55	158.96	202.87	258.92
N_2O	9.32	10.87	13.57	17.26	22.03	28.11	35.88
HG Scenario:	957.84	1116.14	1393.97	2135.48	3439.21	5538.89	8920.44
CO_2	881.23	1026.87	1282.47	1964.67	3164.13	5095.86	8206.93
CH_4	67.29	78.41	97.93	150.02	241.61	389.11	626.67
N_2O	9.32	10.87	13.57	20.79	33.48	53.92	86.84

3.1.4.3 Mitigation Options and Policies

Mitigation measures in the industrial sector include following process changes to reduce CO_2 emission:

- **Material-efficient product design, material substitution, and product and material recycling.**
- **In light industries, mitigation options to reduce GHG emission include efficient lighting, efficient motors and drive systems, process controls, and saving energy in space heating.**
- **More efficient end-use electrical equipment.**
- **Heat and power recovery.**
- **Control of non-CO_2 gas emission.**
- **A wide array of process-specific technologies.**

Introducing new regulations is the most direct method of changing industrial behavior. Among the most viable options for influencing industry's use of energy are equipment efficiency standards, reporting and targeting requirements, and the regulation of utilities to encourage both the implementation of demand-side management programs and the purchase of cogenerated electricity. By excluding sub-standard equipment from the market, equipment efficiency standards can have a large impact in a short time. They can also help to lower the price of higher efficiency equipment by increasing the size of the markets.

Market-based policies, such as cap-and-trade systems and offset programs, have proven effective in controlling and mitigating emission while, at the same time, fostering innovation and investment in new technologies.

3.1.5 Transport Sector Energy Use

3.1.5.1 Current Policies and Mitigation Efforts

National Transport Policy, 2001: With the objective to develop a transport system that is sustainable, reliable, less expensive, safe, comfortable and self-reliant, the National Transport Policy was adopted by the government in 2001. The policies to realize the above objective include, among others, developing a transport system with renewable sources such as electric and solar energy. It also emphasizes development of a transport system that is pollution free. The 2001 sectoral policy on transport system includes sections on rail transport, cable car and ropeways all with renewable energy sources. Development to date, however, remains highly focused towards road transport unlike a balanced policy of a transport system envisaged by the policy with a combination of a mix of railways, river transport and ropeways.

Mitigation Efforts

Euro III standard fuel: Nepal Oil Corporation (NOC) is supplying high octane petrol and diesel of Euro III standard from April 2010, which will give better mileage and increase engine efficiency. The new fuel will also emit low carbon monoxide and harmful particulates and thus, help control environmental pollution that has soared due to increase in the consumption of low grade fuel. NOC has informed that the corporation has started supplying 91-octane petrol throughout the country switching from 88-octane petrol. Also, it is supplying Euro III standard diesel, which contains low sulphur at less than 0.5 percent.

Euro-3 standard vehicle: In a bid to control carbon emission, the government has implemented Euro-3 standard by amending the Euro-1 standard in vehicle emission implemented 16 years ago. The new standard recommended by MOSTE limits carbon emission to 0.64 gram per litre for diesel engines. The Euro-3 standard aims to ban import of substandard vehicles which emit carbon dioxide beyond the given limit. Euro-1 standard vehicles are currently being imported, which emit carbon dioxide between 2.72 and 3.16 gram per litre of diesel. Most vehicles in the country are likely to fail to meet the new standard.

Ethanol as fuel substitution: Government with a notification in the Nepal Gazette required the NOC to distribute petrol with 10 percent of ethanol from January 15, 2004 which still remains to be implemented. Following the above decision of the government, the NOC's lukewarm effort to procure ethanol from the market was not successful because of the price offered by suppliers of ethanol. The supply price of ethanol at that time was not attractive enough to substitute petrol. In addition, arrangements for supply of ethanol-mix petrol at petrol pumps/stations, creation of mixing and storage facilities needed some lead time (WECS, 2010).

Electric vehicle for mass transportation: The advent of *safa* tempo (electric tempo) in Kathmandu has replaced the notoriously environment unfriendly Vikram tempo (diesel tempo). The development and promotion of *safa* tempo in Nepal was initially supported through international projects. This later developed into a bigger electric vehicle (EV) industry with over 700 safa tempos operating in more than 13 routes in Kathmandu.

3.1.5.2 Projection of GHG Emission

The projected GHG emission from the energy use in the transport sector with breakdown of separate gases are shown in Table 3-7.

Table 3-7: Projected GHG emission from energy use in transport sector

Description	Projected GHG emission by year (CO_2 equivalent Gg)						
	2000	2005	2010	2015	2020	2025	2030
BAU Scenario:	951.33	1108.55	1384.49	1736.14	2177.04	2729.91	3423.17
CO_2	939.70	1095.00	1367.57	1714.93	2150.43	2696.54	3381.34
CH_4	2.11	2.46	3.07	3.85	4.83	6.05	7.59
N_2O	9.52	11.09	13.85	17.37	21.78	27.31	34.25
MG Scenario:	951.33	1108.55	1384.49	1760.83	2247.32	2868.21	3660.64
CO_2	939.70	1095.00	1367.57	1739.31	2219.85	2833.16	3615.90
CH_4	2.11	2.46	3.07	3.90	4.98	6.36	8.12
N_2O	9.52	11.09	13.85	17.62	22.48	28.69	36.62
HG Scenario:	951.33	1108.55	1384.49	2120.95	3415.82	5501.21	8859.75
CO_2	939.70	1095.00	1367.57	2095.03	3374.07	5433.98	8751.48
CH_4	2.11	2.46	3.07	4.70	7.57	12.20	19.64
N_2O	9.52	11.09	13.85	21.22	34.17	55.03	88.63

3.1.5.3 Mitigation Options and Policies

Mitigation measures for the transport sector include:

- Improved fuel efficiency through changes in vehicle and engine design (e.g. hybrids), and use of alternative low-carbon fuel sources such as bio-fuels and compressed natural gas (CNG).
- Promotion of modal shifts from road transport to public transport systems including expansion of public transport infrastructure (Public transport technologies such as buses and trains can generally operate with much lower emission per passenger per km than cars or airplanes).
- Integrated land use and transport planning by promoting high-density and in-fill development through zoning policies to reduce urban sprawl (Emission can be reduced by reducing vehicle miles traveled through compact development. Suburban sprawl can be limited through growth boundaries or ordinances. Likewise, incentives and bonuses should be provided for development in existing downtown areas and areas near public transit).
- Promotion of more fuel-efficient, hybrid, cleaner diesel or bio-fuels vehicles.
- Promotion of non-motorized transport (cycling, walking).

Government policies include a combination of market based programs and regulatory measures:

- Market-based programs include increases in fuel taxes, incentives for mass transport systems, and fiscal incentives and subsidies for alternative fuels and vehicles.
- Regulatory instruments include fuel economy standards, mandates on vehicle design or alternative fuels, and direct investment by government in infrastructure improvement, research and development.

3.1.6 Agricultural Sector Energy Use

3.1.6.1 Current Policies and Mitigation Efforts

Due to the low contribution to the overall energy-sector GHG emission at 3%, the agricultural-sector energy use has not attracted significant attention in terms of policies and mitigation efforts.

3.1.6.2 Projection of GHG Emission

The projected GHG emission from energy use in the agriculture sector is presented in Table 3-8.

Table 3-8: Projected GHG emission from energy use in agricultural sector

Description	Projected GHG emission by year (CO_2 equivalent Gg)						
	2000	2005	2010	2015	2020	2025	2030
BAU Scenario:	253.87	295.83	369.47	463.31	580.97	728.50	913.51
CO_2	253.22	295.07	368.52	462.13	579.49	726.65	911.18
CH_4	0.01	0.01	0.02	0.02	0.03	0.03	0.04
N_2O	0.64	0.74	0.93	1.16	1.45	1.82	2.29
MG Scenario:	253.87	295.83	369.47	469.90	599.72	765.41	976.88
CO_2	253.22	295.07	368.52	468.70	598.19	763.46	974.39
CH_4	0.01	0.01	0.02	0.02	0.03	0.03	0.04
N_2O	0.64	0.74	0.93	1.18	1.50	1.92	2.45
HG Scenario:	253.87	295.83	369.47	566.00	911.55	1468.05	2364.32
CO_2	253.22	295.07	368.52	564.56	909.22	1464.31	2358.29
CH_4	0.01	0.01	0.02	0.03	0.04	0.07	0.11
N_2O	0.64	0.74	0.93	1.42	2.28	3.68	5.92

3.1.6.3 Mitigation Options and Policies

Energy use in the agricultural sector can be categorized into following purposes: heating, ventilation, refrigeration and cooling, lighting, motive power (e.g., pumping, lift-irrigation) and field operations including bed cultivation (Warwick HRI, 2007). Heating and field operations make the largest uses of energy, and therefore, these are the target areas for adopting energy saving measures. Heating dominates energy use in protected cropping whereas field operations are predominant in the energy use of the cereals sector. Also, energy use varies between producers of the same crop as not all producers are equally attentive to the issue. Mitigation measures in the agricultural sector include:

Heating in the livestock sector: Poultry farming is very popular in Nepal. Heating energy is used in the poultry industry, principally for the raising of chicks during their first three weeks after hatching. In general, birds are reared in large, wide-span buildings, and heating is supplied by LPG direct-fired, flue-less heaters, or by electrically powered, radiant heaters. There is a considerable potential for energy saving by the replacement of older buildings used in the intensive livestock sector, and the use of either blown fibre or slab insulation products.

Heating used in crop drying and storage: Exposure to sun is the most popular way of drying grains and vegetables in Nepal. However, for commercial purpose, there is a growing usage of direct-fired heaters for grain drying, onion curing, etc. Energy would be saved if all controlled temperature stores (both ambient and refrigerated) and controlled atmosphere stores were to be adequately insulated.

Humidity control is an essential element in crop storage, with de-humidification. Energy can be saved during grain drying by the careful monitoring of ambient outside humidity to ensure that no more heat is supplied to inlet air than is strictly necessary. This can be achieved in bulk grain dryers, for example, by the use of modulating heaters. Excellent control of de-humidification is also given by the use of refrigeration technology.

Field operations and bed cultivation: Field operations and bed cultivation account for a significant share of the amount of energy used in agriculture. The efficiency of energy use in field operations depends upon several factors such as the choice of prime mover (typically a tractor) to carry out the task, the implement that is used, the way in which the prime mover and the implement are combined and operated, ground conditions and soil type. In the long run, a large potential contribution to the improved efficiency of field operations lies in the hands of engine/equipment manufactures; so better designs that consume less fuel should be promoted for importing or manufacturing at home. In contrast, operational efficiencies relating to tractor operation can be significantly influenced by the user.

Motive power: Motive power applications are associated especially with cereals, protected crops, dairying and cattle and poultry sectors. Motive power applications in protected cropping are mainly concerned with water circulation for irrigation, plant feeding and heating. In intensive poultry production, motive power is mainly used in feeding, egg collection, and waste handling. Large pumps are also used in slurry disposal systems.

Circulation pumps used for irrigation and for heating in greenhouses could benefit from the use of pressure linked variable speed drive technology. For reducing electricity use, there would be a knock-on saving due to increased operational efficiency of boiler systems.

3.2 Industrial Process Sector

3.2.1 Current Policies and Mitigation Efforts

Environmental management program in the industrial sector in Nepal was officially initiated in 1993 by United Nation Development Program (UNDP)/ Industrial Pollution Control Management (IPCM) Project. Since then, numerous projects have been launched for the environmental management of brown sector.

Endorsement of standards: A number of regulations including standards have been drafted and endorsed in order to be implemented in the context of emission control. Those regulations came into existence due to haphazard development of industries and acute problems of solid waste, water pollution, air pollution and noise pollution in Nepal.

Cleaner Production (CP): The MOSTE is actively promoting waste minimization measures like CP technique and energy efficiency in Nepalese industries through public private initiatives. CP is an excellent tool to minimize and prevent wastes being produced at the source itself. At the same time, it addresses the energy aspects of the operation through efficiency. With the support of Environmental Support Program (ESP)/DANIDA, the Government has initiated Cleaner Production Policy. ESPS started up its activities in September 1999 in Nepal with the aim to strengthen the overall environmental management of the industrial sector. Among different components, "Promotion of Cleaner Production in Industry" is at present active in more than 50 industries all over Nepal.

EMS intervention: Implementation of Environmental Management System (EMS) in Nepalese organizations was initiated in early 2000s by ESP. But now, a number of organizations have practiced EMS and some of them are already ISO 14001 certified. Besides development of systematic approach in the organizations, the implementation of EMS will also save costs, enhance productivity, create better external and working environment, ease compliance, motivate employees, establish better corporate image and prepare a base for obtaining ISO certification.

Implementation of ISO 14000 series: The objective of ISO 14000 is to establish a system to assess, monitor and manage environmental performances, which can be used to promote continual environmental improvement and the prevention of pollution. Nepal has legislative provisions for introducing the EMS in industries. Rule 18 (2/f) of Environmental Protection Regulation has a provision of Environmental Management System (EMS) by industries. Nepal Bureau of Standards & Metrology (NBSM) acts as the institution for verification and certification of EMS schemes.

3.2.2 Projection of GHG Emission

The emission from mineral products is mainly process-related carbon dioxide resulting from the use of carbonate raw materials. For the 2000/01 inventory, this source sub-category included cement production, and lime production. Although the most significant emission came from cement production (contributing 90.7% of emission for mineral) in the chosen baseline year as compared to lime stone production, the trend of GHG emission from cement and lime production is not fixed (most likely due to unavailability of raw material, fuel or labor, and unfavorable business environment) as evident from the estimate of GHG Inventory for SNC, which is presented below.

Table 3-9: CO_2 emission from the industrial process

Year	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Cement production (CO_2 in Gg)	119	178	134	193	131	200	220	208	171
Lime production (CO_2 in Gg)	12	19	10	307	208	318	1	555	461
Total (CO_2 in Gg)	131	197	144	500	339	518	221	763	632

Due to the lack of uniformity in the component-wise emission from cement and lime production, their sum is considered for projection. A linear projection is used with time-series data from 2001 to 2009 (Figure 3-4).

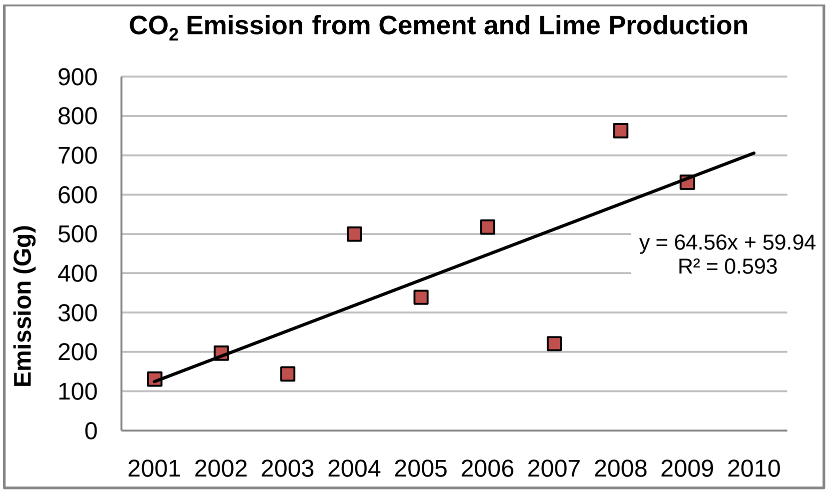


Figure 3-4: CO_2 emission from cement and lime production

From 2010 onwards, the projections are made for BAU, MG and HG scenarios, assuming that the emission follows the energy demand under these scenarios. The projections are depicted in Table 3-10 and Figure 3-5.

Table 3-10: Projected CO_2 emission from cement and lime production (in Gg)

Year	2010	2015	2020	2025	2030
BAU Scenario	705.61	853.30	1032.24	1248.69	1510.46
MG Scenario	705.61	890.80	1136.95	1451.07	1851.93
HG Scenario	705.61	890.80	1631.97	2628.26	4232.88

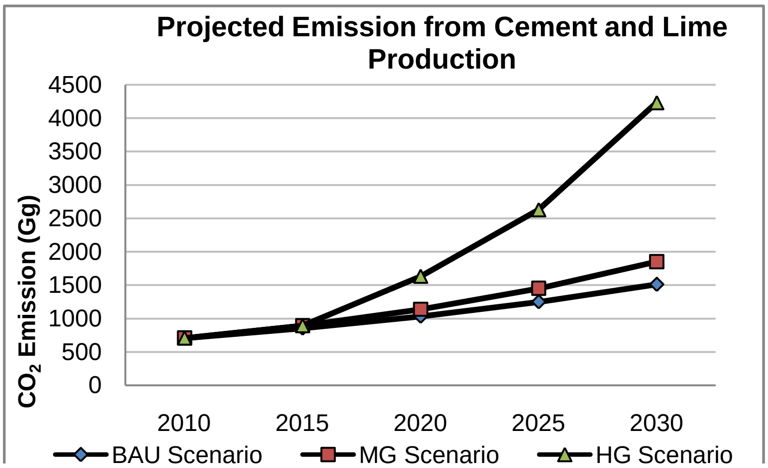


Figure 3-5: Projected CO_2 emission from cement and lime production

3.2.3 Mitigation Options and Policies

The main sources of CO_2 in cement manufacturing are combustion of fossil fuel and limestone calcinations. Approximately, half of the CO_2 emitted by the cement industry originates from the fuel and half from the calcinations that convert raw materials into clinker. Applying different efficient technologies is a good option to achieve moderate reduction of GHG emission. For further reduction, fuel switching should be considered.

Industrial sector is the third largest energy consuming sector in Nepal. Coal, electricity and agricultural residues have larger shares in the industrial energy. In this sector, potential for energy saving and GHG reduction is high because many industrial processes and energy conversion technology are still conventional and energy inefficient. The use of efficient energy conversion technology might save tremendous amount of carbon, which is produced due to the large share of fossil fuels consumed. Improving energy efficiency in the industrial sector (mainly regarding boilers, furnaces, lighting, and electric motors) can reduce huge amount of carbon emission. Measures for mitigation of GHG emission in the industrial process sector with corresponding action plans are summarized in Table 3-11.

Table 3-11: Measures for mitigating GHG emission in the industrial process sector

Policy	Framework	Actions
Energy efficiency policy	Device efficiency standardization Fees, taxes and subsidies to stimulate efficient technology	▪ Energy and environment audits ▪ National efficiency standards ▪ Rules for incentives and penalties
Carbon reduction policy	Emission trading Tax system Setting carbon footprints	▪ CDM project ▪ Tax incentives for less or no GHG emission ▪ Life cycle analysis to display carbon emission-footprints

Hydropower as main source of energy: Switching energy towards cleaner energy, such as hydro-energy, to its fullest extent is the most promising mitigation option for mitigating CO_2 emission.

Energy efficient technology: Replacing ordinary type of equipments by energy efficient one is another attractive option towards mitigating GHG emission.

Establishment of Cleaner Production Centre: Many industries are still unaware of the both environmental and economic benefits of cleaner production/ EMS practices. To generate awareness and to promote CP practices, establishment of a CP Centre can make significant contribution.

3.3 GHG Mitigation Assessment in Agricultural Sector

3.3.1 Current Policies and Mitigation Efforts

Agriculture Perspective Plan (APP: 1995/96-2014/15): The APP is a major strategic plan adopted by the Government of Nepal. Key implementer for this policy is the Ministry of Agricultural Development (MOAD). The APP has been formulated with a view to lead the agricultural sector of Nepal along sustainable high growth path. The objectives/strategies of the APP are:

- **to accelerate growth rate in agriculture through increased factor productivity.**
- **to alleviate poverty and achieve significant improvement in the standard of living through accelerated growth and expanded employment opportunities.**
- **to transform subsistence-based agriculture into a commercial one through diversification and widespread realization of comparative advantage.**

National Agriculture Policy, 2004: National Agricultural Policy, which links up with APP, places commercialization, private sector-led development, and trade at the forefront of the development agenda. This policy has vision of improving living standard through sustainable agricultural development achieved by commercial and competitive farming system. All commodity and subject specific policies which have been or will be formulated in this sector will be guided by this National Agricultural Policy.

The main objectives of this policy are as follows:

- **Increase production and productivity**
- **Increase competitiveness in regional and world markets developing foundations of commercial and competitive agriculture**
- **Protect, promote and utilize existing natural resources, environment and biodiversity**

Some highlights of this policy include: large production pockets with infrastructures; high-value low-volume products, especially in remote areas; insurance; organic farming; attraction to youths; cooperative farming; public-private partnership (PPP) on research, extension and developmental works; contract farming; and providing necessary support to the one-village-one-product movement in Nepal.

Mitigation Efforts

Not much effort in mitigating climate change in agricultural sector is noticed in Nepal, and most of the researches are based only on the impact of climate change on agriculture. Nepal Agricultural Research Council (NARC) has done some of the studies related with Climate Smart Agriculture (CSA) – agriculture that sustainably increases productivity, resilience and adaptation, reduces/removes GHGs (mitigation) while enhancing the achievement of national food security and development goals. NARC has also done a research related with the use of different kinds of fertilizers and CH_4 emission from rice fields. According to this research, use of locally available *neem* oil, *neem* cake and sulfatic fertilizers and System of Rice Intensification (SRI) – an agro-ecological methodology for

increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients – reduces methane gas emission (Malla et.al, 2007).

3.3.2 Projection of GHG Emission

The projection emission of GHGs in the agricultural sector from 2000 to 2030 as per the GHG inventory is presented in Table 3-12.

Table 3-12: Projected emission of GHGs in the agricultural sector

Year	CH_4 (Gg)	N_2O (Gg)	CO_2 eq. (Gg)	Remarks
2000	470.08	27.14	18285.08	Estimation using Module 4 of IPCC Guidelines
2005	511.77	28.49	19579.07	(see Table 2-27 in Chapter 2)
2009	564.30	30.14	21193.7	
2015	614.11	32.64	23014.71	Linear projection
2020	669.53	34.88	24872.93	
2025	729.96	37.28	26885.96	
2030	795.84	39.84	29063.04	

The trend (estimated and projected) of CH_4, N_2O and the total CO_2 equivalent emission from the year 1994 to 2030 is presented in Figure 3-6.

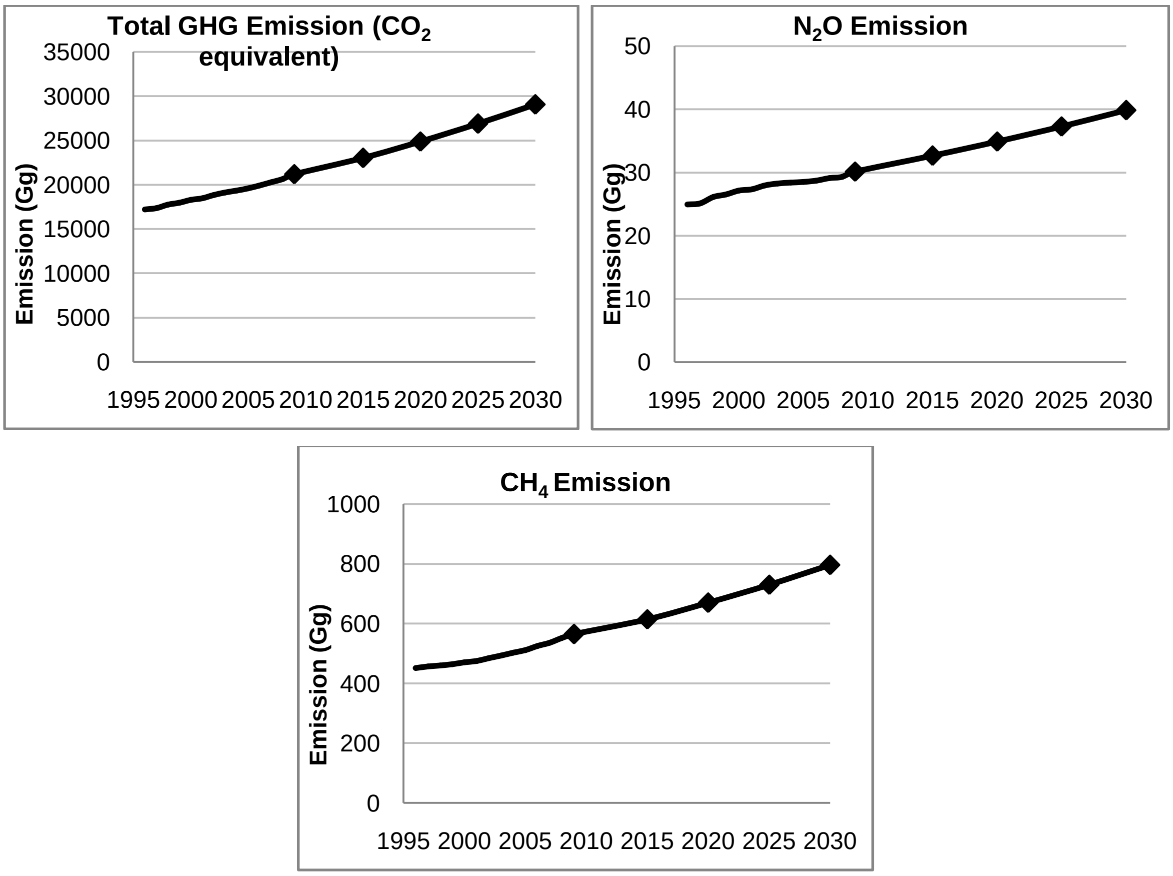


Figure 3-6: GHG emission in agricultural sector: Total GHG (top left); N_2O (top right); and CH_4 (bottom)

3.3.3 Mitigation Options and Policies

The GHG Inventory report shows that the GHG emission in the agricultural sector comprises mainly of CH_4 from domestic livestock enteric fermentation, manure decomposition, and from rice fields and

N_2O from agricultural soils. So, programs to control CH_4 and N_2O emission from such agricultural sources need to be implemented.

CH_4 emission control from domestic livestock: CH_4 emission from domestic livestock is dominated by enteric fermentation and decomposition of manure. Enteric fermentation is a natural process that occurs in the digestive systems of animals such as cattle, sheep, and goats. As much as 7 percent of an animal's feed can be lost as CH_4, so feedlot operators that increase animal digestive efficiency will save feed costs and decrease methane emission. Options for increasing efficiency include increasing the daily percentage of highly digestible feed and correcting nutrients deficiencies in livestock diets.

CH_4 emission from livestock manure can be controlled through biogas technology. Capturing the released CH_4 and using it for energy effectively reduces GHG emission, and also helps to meet the energy deficiency. Biogas programs should be promoted amongst rural communities since it has been proven as an efficient alternative technology for the rural areas to supplement the energy and contribute to environmental protection. Biogas slurry is one of the good fertilizers that may supplement to chemical fertilizer requirement for crop production. Human wastes could also be connected to the digester to provide extra biogas.

CH_4 emission control from rice fields: Because Nepal is an agricultural country with rice being the staple food, and Nepal's total GHG emission is low (or even negative including sink from LULUCF sector), emission control from rice fields is not a priority. This is logical even from the perspective of food security which is more important concern for the country.

N_2O emission control from manure and soils: Nitrous oxide is produced by the processes of denitrification and nitrification. Agricultural N_2O emission is derived from three principal sources (IPCC, 1996):

- **direct emission from soil nitrogen, e.g. applied fertilizers (both manures and artificial), the mineralization of organic soils and crop residues;**
- **emission from livestock wastes in store;**
- **indirect emission from nitrogen lost to the agricultural system, e.g. through leaching, runoff or atmospheric deposition.**

Soil N_2O mitigation options mainly involves adopting a more efficient nitrogen-based fertilizer application rate or reducing total consumption of nitrogen-based fertilizer. The better targeting of fertilizer applications, both in space and time, can significantly reduce nitrous oxide emission from agricultural soils. Land-management strategies which accurately take account of the optimum amounts of fertilizer addition necessary for maximum crop yield and minimum waste are crucial both from environment and economic perspective. Similarly, the exact form of efficient nitrogen-based fertilizer and the best time of year at which to use them is key information on which to base fertilization campaigns.

Beside these, following mitigation measures can be adopted for reducing GHG emission in agricultural sector:

- **Establishing hay meadows with high- yielding fodder legumes and grasses under high nutrient supply condition to reduce grazing pressure on forests**
- **Increasing cropping intensity, promotion of integrated soil fertility (crop intensification and diversification)**

- Improving crop and grazing land management to increase soil carbon storage
- Restoration of degraded lands
- Adjusting time and method of urea application, such as sub-surface application of urea under flooded condition
- Increasing area under organic farming
- Establishing farmers' cooperatives that will, among other things, oversee proper utilization of forage resources through monitoring of stock numbers, grazing duration and grazing time, nutrient management and shrub and weed control
- Dedicated energy crops to replace fossil fuel use and improved energy efficiency

Policies in the agricultural sector include market-based mechanisms such as offset programs and conservation easements, as well as regulatory measures in the form of incentives and taxes. Proper guidelines and incentives for farmers are also necessary that include improved farming practices, cultivation technologies, and livestock management.

3.4 GHG Mitigation Assessment in Land Use Land Use Change and Forest Sector

3.4.1 Current Policies and Mitigation Efforts

Forest Act 1993 and Forest Regulation, 1995: The Forest Act, 1993 is probably the only piece of legislation, which has recognized the indigenous practices of local people and their rights to forest resources. Encouragingly, the Act recognizes the benefits of these practices, and provides the legal measures for handing over the management of community forests to local people. Major goals of this act are to meet the basic needs of local people, attain economic and social development, promote a healthy environment, promote development and conservation of forests and forest products by managing national forests, and provide support for the conservation and development of private forests.

Master Plan for the Forestry Sector, 1988: The Master Plan for the Forestry Sector (MPFS, 1989), prepared between 1986 and 1988 and approved in 1989 provides a 25-year policy and planning framework for the forestry sector.

The long-term objectives of the Master Plan for Forestry Sector include the following:

- to meet the people's basic needs for forest products on a sustained basis
- to conserve ecosystems and genetic resources
- to protect land against degradation and other effects of ecological imbalance
- to contribute to local and national economic growth

Forestry Sector Policy, 2000: The Forestry Sector Policy 2000 is an updated version of the Forestry Master Plan 1998 and subsequent amendments to that document. The policy of 2000 contains development imperatives, outlines, strategies, and programs, and summarizes the investment required to develop the forestry sector. The objectives of this policy are as follows:

- To protect land from degradation by soil erosion, floods, landslides, desertification, and other ecological disturbances.

- **To promote people's participation in land and forestry resource development, management, and conservation.**

- **To improve the legal framework needed to enhance the contribution of individuals, communities, and other organizations to land and forestry resource development, management, and conservation.**

- **To improve and strengthen the organizational framework and the institutions of the forestry sector so that they can better perform their missions.**

- **To provide increased opportunities to the people for forestry resource management under the community, private and leasehold forestry programs as well as the biodiversity conservation program provided in the new forestry legislation.**

- **To manage the natural forests of the Terai and Inner Terai more effectively in order to contribute towards the socio-economic development of the country.**

National Land Use Policy, 2012: In a bid to control haphazard use of land, the Ministry of Land Reforms and Management has drafted National Land Use Policy 2012 with the aim to manage, classify and put land to proper long term use. The policy calls for the land to be classified into six categories - agriculture area, residential area, commercial area, industrial area, forest area and public and other area of necessity, with provisions to preserve at least 40 percent of the total lands area for forestry and allows the government to acquire any land, if necessary, for infrastructure development. The Land Use Plan will be implemented in phases over several years.

The policy aims to discourage people to leave land uncultivated and from using fertile land for non-agricultural purpose. The policy also aims to identify and preserve environmentally sensitive land, and discourage people to reside in the areas prone to natural disaster. The necessary legislation should be in place for implementing this policy.

Mitigation Efforts

REDD + : By far the most discussed initiative for reducing GHG emission in Nepal is the Reduction of Emission from Deforestation and Forest Degradation (REDD) schemes. Currently, the subject of international negotiations is REDD+, which refers to REDD that includes sequestration activities such as enhancing existing degraded forests.

The REDD Cell under the Ministry of Forests and Soil Conservation is implementing the activities under Readiness Preparation Proposal (R-PP) from the grant of Forest Carbon Partnership Facility (FCPF) of the World Bank. Pilot initiatives of forest-based CDM and REDD+ projects have been implemented in Nepal for the past few years, including a groundbreaking REDD+ initiative in Nepal by ICIMOD in partnership with the Federation of Community Forestry Users, Nepal (FECOFUN) and the Asia Network for Sustainable Agriculture and Bioresources (ANSAB).

International Centre for Integrated Mountain Development (ICIMOD), Asia Network for Sustainable Agriculture and Bioresources (ANSAB), and Federation of Community Forest Users' Nepal (FECOFUN) are jointly implementing the project "Design and setting up of a governance and payment system for Nepal's Community Forest Management under Reducing Emission from Deforestation and Forest Degradation (REDD)" in 105 community forests of three watersheds of Nepal, namely; Kayarkhola of Chitwan district, Charnawati of Dolakha district and Ludhikhola of Gorkha district. The project is in operation since July 2009 with financial support of Norwegian Agency for Development Cooperation (Norad). The watersheds cover an area of 27,000 ha where

community forest area alone stands at about 10,266 ha. The first forest carbon stock measurement was undertaken in 2010 and similar measurement was executed in 2011 in February to April.

3.4.2 Projection of GHG Emission

Reducing emission from deforestation could significantly contribute to the overall efforts to stabilize GHG concentrations in the atmosphere, and to mitigate climate change. In Nepal, the forest area decreased at an annual rate of 1.7%, whereas forest and shrub land together decreased at an annual rate of 0.5% during the period 1978/79-1994 (DFRS, 1999). Studies in 20 terai districts suggest that the forest cover has decreased at an annual rate of 0.06% during the period 1990/91-2000/01. These studies reflect that deforestation in Nepal has been in a decreasing trend.

Based on the governmental projections, the INC report predicts a 25% increase in forest carbon by the year 2030/31 as compared to the baseline year 1994/95 due to better forest management leading to carbon conservation. About 51.5 % of the forest of Nepal is reachable, and non-reachable (totaling 2.1 million-hectare) can be considered virtually as permanent carbon sinks (INC Report, MOEST 2012). This report assumes a 5% increase in reachable forests by 2010/11, and an additional 10% increase by 2020/21 and a further 10% increase by 2030/31. Although biomass and carbon per unit area may increase due to increased tree density (stocking) as a result of better management or due to carbon conservation focused management in future, increased area of forest is not foreseen. Under this scenario, the projected carbon sink in forests is given in Table 3-13.

Table 3-13: Projected carbon sink in reachable forest area

Year	Forest Area (10^4 ha)	Total Carbon Release (10^6 tons)	Total Storage of Carbon (10^7 tons)	Total Carbon Sink (10^6 tons)
1994/95 (BY)	217	88	226	2,168
2010/11	229	92	237	2,276
2020/21	251	101	259	2,493
2030/31	273	109	282	2,710

Source: INC (MOPE, 2004). Note: BY- base year.

3.4.3 Mitigation Options and Policies

There are three types of relevant activities that can be used to mitigate climate change: reducing GHG emission, increasing carbon sequestration, and carbon substitution. Carbon sequestration through afforestation/reforestation has received little attention in Nepal's forest sector as existing community forests are not eligible for the CDM under Kyoto Protocol – though if communities reforest or afforest on a degraded land this could be accepted by the CDM. Although the mitigation is not our commitment, we should adopt low carbon emission and climate-resilient path for sustainable socio-economic development.

Based on the analysis of current situations, the mitigation measures in the LULUCF sector include:

- Protecting existing forests, and substituting wood fuel with other fuels. (In some situations, where wood fuel production is highly unsustainable, substituting household wood fuel with fossil fuels may paradoxically constitute a mitigation option).
- Afforestation, reforestation, and forest management to reduce deforestation.
- Harvested wood product management.
- Use of forestry products for bio-energy to replace fossil fuel use.

- Increase carbon sequestration by promoting healthy forests (including urban forestry) and natural open space.

Policies for forest protection and afforestation have to cover a wide range of areas and should include clarifying and securing land tenure for small farmers. The use of incentive programs such as payment for conservation services, market mechanisms such as offset programs for sequestration projects, and enforcing bans on logging in protected areas.

3.5 GHG Mitigation Assessment in Waste Sector

3.5.1 Current Policies and Mitigation Efforts

Solid Waste Management Act, 2011: This act replaces Solid Waste Management and Resource Mobilization Act, 1987 which was a pioneering initiative towards fulfilling the need of legal basis for solid waste management (SWM) in Nepal. The new Act recognizes the need for an integrated solid waste management system with source separation, reduction, reuse, recovery and recycle. It addresses issues such as separation and storage of waste at the point of generation, recycling, composting, sanitary landfill and hazardous waste management. The Act mandates local governments to manage solid waste according to standard technology in environmental friendly manner.

Nepal Environment Policy and Action Plan (NEPAP), 1993: The NEPAP recognizes SWM as a key urban issue in Nepal. It suggests that municipal solid waste (MSW) collection and disposal be organized and managed at the ward level, including the levying and collection of fees from residents. As a follow up (Phase II) Stage of NEPAP (4), the government produced draft Sector Action Plans. The Plans incorporate following specific project proposals in relation to SWM:

- Development of waste exchange and waste minimization program for industries
- Development of Waste Act
- Development of National Waste Management Policy
- Waste Management through private sector

National Solid Waste Management Policy, 1996: The major objectives of this policy are:

- to strengthen local governmental units for more efficient and reliable solid waste management
- to launch awareness campaigns in order to muster public participation
- to involve non-governmental organizations in waste management
- to develop appropriate local technology for waste management
- to manage final disposal sites as per their amount and nature
- to make solid waste management an economically self-sufficient (sustainable) and self-reliant activity
- to promote self-help cleansing schemes
- to mobilize waste as recycling resources

- to privatize solid waste management activity at different steps
- to intervene in solid waste generating activities at source to reduce them; and
- to prioritize public cleansing activities at the local level.

This policy envisages a two-tier institutional system to execute management activities with an aim to have a separate institution from central to local level under which all stakeholders concerned with solid waste management should act. The local solid waste management agency is to function under the instructions from the central level agency.

Local Self-Governance Act, 1999 and Regulations, 1999: It recognizes District Development Committees (DDCs), municipalities, and Village Development Committees (VDCs) as local governments. It emphasizes formulation of local environment management plan and makes municipalities responsible for managing municipal solid wastes. Municipalities are entitled to preserve water bodies such as lakes and rivers, assist in controlling environmental pollution of water, air, land and prevent spreading of infectious diseases.

Sustainable Development Agenda for Nepal (SDAN), 2003: The SDAN is a wide-ranging agenda, which incorporates several goals related to the environment. It states that the government will encourage research and industry to work together to create cyclical flows of material, requiring factory products to be easily disassembled and separated by material type, and factory by products to be reused. The agenda also includes a commitment to create conditions that facilitate establishment of recycling centers that have economy of scale and establishment of hazardous waste management centers whose costs are met by the product causing the waste. Only non-recyclable waste is to be disposed of in environmentally-sound sanitary landfills.

Mitigation Efforts

Considerable efforts have been made by municipalities, NGOs and private sector to improve solid waste management in Nepal. The main areas of focus for these agencies have been collection, composting and recycling. The municipalities have become interested to make improvements in the final disposal, which has often been a neglected aspect of waste management in the past.

Municipal role: Although most of municipalities have less infrastructural, technical and financial resources to tackle the problems of waste management, SWM is one of the key municipal priorities due to an increase in public awareness. Municipalities are promoting waste reduction, source separation, composting, reuse, and recycling among communities. Some municipalities have joined hands with communities and private sector to introduce innovative approaches for cost-effective and efficient waste management.

Source separation: Some attempts have been made in Nepal to implement source-separated collection systems by NGOs and private sector. Separation of waste at source makes recycling and composting of waste much easier.

Recycling: Recycling of solid waste reduces amount of waste that needs to be disposed, cost of waste management and GHG emission.

Composting: On average, about 70 percent of the household waste generated in municipalities of Nepal consists of organic matter. Bhaktapur Municipality has a compost plant with a capacity to process about 6 tons of waste per day. Hetauda is also in the process of setting up a 3 ton per day compost plant with community and private sector participation. Kathmandu Metropolitan City has also established a vermin-composting system with a capacity to process about 1 ton of vegetable

market waste per day. In order to promote household composting, several municipalities (e.g., Kathmandu, Lalitpur, Hetauda) are selling compost bins of various sizes at subsidized rates.

Anaerobic digestion for biogas: Anaerobic digestion of waste to produce biogas and slurry is another way to recycle organic waste. In rural Nepal, thousands of households have set up domestic biogas plants to manage their waste, mainly cow dung and toilet waste, and produce biogas for use as a cooking fuel in their kitchen. More recently, some organizations and institutions have also started producing biogas from vegetable market waste and kitchen waste in urban areas.

Landfilling: In most of the municipalities in Nepal, waste is simply being dumped in rivers or public places. Out of 58 municipalities, 26 have open dumping, 13 have river site dumping and 8 have roadside/ river-site dumping. Two municipalities (Lekhnath and Khandbari) do not have any system for solid waste disposal (SWD) till date. Tribhuvannagar, Dhankuta, Tansen, Kathmandu, Lalitpur and Pokhara have sanitary landfill for SWD. Sanitary landfill of Tribhuvannagar is built and operated through a partnership between local community and municipality. The organic waste is composted in pits, and the remaining waste is landfilled and covered with soil. However, none of the SWD system in Nepal has gas flaring facilities to reduce GHG emission.

Private sector participation: Private sector participation (PSP) in solid waste management can improve efficiency, reduce the need for municipal investment, and share risks associated with introducing a new technology or system. In spite of these clear benefits, many municipalities have not been able to take advantage of PSP in waste management. However, some municipalities including Kathmandu, Biratnagar, Hetauda, Bharatpur and Kirtipur have introduced PSP in SWM. Kathmandu Metropolitan City initiated the process of inviting private sector to establish a compost plant and also signed a memorandum of agreement with a private party for this purpose.

Public participation: As waste is generated by people, their participation is essential to develop and functioning of a well-managed system. Some municipalities have initiated programs to educate local communities and involve them in waste management. Kathmandu Metropolitan City has a separate Community Mobilization Unit (CMU) within its Environment Department that is working with various community groups, youth groups and school children to raise awareness and to provide training and necessary support for effective SWM.

3.5.2 Projection of GHG Emission

Production of solid waste in cities is directly proportional to the urban population. Table 3-14 shows projection of urban population.

Table 3-14: Urban population

Year	1971	1981	1991	2001	2011	2021*	2031*
Urban population	461,938	956,716	1,682,274	3,227,879	4,523,820	6,112,657	7,408,526
Annual growth rate (%)		7.28	5.64	6.52	3.38	3.01	1.92

Source: Relevant census data. *projection.

According to Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual, total methane emission from solid waste is given as

Methane emission (Gg/yr) =

$$\left(MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12 - R\right) \times \left(1 - OX\right)$$

where,

MSW_T = total MSW generated (Gg/yr) = population X per capita solid waste generation rate per day X 365/1000000. Note: per capita solid waste generation rate is taken as 0.37 kg/capita/day.

MSW_F = fraction of MSW disposed to solid waste disposal sites which is estimated to be 60% (Alam et.al., 2008, SWMRMC, 2004)

MCF = methane correction factor (fraction) = 0.6 (Revised IPCC 1996 default value)

DOC = degradable organic carbon (fraction) = 0.77(Revised 1996 IPCC default value)

DOC_F = fraction DOC dissimilated = 0.5 (Revised 1996 IPCC default value)

F = fraction of CH_4 in landfill gas (default is 0.5)

R = recovered CH_4 (Gg/yr) (0 for existing scenario, 10, 25 and 50 for other three scenarios)

OX = oxidation factor (fraction - default is 0)

Using this equation, methane emission from solid waste produced in cities is estimated for 30 years with 2000 as base year. Methane emission from rural sector is neglected as this sector generates low waste, which is self-managed aerobically. Beside current scenario where there is no any methane recovery system, three other scenarios are considered with methane recovery options. Methane can be recovered form solid waste either by composting of organic waste or methane capture from landfill sites. In total, the following 4 scenarios are considered.

Business-as-Usual (BAU) Scenario: No methane recovery

Scenario10%: 10% methane recovery

Scenario25%: 25% methane recovery

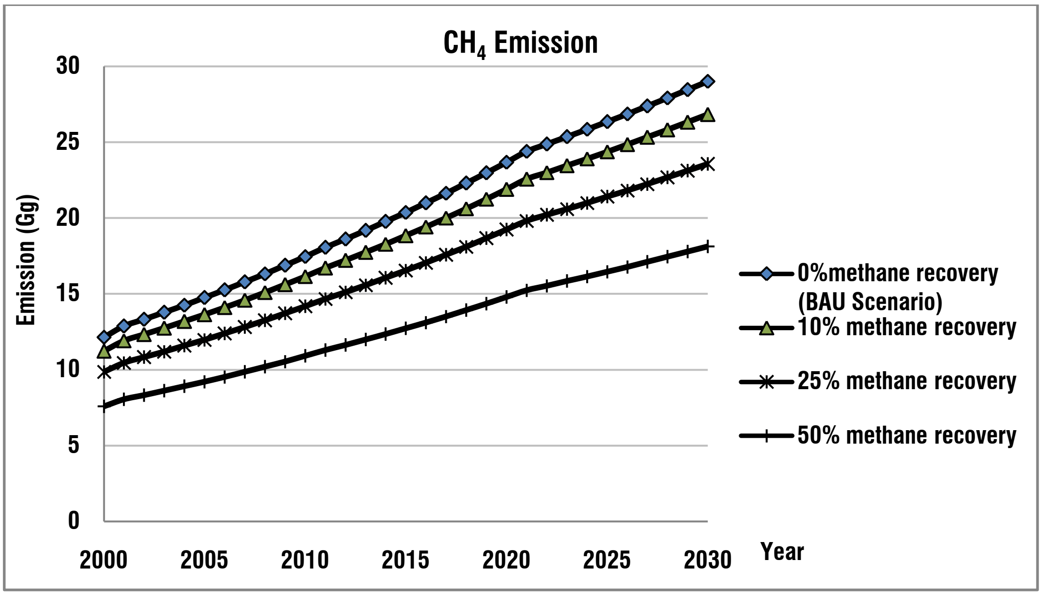
Scenario50%: 50% methane recovery

Methane generation for years 2015, 2020, 2025 and 2030 considering four different scenarios is given in Table 3-15 and Figure 3-7.

Table 3-15: Projected methane emission under different scenarios

Scenario	CH_4 Emission (Gg)				
	2000	2015	2020	2025	2030
BAU Scenario	12.16	20.38	23.69	26.36	29.02
Scenario10%	12.16	18.85	21.91	24.38	26.84
Scenario25%	12.16	16.56	19.24	21.42	23.58
Scenario50%	12.16	12.74	14.80	16.47	18.14

Figure 3-7: CH_4 emission in the solid waste sector



3.5.3 Mitigation Options and Policies

Mitigation measures in the waste sector include source reduction through waste prevention, recycling, composting, waste-to-energy incineration, and CH_4 capture from landfills and wastewater. Policies for waste minimization and GHG reduction include taxes on solid waste disposal (bag fees), market incentives (e.g. offsets) for improved waste management and recovery of CH_4, and regulatory standards for waste disposal and wastewater management (e.g., mandatory capture of landfill gas).

Use of 3R Principles: The 3R principle (reduce, reuse and recycle) for solid waste management could be the cost effective mitigation option for Nepal. Recycling involves collection of used and discarded materials, processing these materials, and making them into new products. It reduces the amount of waste that is thrown into the community dustbins, thereby making the environment cleaner, and saves raw materials as well as contributes to methane production. Composting returns the organic matter to land, and thereby reduces depletion of resources and balances eco-cycle of agricultural production.

Regulation is required to ban entry of recyclable waste in landfill. Several private entrepreneurs as well as NGOs and CBOs have emerged recently in waste management with 3R principles. Public private partnership (PPP) models are already being explored in this area, which should be encouraged.

Source Reduction: Methane generation can be reduced by means of reducing volume of organic solid waste at the source. Reduction of organic waste generation minimizes organic matter to be treated or disposed. Municipalities, community and NGOs can work together to improve current practices in this area. Regulation should be made to make source reduction at point of generation compulsory.

Waste Segregation: Waste segregation is the process by which waste is separated into different elements. Waste can be segregated as Biodegradable and Non-biodegradable. Biodegradable waste includes organic waste, e.g. kitchen waste, vegetables, fruits, flowers, leaves from the garden, and paper, which can be processed for compost. Waste segregation can be practiced manually at the household level, and the segregated waste can be collected through curbside collection schemes. Waste segregation increases capacity of recycling, composting, and recovery process.

Municipalities, community and NGOs can work together to improve current practices in this area. Regulation should be made to make waste segregation effective.

Anaerobic digestion for Biogas: Anaerobic digestion of waste to produce biogas and slurry is another way to recycle organic waste and reduce GHG emission. Public Private Partnership models should be explored and encouraged in this area.

Sanitary landfill sites with methane capture: The methane produced from sanitary landfills can be tapped, and used as fuel if gas collection system is installed. Regulation is required for all municipalities to have sanitary landfill sites with compulsory flaring of landfill gas.

Proper guidelines and strategies are necessary for developing landfill sites so that methane gas can be trapped and utilized. OM can be converted into biogas through anaerobic digestion, especially from animal waste. Energy recovery can be done in community and massive population camps. For this, regulation for compulsory recovery in army, police camps, school and hostels would be helpful.

Healthcare Waste Management: In Nepal healthcare waste is often disposed alongside municipal solid waste (MSW). Waste segregation is neglected by the majority of healthcare institutions. The existing policy – the Healthcare Waste Management Guidelines (2009) – is not effectively followed till date. Moreover, specific landfills for healthcare and hazardous waste are yet to be developed. Therefore, an overall improvement in healthcare waste management is needed, with a focus on the enactment of a clear healthcare waste policy. Healthcare institutions can reduce their contribution to the GHG emission through the following measures:

- Recycling and buying recycled products
- On-site wastewater pre-treatment and solid waste management improvement

Statutory Framework: In Nepal, statutory framework has been established for SWM. However, it is not adequate for the effective and efficient resource recovery and recycling activities until and unless followed by proper regulations, guidelines, standards, plans and programs. Furthermore, little attention has been paid towards the enforcement of the existing policies and acts. Solid Waste Management Act 2011 recognizes the need of integrated solid waste management with source separation, reduction, reuse, recovery and recycle. Although legal provisions in this act are well defined, there is an urgent need of regulations and technical guidelines to make these provisions proactive for SWM.

Public participation: Community awareness on SWM can play a major role in promoting measures such as at-source segregation, recycling and reusing of waste. Local government and NGOs should effectively co-ordinate to ensure community participation through awareness-raising programs. Municipalities should coordinate, encourage and work with local NGOs and communities which are working for reduction, reuse and recycling of waste.

Private sector partnership: Due to financial and resource limitations of local governments, engaging private sector as waste management service providers is a viable option. However, private sector operators may not be attracted without the necessary policy measures, incentives and investment environment.

Tax waiver for recycling enterprises: Recycling is an important part of sustainable waste management. Enterprises that deal with recycled materials could be encouraged by a waiver of local government taxes.

Financial management: Most municipalities in Nepal have limited resources to facilitate proper SWM services. A systematic and organized approach to SWM with financial support should be provided by the central government.

3.6 Requirements for Implementation of Mitigation Actions

To implement mitigation measures at ground levels, followings are the basic requirements in context of Nepal.

Policy requirements: Government of Nepal has already prepared and endorsed National Adaptation Program of Action (NAPA), Local Adaptation Plan of Action (LAPA), Climate Change Policy, Environment Protection Act 1997, Environment Protection Rules 1997 and several other policies that will be instrumental to mitigate the effects of climate change. These policies will be able to produce results only if supplemented by necessary guidelines, regulations, work procedures, action plans and standards. Also, climate change mitigation is a cross-cutting issue. So, policies should be designed so as to involve multidisciplinary stakeholders.

Coordination: Integrating climate change into development policy, planning and implementation requires vigorous efforts from a wide range of stakeholders. In recent years, institutional, collaborative and programmatic activities have intensified to address the issue of climate change. Efforts to mobilize funds to implement programs on climate change are under way from the government as well as from donors. However, there is a poor coordination among stakeholders responsible for climate change risk management and environmental protection. This coordination should be made more cohesive.

Funding: The current economic situation of the country suggests that there is a need to allocate more resources to develop physical infrastructure, and increase people's access to basic services. Development actors are not foreseeing the need for green development. There is greater understanding that least developed countries with fragile economy and ecosystem need additional funding to tackle adverse impacts of climate change.

Technical knowledge and research: It is important to give attention to develop a capable organizational structure with adequate financial and human resources to perform evidence based research on climate change issues specific to Nepal, and on piloting and promoting appropriate local adaptive knowledge. There is a need to effectively enhance the capacity of public institutions, planners, technicians, private sector, NGOs and civil society involved in the development work.

Result based performance: Weak environmental governance due to an extended political transition and various other factors could affect implementation of mitigation measures. There is a need to have proper business plan related to mitigation measures with clear monitoring and evaluation (M&E) provision on the basis of results obtained by all stakeholders.

Public awareness: Empowering communities through education to promote awareness is a key prerequisite for proper implementation of mitigation measures.

Green development: Since industrial development in the country is at early stage, industrial promotion and environmental protection need to proceed concurrently. To manage industrial environment, environmental standards are pre-requisites at local context because an industry may not be able to follow internationally accepted standards overnight. Environmental management system (EMS), if adopted by industries, will assist to meet industry-specific emission standards, waste minimization and cost savings procedures. Industrial in-house management by good housekeeping practices, and behavioral change in customary practices would substantially reduce industrial pollution load.

Clean Development Mechanism (CDM): The Clean Development Mechanism (CDM) is a cooperative mechanism established under Kyoto Protocol to assist developing countries in achieving sustainable development by promoting environmentally friendly investment from industrialized country governments and businesses.

3.7 Action Plans

The Climate Change Action Plan identifies actions already underway as well as recommended actions that will effectively enhance the Government of Nepal's response to climate change. The actions support one or more of the goals of the climate change mitigation strategy.

Table 3-16: Proposed Action Plans with targets to reduce GHGs emission

Sector	Target	Action Plans
Energy, Residential and Commercial	The share of traditional energy sources in the residential sector (e.g., agricultural residue, animal dung, fuel wood) is reduced by 5% till 2017 and thereafter by 15% till 2030.	– Develop energy efficiency standards. Financial support to upgrade existing homes or build new homes to meet standards. – Develop Leadership in Energy and Environmental Design (LEED) certified energy efficiency standards for new or renovated commercial and institutional buildings. – Develop policies for promotion of renewable energy (e.g., wind, solar and hydropower) – Financial support to install alternate energy systems such as solar, wind, micro-hydro, ICS etc. Alternative energy promotion in urban areas too.
Energy, Industrial	The share of coal in the industrial sector is reduced by 5% till 2017 and thereafter by 15% within 2030	– Develop hydropower projects. Subsidize use of hydro-electricity and other green energies for gradual replacement of the use of fossil fuels.
Energy, Transportation	The share of fossil fuel in the transport sector is reduced by 3% till 2017 and thereafter by 10% within 2030	– Encourage purchase of fuel efficient vehicles as well as promote public and active modes of transportation. – Upgrade and effectively implement Vehicle and Transport Management Act 1993 and Nepal Vehicle Mass Emission Standard 1999 which is clarified as similar to Euro-1 standard to Euro-3 standard – Conduct vehicles test through ultra-modern equipments from Vehicle Fitness Test Centre (VFTC) – Formulate new National Transportation (Vehicle) Policy which will encourage to import and manufacture environment friendly and low pollutant vehicles in Nepal
Industrial Process	Reduce GHGs emission from industries by 3% till 2020 and thereafter by 6% within 2030	– Prepare rules for industries to conduct energy and environment audits – Conduct efficient monitoring of national efficiency standards – Conduct life cycle analysis to display

Sector	Target	Action Plans
		carbon emission-footprints – Implement Environment Management System (EMS) in all industries
Agricultural Process	Reduce GHGs emission from agricultural sector by 5% till 2020 and thereafter by 10% till 2030	– Prepare guidelines for farmers that include proper livestock management. – Establish farmers' cooperatives that will, among others, oversee proper utilization of forage resources through monitoring of stock numbers, grazing duration and grazing time, nutrient management and shrub and weed control
Land Use, Land Use Change and Forest	Increase carbon sink through forestation (10 % of degraded lands to be covered by forest within 2020 and 20% within 2030)	– Restore degraded lands through forestation (e.g., promotion of community forest and lease forest)
Waste	10% methane recovery of waste within 2020 and 25% methane recovery within 2030	– Support municipalities in incorporating solid waste management related programs and actions in the annual plan and budget. – Develop code of practices for waste management, promulgation of bylaws, directives. – Promote municipal/community composting as well as household composting of organic wastes – Develop landfill sites with methane recovery facilities – Ensure financial sustainability by enhancing efficiency and promoting cost recovery mechanism

Chapter 4

Vulnerability and Adaptation Assessment

4.1 Definitions

Climate change vulnerability and adaptation assessment provides information regarding the programs that include measures to facilitate adequate adaptation to climate change.

IPCC Third Assessment Report defines 'vulnerability' as "the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes and thus vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (IPCC 2001, p. 995).

European Commission defines 'adaptation' as "anticipating the adverse effects of climate change and taking appropriate action to prevent or minimize the damage they can cause, or taking advantage of opportunities that may arise" (source: http://ec.europa.eu/clima/policies/adaptation/index_en.htm). Well planned, early adaptation action saves money and lives later.

4.2 Observed Climatology

Nepal covers a broad spectrum of ecological zones in Central Himalayas. The topography varies significantly over the area, and hence besides the atmospheric circulation, the climate of Nepal is influenced by a variety of physiographic features.

Statistical analysis: In this study, data from Department of Hydrology and Meteorology (DHM), Government of Nepal have been used in analyzing temperature (both maximum and minimum) and precipitation. Thirty year time series data prior to 2010 observed at 110 stations for surface air temperature and 309 stations for precipitation have been used. These stations are in general well distributed in lower altitude regions of the country; however, at higher altitude regions the numbers of stations are few, which results in immense limitation in understanding the climate of Nepal.

Rclimdex software is used to control the quality of both temperature and precipitation data. The linear trend computed in this study is considered as a monotonic increase or decrease in the average value of the parameter that is observed between the beginning and ending of the period under consideration. While computing trends, special attention is given for selecting data. Within thirty years period, those stations having maximum three intermittent missing monthly values in the series are chosen and filled. Data filling algorithm consisted of three steps: (a) computation of mean, standard deviation and standardized anomaly at each station, (b) gridding of the standardized anomaly values, and (c) missing value is estimated from the mean, standard deviation and nearest gridded standardized anomaly value. This method has advantage of preserving mean and gridding errors if any are very small. Gridding technique applied is an inverse square distance averaging method (Pant and Kumar, 1997).

Temperature trend: The country's annual mean temperature field and the distribution of annual mean temperature trend is depicted in Figure 4-1.

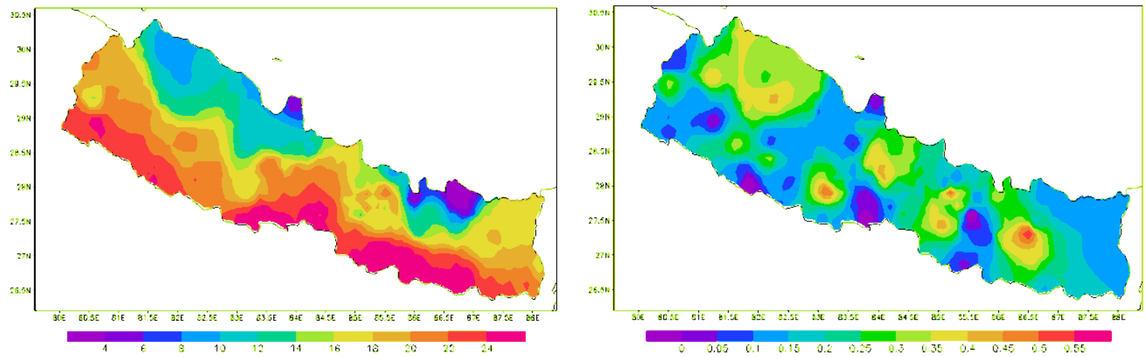


Figure 4-1: Annual mean temperature (˚C) (left); annual mean temperature trend (˚C/ decade) (right)

In mean annual distribution, the Terai region has maximum temperature of more than 24°C and northern high mountainous region has lowest minimum temperature of less than 4°C. All-Nepal annual mean maximum temperature is 23.6 °C and that of minimum is 11.6°C. From the distribution of annual mean temperature trend, it is evident that, except for small isolated pockets, most of Nepal has an increasing trend upto 0.55° C per decade.

Precipitation Trend: Annual distribution of precipitation over Nepal and trend are shown in Figure 4-2. It is observed that the highest precipitation of more than 5000 mm centered over southern flank of Annapurna range and the driest part with about 500 mm on the lee side of the same range (Figure 4-2, left). This shows the importance of topography on spatial variations of precipitation distribution in Nepal. In addition, eastern high altitude regions have two pockets of about 3000 mm annual precipitation. Rest parts of the country have precipitation distribution of approximately 1000-2000 mm, which increases towards northern mountains, except over western part of the country where it decreases towards north. All-Nepal average annual precipitation is 1683 mm of which 1330 mm falls during summer monsoon.

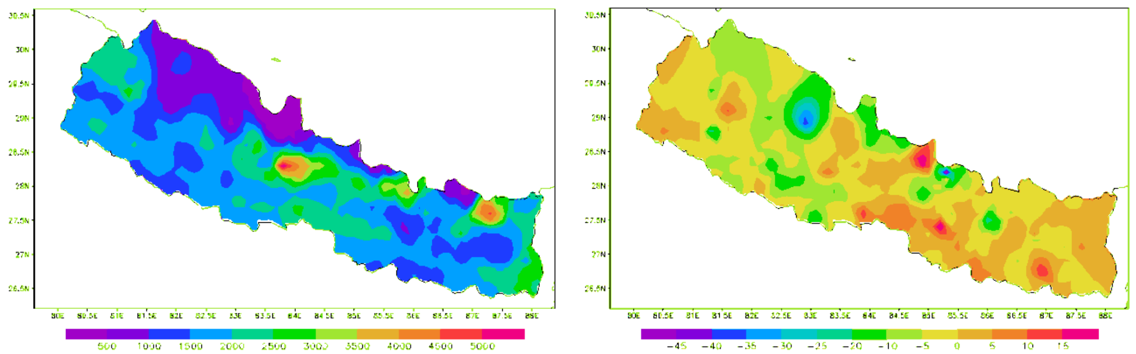


Figure 4-2: Annual precipitation (mm) (left); annual precipitation trend (% of annual /decade) (right)

The annual precipitation in most part of the country, in general, shows a positive trend with maximum increase of about 15% of the annual amount per decade over few isolated pockets (Figure 4-2, right) while some places of west Nepal show negative trend. Percent distributions of summer monsoon precipitation to annual total presented in Figure 4-3 shows the importance of monsoon circulation to the precipitation input over Nepal. It is seen that except the northwestern rain-shadow region, around 80 percent of annual precipitation in Nepal is contributed by summer monsoon.

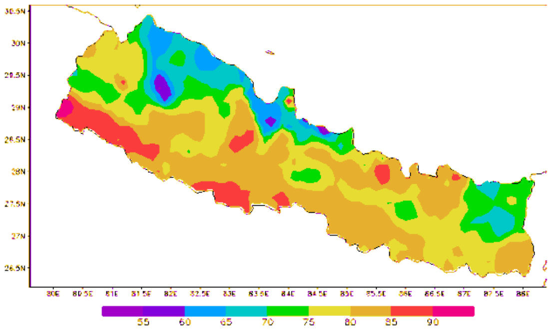


Figure 4-3: Percent of monsoon precipitation to annual precipitation

Extreme Weather: It is likely that climate change in Nepal will increase the frequency and magnitude of extreme weather events. In this section, extreme climatic events are examined by means of some climate change indices. These indices are derived from the daily temperature and precipitation data using RClimDex software. The results are presented in Figures 4-4 and 4-5.

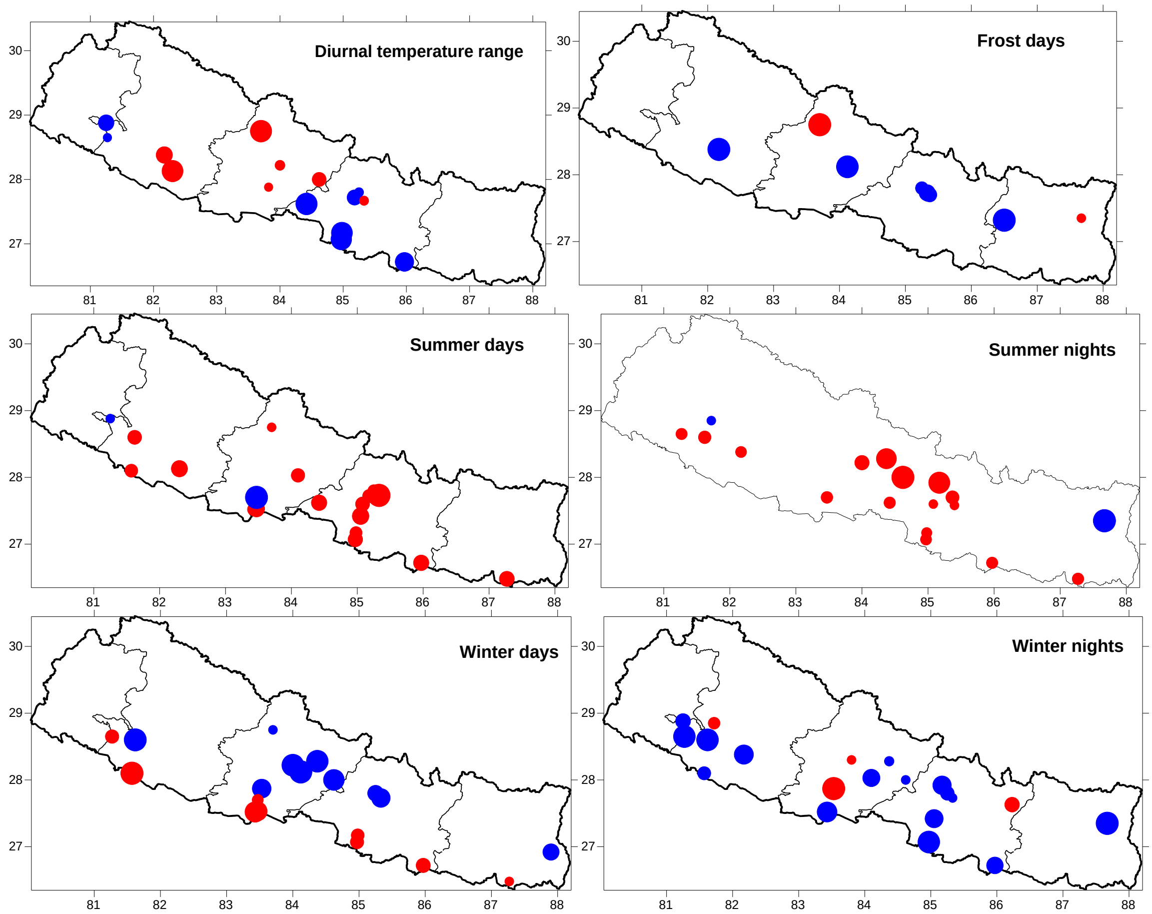


Figure 4-4: Trend of change in temperature indices in a year

Note: (1) Diurnal temperature range: -0.053 to +0.05; frost days: –0.446 to +0.921; summer days: -0.249 to +1.214; summer nights: -1.974 to +2.06; winter days: -0.053 to +0.113; and winter nights: -0.068 to +0.078. (2) Blue and red circles represent decreasing and increasing trends respectively, and the size of the circles are proportional to the magnitude of the trends. (3) Only trends having 90% or higher statistical significance are presented in these figures.

Temperature Extremes: Figure 4-4 depicts annual trends in various temperature indices, where the trends in diurnal temperature range (monthly mean difference between daily maximum and minimum temperatures) are positive over most of the stations and negative over southern plain. In addition, decreasing trends in occurrences of frost days (annual count when daily minimum temperature is less than 0 ºC) are evident over the mountainous region. Further, increasing trends in summer days as well as summer nights and decreasing trends in winter days as well as winter nights over most of the stations, except increasing trends of winter days over southern Terai region which could be due to persistent winter fog over Terai region, are evident.

Precipitation Extremes: Figure 4-5 shows annual trends in various precipitation indices, where indices like monthly maximum one day precipitation amount, annual count of days when precipitation of 50 mm or more falls, extremely wet days (annual total precipitation when rainfall exceeds 99th percentile) all exhibit increasing trends in many stations particularly in the west and decreasing trends in some mountainous locations. However, the annual total precipitation in wet-days (days with 1 mm or more precipitation) does not exhibit increasing trends. In addition, increasing trends in consecutive dry days (maximum number of consecutive days with rainfall less than 1 mm) and decreasing trends in consecutive wet days (maximum number of consecutive days with rainfall equal or more than 1 mm) over most of the stations are good indicators of increasing extreme precipitation events in Nepal.

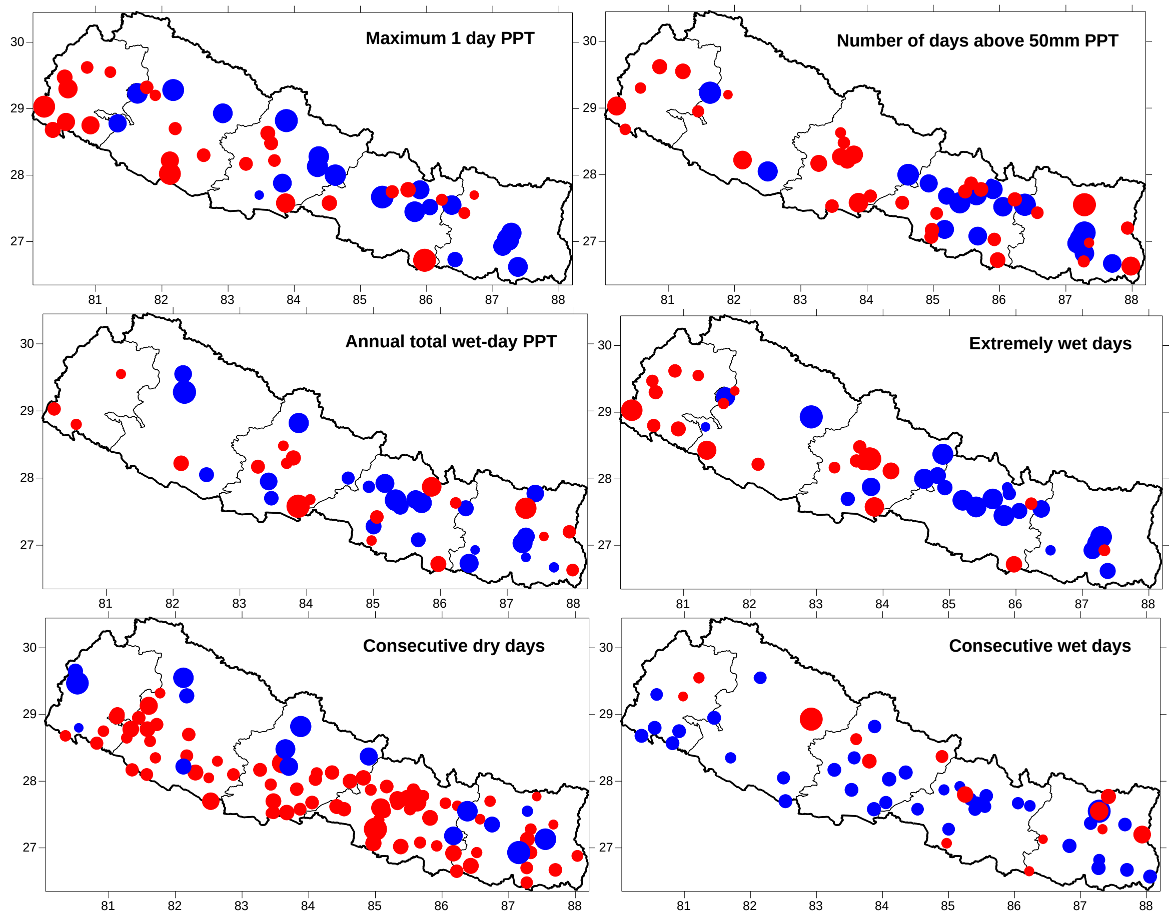


Figure 4-5: Trend of change in precipitation indices in a year

Note: (1) Maximum 1-day precipitation: -3.331 to +2.735; number of days with more than 50 mm precipitation: -0.286 to +0.260; annual total wet-day precipitation: -16.815 to +28.060; extremely wet-day precipitation: -8.252 to +10.672; consecutive dry days: -0.60 to +2.09; and consecutive wet days: -0.44 to +0.855. (2) Blue and red circles represent decreasing and increasing trends respectively, and the size of the circles are proportional to the magnitude of the trends. (3) Only trends having 90% or higher statistical significance are presented in these figures.

4.3 The Climate Models (GCMs and RCM)

4.3.1 Selection of Appropriate Climate Model

The Intergovernmental Panel on Climate Change (IPCC) forecasts that there will be an increase during this century in the average global surface air temperature by 2.8˚C, with best-guess estimates of the increase ranging from 1.8 to 4.0˚C (IPCC, 2007). For such projections of climate under different scenarios (IPCC), General Circulation Models (GCMs) are realistic and generally applied. However, due to poor spatial resolution, these models are unable to capture climatic details forced by local topographical variations. Hence, in a country like Nepal, downscaling of the GCM products is required. There are, in general, two methods for downscaling such products in practice: (i) dynamical downscaling (also called Regional Climate Models) and (ii) statistical downscaling (in this method, observed climate data are used to find the relationship between large-scale climate variables and local surface variable).

In this study, dynamical downscaling approach is applied. Impact of global warming on Nepal's climate is examined using Hadley Centre's high resolution regional climate model called PRECIS (Providing Regional Climate for Impact Studies). Three simulations from a 17-member Perturbed Physics Ensemble generated using Hadley Center Coupled Model (HadCM3) are available from Indian Institute of Tropical Meteorology (IITM), Pune, India. These 17 different members ensemble are for the Quantifying Uncertainty in Model Predictions (QUMP) project. The PRECIS simulations corresponding to the SRES A1B (IPCC) emission scenario are carried out for a continuous period of 1961–2098.

Climate projections: The climate projections are examined over three time slices, viz. short (2020s, i.e. 2011–2040), medium (2050s, i.e. 2041–2070) and long (2080s, i.e. 2071–2098) changes. Results of these analyses are useful for impact assessment studies and for planning adaptation and mitigation measures in Nepal.

Validation of the model: Validation expresses the capability of the model to capture the diversity of a climatic element at certain location by comparing its observed and modeled annual cycles. The systematic fluctuations of any climatic element across the seasons are generally reflected by such cycles, where amplitude of the cycles typically shows the diversity of the climate. The second method of validation is done by quantifying the model errors and assessing causes of errors. One of the widely used methods for quantifying the model errors is by subtracting baseline modeled value from the observed, also called bias of the model.

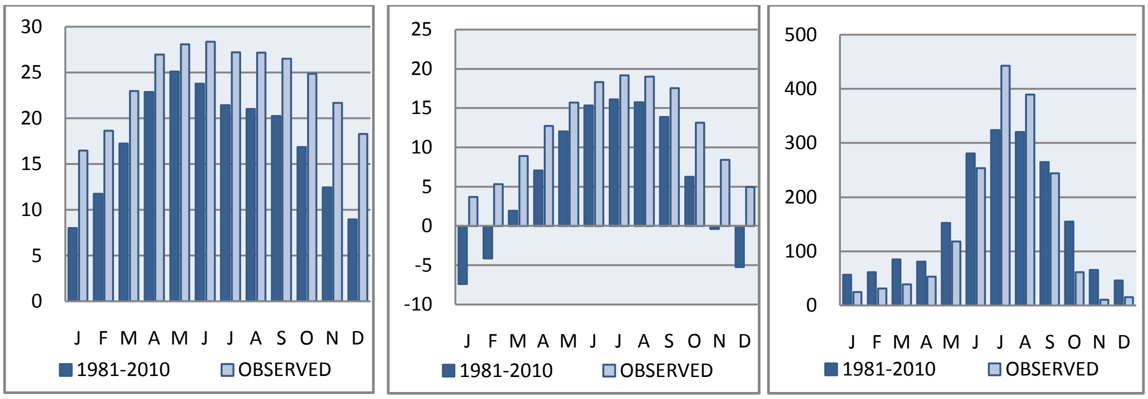


Figure 4-6: Annual cycles of model baseline and observed maximum temperature (ºC) (left), model baseline and minimum temperature (ºC) (center), and model baseline and observed precipitation (mm) (right)

Note: J to D denotes 12-months starting from January to December.

Figure 4-6 (left and center) depicts annual cycles of observed and PRECIS simulated maximum and minimum temperatures during the model baseline period (1981-2010). These figures show that the model excellently captures the annual cycles of both temperatures. However, some degree of systematic cold bias is present in the entire monthly estimation of both maximum and minimum temperatures. In maximum temperature, the model simulates lowest seasonal bias of 4.3˚C in spring and highest of 8.6˚C in autumn (Table 4-1). Similarly, in the case of minimum temperature, the model simulates lowest seasonal bias of 3.3˚C in summer and highest of 10.2˚C in winter.

Table 4-1: Observed all-Nepal seasonal and annual temperature and their PRECIS-projected values during baseline period (1981-2010) including increment during 2020s, 2050s, and 2080s

Season	OBS (˚C)	Baseline (˚C)	Bias (˚C)	2020s (˚C)	2050s (˚C)	2080s (˚C)
Maximum Temperature:						
DJF	17.8	9.5	8.3	1.5	2.8	4.4
MAM	26.0	21.7	4.3	1.1	2.6	4.5
JJAS	27.3	21.6	5.7	1.0	2.1	3.3
ON	23.3	14.7	8.6	1.2	2.7	3.8
Annual	23.6	16.9	6.7	1.2	2.6	4.0
Minimum Temperature:						
DJF	4.7	-5.6	10.2	2.3	3.9	5.4
MAM	12.5	7.0	5.4	1.2	2.9	4.2
JJAS	18.5	15.3	3.3	1.2	2.4	3.4
ON	10.8	2.9	7.8	2.5	3.8	5.0
Annual	11.6	4.9	6.7	1.8	3.3	4.5

Note: (1) 2020s: 2011-2040; 2050s: 2041-2070; and 2080s: 2071-2098. (2) DJF denotes December-January-February; MAM denotes March-April-May, and so on.

Annual cycles of observed and PRECIS simulated monthly precipitation during the baseline period (1981-2010) is presented in Figure 4-6 (right). In general, the model captures the observed annual precipitation cycles very well. However, the figure depicts that the model overestimates precipitation throughout except during core-monsoon months of July and August, where it is underestimated. The magnitudes of these biases is found highest (206 % of the post-monsoonal average) in post-monsoon and smallest (11 % of the monsoonal average) in summer monsoon (Table 4-2).

Table 4-2: Observed all-Nepal seasonal and annual precipitation and their PRECIS projected values during baseline period (1981-2010) including changes during 2020s, 2050s and 2080s

Season	OBS (mm)	Baseline (mm)	Bias (%)	2020s (%)	2050s (%)	2080s (%)
DJF	71	163	-130	-15	3	-12
MAM	211	319	-51	4	10	-3
JJAS	1330	1190	11	-1	8	20
ON	72	220	-206	-4	-5	3
Annual	1683	1892	-12	-2	6	12

Note: (1) 2020s: 2011-2040; 2050s: 2041-2070; and 2080s: 2071-2098. (2) DJF denotes December-January-February; MAM denotes March-April-May, and so on. (3) Bias and changes are in percentage of their normal values.

4.3.2 Climate Scenarios (2020s, 2050s, 2080s)

Temperature change: Distributions of the PRECIS projected annual maximum and minimum temperatures for baseline period (1981-2010) and increment during short (2011-2040), medium (2041-2070) and long (2071-2098) term durations are respectively depicted in Figures 4-7 and 4-8. These distributions show warming trends of both maximum and minimum temperatures during the entire 21st century over whole country, in general, with higher intensities at higher altitude regions.

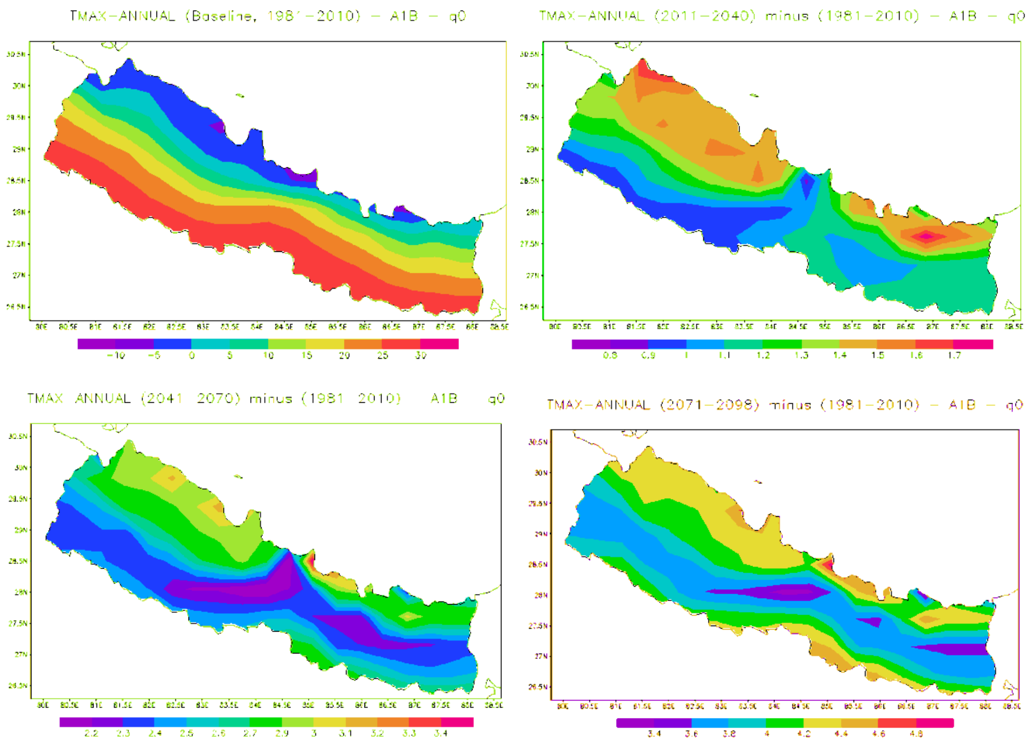


Figure 4-7: PRECIS-projected annual maximum temperature for baseline period (1981-2010) and its increment during 2020s, 2050s, and 2080s

Note: 2020s – short term (2011-2040); 2050s – medium term (2041-2070); and 2080s – long term (2071-2098).

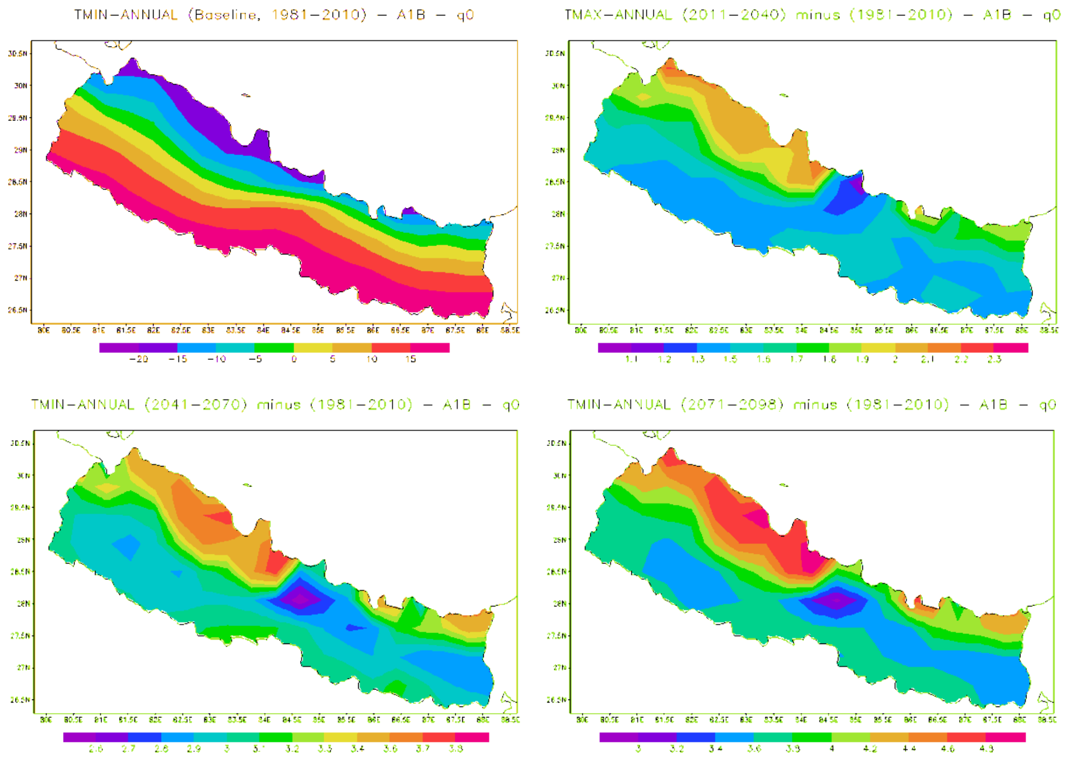


Figure 4-8: PRECIS-projected annual minimum temperature for baseline period (1981-2010) and its increment during 2020s, 2050s, and 2080s

Note: 2020s – short term (2011-2040); 2050s – medium term (2041-2070); and 2080s – long term (2071-2098).

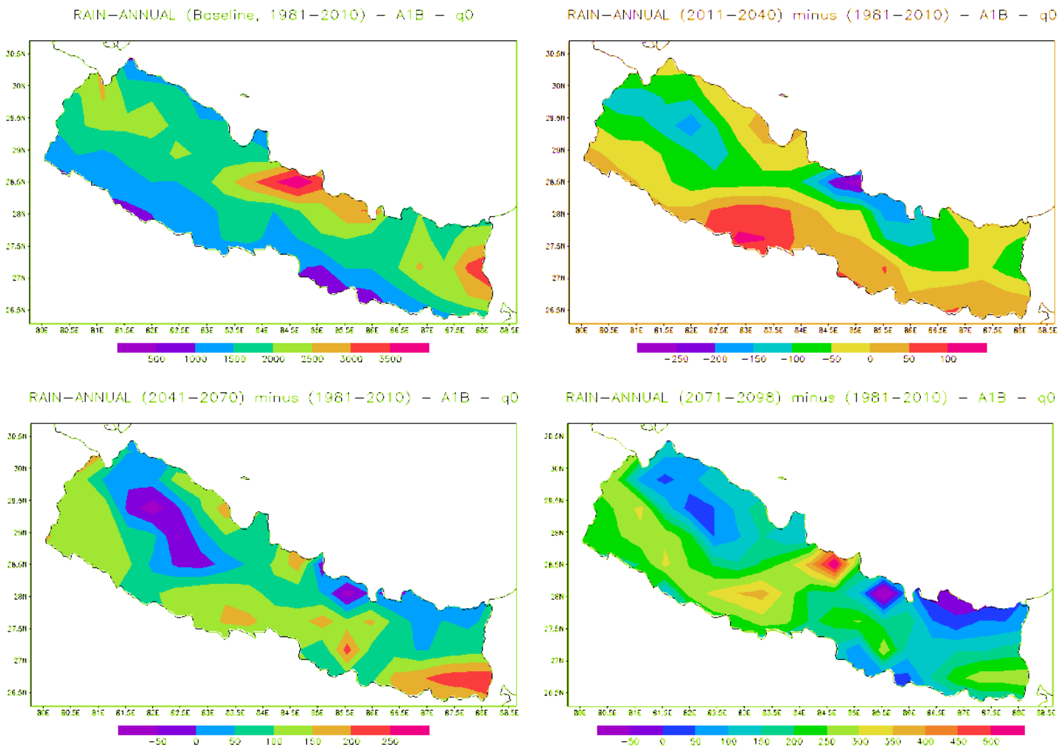


Figure 4-9: PRECIS-projected annual precipitation for baseline period (1981-2010) and its increment during 2020s, 2050s, and 2080s

Note: 2020s – short term (2011-2040); 2050s – medium term (2041-2070); and 2080s – long term (2071-2098).

Overall seasonal maximum temperature in the country is found to have the largest increase of 4.5˚C in spring and smallest increase of 3.3˚C in summer, whereas minimum temperature in the country is found to have the largest increase of 5.4˚C in winter and smallest increase of 3.4˚C in summer by the end of the 21st century (Table 4-1).

Precipitation change: Distributions of the PRECIS projected annual precipitation for baseline period (1981-2010) and percent increment from the baseline during short (2011-2040), medium (2041-2070) and long (2071-2098) term durations are shown in Figure 4-9. Overall annual precipitation in the country is found to be decreasing by 2% of the baseline amount by 2020s. However, it increases by 6% and 12% of the baseline by 2050s and 2080s respectively (Table 4-2).

4.4 Agricultural Sector

4.4.1 Impacts of Climate Change on Crop Production

Agriculture in Nepal is highly vulnerable to climate change due to its rugged terrain with steep topography, tectonically active geology and related risks of the natural disasters. Large proportion of marginal farmers with small landholding, limited irrigation availability, low income level, limited institutional capacity, and greater dependency of agriculture on climate-sensitive natural resources increase the degree of vulnerability (Regmi and Adhikari, 2007; World Bank, 2008).

Climate change has potential effects on costs of production, farm revenues, employment, income, consumption, and finally on the GDP. Effect of climate change on crop productivity along with farm productivity is particularly sensitive because of its strong linkage with food security.

Farmers are likely to face three types of costs from climate change, namely, direct impact, indirect impact, and adaptation costs (Pant, 2011).

- **Direct costs from the effects of climate change on crop production, livestock production, and risks of natural hazards.**
- **Indirect costs from the effects of climate change on socioeconomic conditions and lost opportunities for their advancement of the living conditions.**
- **Costs of adaptation incurred to keep themselves away from or minimize the negative effects of climate change.**

Climate Variability and Crop Productivity

Many studies have attempted to estimate impacts of climate change on agriculture mostly by combining crop growth models with economic models (Parry et al., 1999; Tsigas et al., 1997). Effects of climate change on agricultural production have been assessed econometrically taking the major crops rice and wheat as the indicator crops.

Using projected climate parameters, and projected water availability from the water modeling component, the effect of climate change on crop productivity is estimated using a regression model of the following functional form (with correction of confounding effects of the technological changes on the crop yield) : $Y = \beta_0 + \beta_1 C + \beta_2 W + \beta_3 T + \mu$, where, Y is a vector of percent changes in yields estimated from the historical data, C is a vector of climate change variables (temperature, rainfall etc) observed in the past, W is a vector of water availability variables (irrigation, rainfall distribution), T is technological changes, μ is a vector of errors, and β_i (i=1,2,…) is the parameter that indicates the relationship between changes in climate, water and technology. β_0 is the intercept term indicating that there is yield even without any change in the climate and water parameters.

The historical crop yield data have been obtained from the publications of the Ministry of Agriculture and Cooperatives and the Central Bureau of Statistics; climate change variables data such as temperature and rainfall from the Department of Hydrology and Meteorology. But national aggregation of such data is difficult as it removes the individual variations at the local level. Considering this difficulty, the model estimated for three locations across the country. Three districts with the high production of rice and wheat from eastern, central, and western parts of the country were identified and the time series model was fitted with the meteorological data from the nearest station. Three districts namely Morang, Rupandehi, and Kailali were selected for this study.

Effect of Climate Change on Rice Production: The paddy yield data for last 39 years were compiled for three districts Rupandehi, Morang and Kailali (Table 4-3). The highest average yield over the years was found in Morang district followed by Rupandehi.

Table 4-3: Descriptive statistics of paddy yield in three districts

S.N.	Paddy Yield in Districts (kg/ha)	Years	Mean	Standard Deviation	Minimum	Maximum
1	Rupandehi	39	2256.56	563.69	1105	3500
2	Morang	39	2367.28	553.09	1598	3284
3	Kailali	39	2179.26	464.87	778	3020

Data source: MOAC (different years)

The analysis showed that the rice yield was affected by temperature regime (see Table 4-4). Maximum temperature in the month of July reduces rice yield in Kailali district by 259 kg/ha. Kailali district, being at the western part of the country, receives the monsoon rains later than in Morang and Rupandehi. This may be the reason that an increase in the maximum temperature in July

decreases the rice yield in Kailali. Similarly, a degree rise in temperature in September decreases the rice in Morang by 141 kg/ha. These figures show that increase in maximum temperature during summer season can reduce rice production. On an average, every degree rise in temperature during July-September decreases paddy production by 235 kg/ha which is 10.37% of the average production. Similarly, every millimeter increase in rainfall during the crop season increases the paddy production by 0.50 kg/ha. Atmospheric concentration of CO_2 is not affecting the rice yield. It is due to the reason that the CO_2 concentration in the atmosphere is slightly multi-collinear with the temperature as the former is the cause and later is the effect. However, it is to be noted that Increase of amount of rain may not always increase paddy production. Hence, it would be better to include the intensity and distribution of rain over the years and its effects on paddy production.

Table 4-4: Effects of monthly precipitation and maximum temperature on paddy yield

S.N.	Variables	Rupandehi		Morang		Kailali	
		Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
1	July max. temperature	199.29	143.88	-43.86	67.28	-259.35**	115.84
2	August max. temperature	-305.58*	177.10	25.49	63.23	60.75	157.76
3	Sept max temperature	-214.36	200.78	-140.94**	68.00	61.55	154.63
4	Oct max temperature	165.80	106.80	57.15	43.65	107.14	111.00
5	Precipitation in July	0.80	0.55	0.01	0.19	-0.54	0.53
6	Precipitation in August	-0.62	0.57	0.50**	0.24	0.31	0.63
7	Precipitation September	0.84	0.75	-0.40	0.30	0.70	0.63
8	Precipitation in October	1.43	1.16	0.47	0.32	0.77	0.94
9	CO_2 (ppm)	6.25	8.78	2.27	2.73	-7.11	4.98
10	Constant	2550.91	7254.56	2402.08	2461.20	3761.16	4301.35
	Observations	32		37		30	
	R-squared	0.260		0.340		0.310	

Data source: MOAC (different years). Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Rise in monthly minimum temperature however, does not decrease the paddy yield. Instead, every degree rise in the minimum temperature during the month of October increases the rice yield in Rupandehi district by 222 kg/ha (Table 4-5).

Table 4-5: Effects of monthly precipitation and minimum temperature on paddy yield

S.N.	Variables	Rupandehi		Morang		Kailali	
		Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
1	Min. temperature in July	-96.93	328.07	-117.22	125.64	65.83	186.65
2	Min. temperature in Aug	-180.91	275.60	162.72	137.35	-261.69	268.67
3	Min. temperature in Sept	-57.54	239.65	-41.16	123.21	173.73	161.17
4	Min. temperature in Oct	222.09*	127.49	61.11	44.20	32.02	72.67
5	Precipitation in July	-0.26	0.54	-0.08	0.20	0.38	0.53
6	Precipitation in August	-0.27	0.62	0.54**	0.26	-0.17	0.45
7	Precipitation September	0.35	0.74	0.11	0.33	0.55	0.49
8	Precipitation in October	-0.65	1.37	0.08	0.32	-0.52	0.94
9	CO_2 (ppm)	4.10	5.38	-0.73	2.03	-3.20	4.89
10	Constant	2846.47	6811.05	-1363.95	2246.91	1131.13	6302.11
	Observations	30		37.00		30.00	
	R-squared	0.201		0.280		0.230	

Data source: MOAC (different years). Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Effect of climate change on wheat production: Wheat yields in the study districts are presented in Table 4-6. The average wheat yield is highest in Morang followed by Rupandehi. As in the case of rice, the wheat yield is minimum in Kailali district among the three.

Table 4-6: Descriptive statistics of wheat yield in study districts

S.N.	Variable	Year	Mean	Standard Deviation	Minimum	Maximum
1	Wheat yield in Rupandehi (kg/ha)	39	1613.74	603.23	600	3067
2	Wheat yield in Morang (kg/ha)	39	1623.46	452.4	600	2400
3	Wheat yield in Kailali (kg/ha)	39	1515.74	520.29	611	2641

Data source: MOAC (different years).

Results show that every degree increase in the maximum temperature in the month of January increases the wheat yield by 63 kg/ha in Morang (Table 4-7). Every millimeter increase in rainfall during January increases the wheat yield by 4 kg/ha. Increase in CO_2 concentration is expected to increase the wheat yield. But, this could not be demonstrated with the econometric models due to the fact that the CO_2 concentration in the atmosphere has multi-collinearity effect.

Table 4-7: Effects of monthly precipitation and maximum temperature on wheat yield

S.N.	Variables	Rupandehi		Morang		Kailali	
		Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
1	Max. temperature in November	-6.01	78.03	-38.31	47.95	39.28	89.87
2	Max. temperature in December	69.08	44.48	-12.47	48.60	-3.20	59.49
3	Max. temperature in January	54.31	52.77	62.49**	30.20	-27.69	35.55
4	Max. temperature in February	-10.69	58.28	-6.07	32.53	-0.60	38.76
5	Max. temperature March	-66.10	92.87	-62.82	41.96	62.12	64.04
6	Precipitation in November	-5.46	3.89	0.19	1.92	6.44	11.15
7	Precipitation in December	2.06	2.65	-4.46	2.88	-0.02	1.98
8	Precipitation in January	9.98***	3.19	4.22*	2.33	0.87	1.86
9	Precipitation in February	4.29	3.13	-0.72	2.26	1.91	1.44
10	Precipitation in March	-3.21	4.81	-0.09	2.61	3.11	2.96
11	CO_2	0.74	4.05	-0.48	2.11	-5.05	3.79
	Constant	-726.00	3273.68	2316.96	1917.30	-601.12	2842.19
	Observations	34.00		36.00		29	
	R-squared	0.450		0.360		0.215	

Data source: MOAC (different years). *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-8: Effects of monthly precipitation and minimum temperature on wheat yield

Variables	Rupandehi		Morang		Kailali	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Min. temperature in Nov	-59.64	62.00	30.24	40.16	46.57	35.82
Min. temperature in Dec	-56.73	111.13	17.07	47.45	-47.60	39.07
Min. temperature in Jan	49.89	85.99	16.07	46.21	-38.80	43.59
Min. temperature in Feb	3.12	3.16	-12.53	28.92	70.50*	39.56
Min. temperature March	2.98	132.57	-20.05	39.75	-48.04	29.84
Precipitation in Nov	-0.97	4.19	-0.99	2.13	6.99	8.15
Precipitation in	-1.17	4.24	-3.66	2.79	-0.52	1.77

Variables	Rupandehi		Morang		Kailali	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
December						
Precipitation in January	2.57	4.92	3.53	2.42	2.38	1.42
Precipitation in February	3.45	2.98	1.33	2.11	1.26	1.15
Precipitation in March	-1.12	3.68	0.87	2.15	-1.37	2.01
CO_2	-0.80	4.13	-3.29	2.91	-2.49	3.14
Constant	1224.34	1950.65	852.96	844.36	894.25	1109.06
Observations	30.00		36		29	
R-squared	0.390		0.256		0.401	

Data source: MOAC (different years). Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Crop yield under projected climate change: Climate change decreases rice and wheat production in main grain growing areas in Nepal. Rise in maximum temperature during the crop season decreases the rice yield. The loss was projected using the coefficients estimated earlier and PRECIS-projected values of climate parameters. Everything else remaining the same, the net decrease in rice production is projected to be 51 thousand metric tons in 2020s; 216 thousand metric tons in 2050s and 412 thousand metric tons in 2080s. The decrease in 2020s is 1.6% of the present production, that in 2050s is 6.7% of the present production and in 2080s is 12.9% of the present production (Table 4-9).

Table 4-9: Change in rice production due to changes in temperature and precipitation

S.N.	Parameter	Season	Production change (metric tons)			Production change (as % to 2011 production)		
			2020s	2050s	2080s	2020s	2050s	2080s
1	Maximum temperature	JJAS	-240,638	-505,340	-794,106	-7.53	-15.81	-24.85
2	Minimum temperature	JJAS	0	0	0	0.00	0.00	0.00
3	Precipitation	JJAS	-170	1,364	3,409	-0.01	0.04	0.11
4	Minimum temperature	ON	189,282	287,708	378,564	5.92	9.00	11.85
	Net change		-51,527	-216,268	-412,133	-1.61	-6.77	-12.90

Rise in maximum temperature during the crop season increases wheat yield. Rise in minimum temperature has no effect on wheat yield. Decrease in precipitation during the crop season is the main problem of climate change in wheat production. With the mixed effects of temperature and precipitation, the wheat production in the main wheat growing area (Terai) is projected to decrease by 176 thousand tons in 2020s, a small increase of 64 thousand metric tons in 2050s and a decrease of 111 thousand metric tons in 2080s (Table 4-10). The projected change in production is equivalent to 15.5% decrease in 2020s, 5.6% increase in 2050s and 9.7% decrease in 2080s in terms of present level of production.

Table 4-10: Change in wheat production due to climate change

S.N.	Parameter	Season	Production change (metric tons)			Production change (as % to 2011 production)		
			2020s	2050s	2080s	2020s	2050s	2080s
1	Max. temperature	DJF	14,059	26,243	41,239	1.24	2.31	3.62
2	Min. temperature	DJF	0	0	0	0.00	0.00	0.00
3	Precipitation	DJF	-190,554	38,111	-152,443	-16.74	3.35	-13.40
	Net change		-176495	64354	-111204	-15.51	5.66	-9.77

The results are obtained from major food producing areas for major staple foods. Assuming that the projected loss of rice and wheat yields in Terai region is applicable to the whole country and also to other cereal crops, the climate change is likely to reduce food production in Nepal. Everything else remaining the same, the national loss in food production is expected to be 5.3% in 2020s, 3.5% in 2050s and 12.1% in 2080s. The loss of food grain thus accounts to 435 thousand metric tons in 2020s, 302 thousand metric tons in 2050s and 1040 thousand metric tons in 2080s. However, it is to be noted that increase in maximum temperature may not have adverse effect on rice yield in hills and mountains.

4.4.2 Impacts of Climate Change on Livestock Production

There is a growing concern on the effects of climate change on livestock production. Climate change can have positive as well as negative impacts on livestock production. On positive aspect, rise in temperature may result into more greenery and pasture land, benefiting livestock production in high mountains. However, opinions are divided.

Dixon et al. (2003) predict smaller impacts on livestock yields per se compared with grassland biomass because of the ability of livestock to adjust consumption in response to the changes. On contrary, several studies (e.g., Dercon, 2006; Hertel and Rosch, 2010; Kabubo-Mariara, 2009; Mader and Davis, 2004; SCA, 1990) show that climate change adversely affects livestock and poultry production. Kabubo-Mariara (2009) argues that livestock production is highly sensitive to climate change; there is a non-linear relationship between climate change and livestock productivity. Rising temperature increases lignification of plant tissues and reduces digestibility (Minson, 1990), reducing meat and milk production in range-based livestock production system. Likewise, increased heat stress alters heat exchange between animals and environment affecting their feed intake and metabolism (SCA, 1990; Mader and Davis, 2004). For example, water buffaloes need frequent bath for heat exchange. Drying of ponds due to drought can deprive them from taking baths, adversely affecting their productivity. Similarly, increased energy deficits may decrease cow fertility, fitness, and longevity (King et al., 2006).

Increased temperature and humidity will increase the risks of mortality and morbidity among the livestock and poultry. Amundson et al. (2005) also report a decline in conception rates of cattle (bos taurus) for temperatures above 23.4°C. But, Rotter and van de Geijn (1999) suggest that impacts of heat stress may be relatively minor for the more intensive livestock production systems where some control can be exercised over the exposure of animals to climate change. It means that the loss in the livestock production depends on the degree of control of the shed. As the developed countries can control the livestock production conditions minimizing the losses from climate change, the global price for the livestock products may not increase much due to climate change. Thus, Nepalese livestock farmers who cannot control the production conditions of the livestock are bound to suffer from the both, reduced production and inadequate rise of the price.

Climate change also increases mortality and morbidity of animals particularly from the climate sensitive infectious diseases (Patz et al., 2005b). Increases in zoonotic diseases among the animals also increase the risks of transmission of such diseases in the human being. In summary, as a result of climate change, Nepalese farmers have to bear loss from the livestock production (Pant, 2011).

Studies show that globally, climate change will have major impacts on more than 600 million people who depend on livestock for their livelihoods (Thornton et al., 2002). These impacts include: reduction in the productivity of rain-fed crops used for livestock and poultry feed; reduction in productivity of forage crops; reduced water availability and more widespread water shortages; and changing severity and distribution of important human, livestock and crop diseases. Major changes can, thus, be anticipated in livestock systems, related to livestock species mixes, crops grown and feed resources and feeding strategies (Thornton et al. 2009). Such changes increase the costs of livestock production.

Climate change is feared to have impacts on feed crops and grazing systems, for example, greater incidences of droughts can decrease fodder production and rise in temperature can change the species-mix in the pasture (Hopkins and Del Prado, 2007). Increase in the temperature changes the rangeland species distribution, composition, patterns and biome distribution (Hanson et al., 1993) increasing the need for feed supplements. With climate change, the cost of water for the livestock farming will increase. The livestock need water daily and frequently and also for animal feed production. But, the literatures on the added water costs for livestock production are not readily available.

Climate change also increases the costs of veterinary medicines in livestock and poultry production. Though the impacts of climate change on animal diseases and their vectors depend on the ecosystems and their changes, nature of the pathogen and the susceptibility of the livestock (Patz et al., 2005a), the cost of the treatment is likely to rise. The effects of climate change on the health of livestock and poultry are reported by many studies (Harvell et al., 1999, 2002; Baylis and Githeko, 2006). Increased temperature and relative humidity also increases risks on aflatoxin development in feed stuffs increasing the risks of poisoning among animals (Pant, 2011).

4.4.3 Efforts for Reducing Vulnerability

NAPA recommends several adaptation programs for reducing vulnerability to climate change (MOE, 2010). It emphasizes on awareness raising, capacity building and technology transfer. Several technologies are already available that are useful for climate change adaptation and vulnerability reduction.

NARC is engaged in breeding drought-tolerant varieties of the crops such as Hardinath-1, Radha-4, Barkhe, Sukkha Dhan 1, 2 and 3 varieties of rice, Sworna Sub 1 rice variety for submerged condition, Gautam and WK 1204 varieties of wheat and Manakamana, Rampur Composite, and Deuti varieties of maize. NARC has also released rice variety for submerged condition (IR 64). There is immense scope for climate change adaptation through developing drought and submerged tolerant, early maturing and pest resistance varieties, and varieties suitable for high temperatures. In addition, many farmers and some NGOs are also involved in developing crop varieties suitable for changed climatic conditions.

A number of efforts have been initiated by the Government of Nepal to reduce the vulnerability of climate change. These include: System of Rice Intensification (SRI); green manure; conservation tillage practices; use of plastic house and water sprinklers; sustainable agriculture soil and water conservation; slope stabilization and landslide control; rainwater harvesting, rangeland and forage improvement; cultivation on river beds and shrub land; livestock shed improvement; bio-energy; and adoption of biogas. These efforts need further up-scaling along with other new initiatives.

4.5 Water Resources Sector

4.5.1 Impacts of Climate Change on Water Availability

Although climate change is a global phenomenon, its impact on local hydrology is considerable. The spatial and temporal distribution of fresh water is highly sensitive to climate change resulting in more unfavorable situation. These impacts are more prominent in mountainous country like Nepal. The dense orographic barriers and substantial snow and glacier cover areas are mainly accountable for such responses affecting the planning, development and management of water resources of the country.

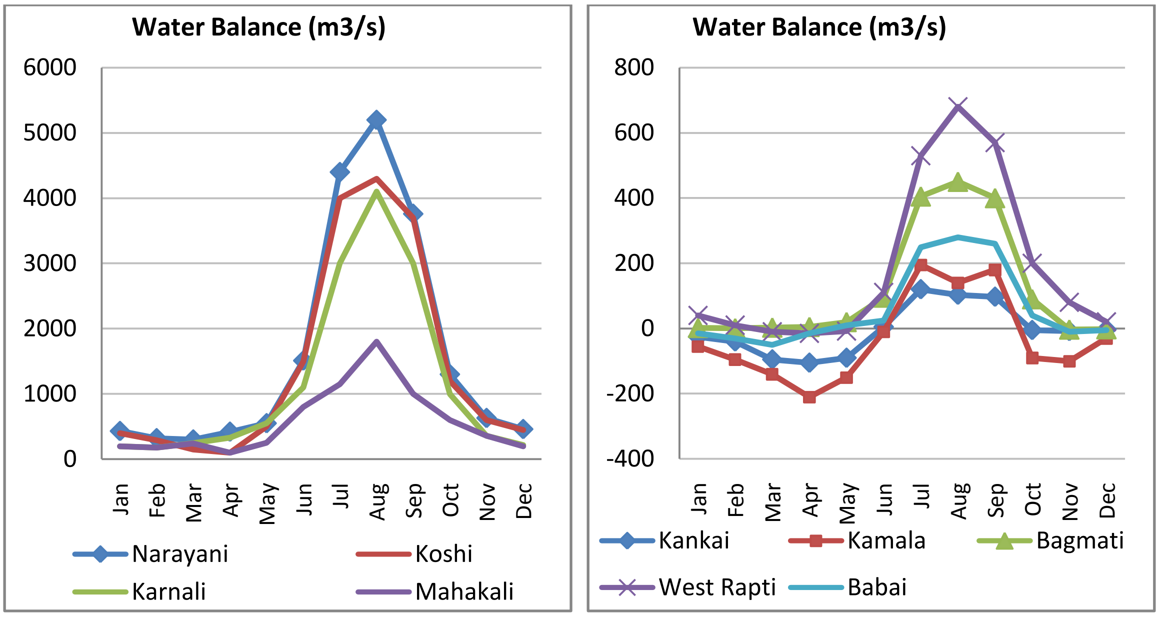


Figure 4-10: Water balance in major river basins (left) and medium river basins (right)

The water balance in the river basins is presented in Figure 4-10. It can be seen that the major basins have surplus flow but the medium basins have deficit flow in the dry season. Hydrological seasons in Nepal are categorized into: (a) dry pre-monsoon (March–May) with almost no rain; (b) rainy monsoon (June–September); and (c) post-monsoon (October–February) with little rain.

Moreover, specific discharge in rivers of Nepal is not uniform but varies randomly. Climate change significantly increases the intra-annual variability of stream flow (Agrawal et al., 2003). For example, a study has shown that the range of flow (i.e. difference between the highest and the lowest flows) of the Bagmati River would increase from the present 268 m^3/s (i.e. from 7.3 m^3/s to 275.3 m^3/s) to 371.6 m^3/s (i.e. from 6.9 m^3/s to 379.6 m^3/s) for a temperature rise of 4ºC and a precipitation increase of 10%.

Using WatBal model, MOPE (2004) revealed that for an increase in temperature of 4% and an increase in precipitation of 10%, the runoff in Karnali, Narayani, Koshi and Bagmati rivers would increase by 1%, 9%, 5% and 11% respectively. Using WatBal simulation, another study revealed that for an increase of temperature of 4ºC and an increase in precipitation of 10%, the runoff in the Bagmati River in Chovar and Langtang Khola in Langtang would increase by 3.8% and 2.2% respectively (Chaulagain, 2007).

Trend of annual discharge of three major river basins (Koshi, Gandaki and Karnali) indicates that discharge in these major basins is decreasing annually but contrary to this fact, annual discharge in southern basins are in increasing trend. Bagmati river basin which originates in Middle mountain region also has decreasing annual flow. Time series analysis of monthly discharge data shows a decreasing trend in monsoon season (June – September) whereas an increasing trend in other months.

The spatial analysis has shown that the average flows of rivers in the eastern and far western mountains have a decreasing trend, however in central and western mountains there is no significant trend. Similarly, the increasing trend in annual discharge of Babai and Rapti river basins is due to increasing trend in monsoonal rainfall amount over mid western hills of Nepal.

Although overall change in mean annual stream flow is not very noticeable in most of the basins, the month-wise distribution is apparent. It would obviously affect the seasonal water availability in the river. Early shift of the hydrographs has been observed in snow-fed river basins such as Kaligandaki as well as in midland originated rivers such as Bagmati. The shifting of hydrograph has also affected the normal water withdrawal pattern of the river. These trends in stream flow have direct impact on hydropower generation, irrigation and water supply.

There might be significant decline in dry season flows in certain rivers, which is quite critical for both water and energy supply. For example, in case of Bagmati River, the long term 92.3% dependable flow is now 21.1 m^3/s and is projected to decline to 9.86 m^3/sec by 2030. In case of CO_2 doubling, the flow will be only 7.43 m^3/s. Besides, the intra-annual variability of stream flow is also projected to increase significantly. The current range of flows of Bagmati River is 316.26 m^3/sec (from a low of 21.1 m^3/sec to a high 337.36 m^3/sec). Under climate change situation, this variability in flow will increase to 810.37 m^3/sec (from a low of 7.43 m^3/sec to a high of 817.8 m^3/sec) – posing more complexity for water resources managers, planners and engineers.

The installed capacity of most of the hydro power plants are designed based on 65% dependable flow using past records of few years. From the evidences of Bagmati River, estimation of such dependable flow using projected flow from climate model would be much less as compared to that estimated using classical method. This would, therefore, reduce the electricity generation of existing plants considerably in future. This runoff decrease will also affect Nepal's economically feasible hydropower potential.

Assessment of climate change impacts is generally done by using models. In order to assess the likely impacts on water availability regarding rivers in Nepal, 30 river systems – of different sizes and spatial distribution – are selected for analysis. To predict change in the response of the river system with the projected average decadal change in precipitation and temperature for the period 2020s, 2050s and 2080s, a simplified Water Balance Model is used.

The model

A monthly water yield model developed by Crawford (1981) is used in this study that best represents the watershed system through a simplified water balance equation. The Crawford model is a deterministic conceptual type with moderate input data requirement. Major components of hydrologic processes are lumped over a finite time interval (monthly) and are represented mathematically as flows and storage (Crawford, 1984). The general flow diagram is illustrated in Figure 4-11. Three fitted parameters representing these major hydrologic processes can be estimated from limited meteorological data in order to establish rainfall runoff relationship for catchments within their region. Furthermore, Crawford model simulates rainfall runoff process in small catchments by continuously accounting for the moisture content in two different and mutually interrelated storages: soil moisture storage and groundwater storage.

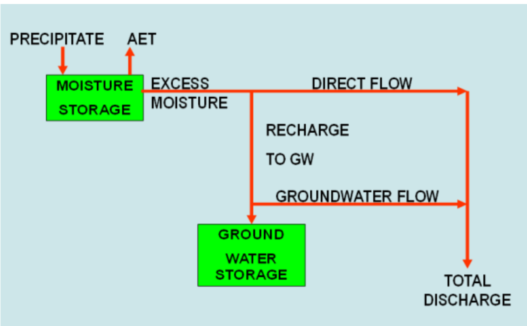


Figure 4-11: A Simplified (Crawford) Water Balance Model

The input parameters for the Crawford model consist of: (i) Model parameters; (ii) Initial storage conditions; (iii) Meteorological data; and (iv) Hydrometric data for calibration period. The meteorological data required are precipitation data and potential evapotranspiration data. The potential evapotranspiration is computed from Cropwat software developed by FAO, which is based on Penman-Montheith method (FAO, 1992). The main components of the water balance model are structured in the following pattern:

Watershed characteristics: Calculation of monthly flows uses three coefficients that represent watershed characteristics – Nominal, Psub and GWF, which are defined as follows.

- Nominal is the soil moisture storage level that permits half of any positive monthly water balance to leave the watershed as excess moisture, where excess moisture is either direct runoff or groundwater flow. The soil moisture storage level varies and may be less than or greater than Nominal. When the soil moisture storage is less than Nominal, the majority of any positive monthly water balance is retained in the soil moisture. When the soil moisture storage is greater than Nominal, the majority of any positive monthly water balance becomes direct runoff or/and addition to the groundwater storage.

- Psub is the fraction of runoff that moves out of the watershed on subsurface flow paths rather than as direct or surface runoff. The total flow that a watershed provides consists of surface or direct runoff that creates the peak flows and subsurface flows that provide the low flows. Low-permeability soils that have low-infiltration capacities yield large amounts of surface or direct runoff and low sustained discharges. Soils that have high-infiltration capacities yield higher sustained discharges. Therefore, streams that have high minimum discharges are those with highly permeable sandy soils and fractured or permeable subsurface geology.

- GWF is an index to the time of flow along subsurface flow paths that enter the stream. It is the fraction of the total volume of water on groundwater flow paths that will enter the stream in the current month.

Nominal, Psub and GWF change from one watershed to another.

Actual evapotranspiration: Actual evapotranspiration (AET) is based not only on the precipitation and potential evapotranspiration but also on the soil moisture conditions of the watershed. In Crawford water balance model, it is computed by soil moisture ratio of different months, which is obtained from soil moisture storage (initial soil moisture in case of first month) divided by the Nominal, catchment characteristics and the ratio of rainfall to potential evpotranspiration (PET).

Soil storage ratio = Soil moisture storage / Nominal

Nominal = 100 + C x Annual precipitation, where C denotes catchment characteristics

AET = PET x Apt, or Apt = AET/PET, where Apt denotes ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET), obtained from soil storage ratio and ratio of rainfall to potential evapotranspiration.

Direct runoff: Direct runoff depends upon the precipitation and watershed characteristics, represented by the excess moisture and recharge to the ground water excess moisture is obtained by the product of excess moisture ratio and water balance in the soil storage where as recharge is the product of Psub and excess moisture and expressed in the following way

Direct flow = Excess moisture – Recharge to groundwater

Excess moisture = Excess moisture ratio x Water balance

Recharge = Psub x Excess moisture, where Psub denotes catchment characteristics

Ground water flows or base flow: Ground water flow or base flow is mainly depends upon the recharge to the ground water from the excess moisture level and the rate of discharge from the ground water storage to the river. The basic relationship of ground water flow can be expressed by the formulae.

Groundwater flow = GWF x Gr

Gr = GWS+ Recharge to groundwater, where GWS denotes groundwater storage

Spatial and Temporal Hydro-meteorological Records

The model uses time series data of monthly precipitation, potential evapotranspiration and streamflow to enable calibration, which are collected from DHM. Spatially weighted time series data of precipitation are developed. In case of single station, point precipitation is considered as an average value for whole catchment. The spatially averaged time series of monthly temperatures are combined with the estimates of extraterrestrial solar radiation for each basin to obtain the time series data of monthly potential evapotranspiration using Penman's method. Table 4-11 presents details of the flow stations used for calibration and validation of the model.

Table 4-11: Long term average discharge of various river systems of Nepal (in m^3/s)

Location	Latitude	Longitude	Elevation (m)	Drainage Area (km^2)	Start of Record	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rasnalu	27 34 30	86 11 50	1120	313	4/6/1964	1964-2008	5.80	4.89	4.55	5.05	8.17	33.81	84.07	87.80	53.02	23.63	11.55	7.64
Tumlingtar	27 18 20	87 13 15		375	1/2/1974	1974-2006	6.29	5.3	4.89	6.56	16.2	33.4	51.8	53.6	48.4	25.9	12.9	8.26
Rajdwali	26 52 45	87 55 45		377	1/1/1983	1983-2006	6.2	5.28	5.22	6.53	10.3	27.8	65.7	64.4	59.8	29.4	11.8	6.99
Khokana	27 16 00	85 13 00	1255	607	6/1/1991	1992-2010	4.62	3.86	3.09	3.26	5.89	14.8	46.4	56.6	35.4	13.9	7.84	5.8
Jalbire	27 48 20	85 46 10	793	629	12/25/1963	1964-2006	12.8	11.1	10.6	12	17.2	50.9	132	164	113	50.8	25.1	17
Sangutar	27 20 10	86 13 10	543	823	3/24/1964	1964-2006	14.6	12.1	11.3	12.4	17.6	50.5	145	167	121	59.9	30.7	20
Mainachuli	26 41 12	87 52 42	125		1/5/1971	1972-2010	12	10.3	9.34	11.4	21	66.5	196	197	131	62.7	25.5	15.8
Barhbise	27 47 10	85 53 20	840	2410	2/17/1965	1965-2006	24.2	21.4	20.6	24.8	38.3	86.5	180	252	168	80.1	42.5	29.2
Busti	27 38 05	86 5 12	849	2753	1/14/1970	1971-2006	28.7	24.7	23.6	27.9	51.1	164	414	483	305	120	59.3	38.8
Rabuwa Bazar	27 16 00	86 39 50	460		10/3/1964	1964-2010	44.5	36.6	34.9	41.7	72.2	246	570	604	445	189	89.5	58.2
Mulghat	26 55 50	87 19 45	276	5640	3/11/1965	1965-2006	67.9	55.8	54.8	81.1	184	492	951	1040	736	351	155	94.2
Belkot	27 51 35	85 8 18	610	653	6/17/1968	1969-2006	9.63	7.29	5.23	5.62	9.94	34.3	99.1	129	92.3	43.2	21.8	13.1
Rajaiya	27 26 30	84 58 15	332	C	1/1/1963	1963-2010	10.5	8.91	7.47	7.22	8.41	21.2	67.2	77.3	62.9	29.6	15.7	11.4
Garambesi	28 3 41	84 29 23	442	308	11/20/1963	1964-2006	5.93	4.9	4.47	4.72	6.77	21.4	68.3	75.9	57.8	26.2	12.6	7.75
Borlangpol	27 58 20	83 35 20	749			2000-2006	2.2	1.87	1.65	1.87	5.32	23.2	54.4	47.2	30.6	9.92	4.25	2.7
Tigra gaon	28 3 00	82 49 40	738	653	12/21/1999	1978-1995	6.09	5.14	4.67	3.74	4.24	18.6	67.6	90.3	73.4	30.3	12.2	7.4
Gujar Gaon	29 31 00	80 35 0	1275	154	5/11/1983	1966-1987	1.41	1.36	1.54	1.13	1.17	11.6	22.8	33.7	17.7	6.07	2.63	1.79
Diware	29 12 00	81 55 00	2073	824	3/17/1964	1967-2006	6.19	5.72	7.52	10.7	13.5	19.5	44.9	64.8	44.3	21.8	10.9	7.66
Daredhunga	28 17 58	82 01 30	579	816	1/1/1972	1972-2006	4.32	3.82	3.08	2.65	3.15	6.61	27.4	42.9	36.7	17.3	7.2	4.78
Karkale Gaon	29 40 20	80 33 30	685	1150	1/1/1965	1965-2006	20.9	19.1	19.4	22.2	27.8	49.5	115	148	108	53.2	32.3	24.7
Mangalsen	29 9 24	81 12 30	506	1576	5/12/2000	2000-2006	15.8	17.7	17.5	16.6	23.5	45.7	216	286	193	67.7	31.2	20.2
Nagma	29 12 00	81 55 00	2043	1870	3/19/1964	1973-2006	18.1	15.6	15.3	20.9	32.2	43.8	89.5	128	102	57.4	31.7	22.9
Nayagaon	28 4 20	82 48 00	536	1980	1/1/1964	1965-2009	16.8	14.3	12.2	10.8	11.3	34.2	125	214	175	73.1	30	20.2
Rimna	28 42 30	82 17 30	772		6/18/1972	1977-2006	42.4	36.4	38.7	61.7	127	220	479	574	374	173	87.7	56.8
Bagasotigaun	27 54 00	82 51 00	381	3747.19	8/5/1975	1976-2010	26.4	22.2	18.4	15.5	18.7	71.9	243	373	302	107	49.8	33.9
Rasnalu	27 34 30	86 11 50	1120	313	4/6/1964	1964-2008	5.81	4.9	4.55	5.06	8.17	33.81	84.07	87.8	53.02	23.63	11.56	7.64
Kulekhani	27 35 10	85 09 30			11/30/1963	1963-1977	1.35	1.22	1.14	1.14	1.27	4.62	10.2	9.6	7.66	3.94	2.27	1.64
Lothar	27 35 40	84 43 00	336	169	11/30/1963	1964-2004	1.86	1.52	1.38	1.42	2.05	5.66	25	30.2	23	9.36	4.14	2.59
Manahari	27 33 00	84 48 10	305	427	6/13/1963	1964-2006	6.16	5.07	4.64	5.55	6.66	17.4	57.5	74.2	59.4	19.3	10.9	7.81

Model Calibration and Validation

The model is calibrated for the river systems using observed monthly rainfall, potential evapotranspiration and observed stream flow records. The model parameters have been optimized to satisfy the minimization of root mean square error between observed and simulated flows. The model parameters are further validated with independent set of observed data. The final parameters are presented in Table 4-12. Figure 4-12 shows sample calibration and validation of the model for Khimti River.

Table 4-12: Calibrated parameters of the model

S.N.	St. No.	River	Location	C	PSUB	GWF
1	650	Khimti Khola	Rasnalu	0.244	0.3	0.1
2	602	Sabhaya Khola	Tumlingtar	0.245	0.45	0.2
3	728	Maikhola	Rajdwali	0.269	0.5	0.19
4	550.05	Bagamati River	Khokana	0.154	0.5	0.3
5	620	Balephi Khola	Jalbire	0.259	0.25	0.1
6	660	Likhu Khola	Sangutar	0.36	0.7	0.25
7	795	Kankai River	Mainachuli	0.268	0.58	0.3
8	610	Bhote Koshi	Barhabise	0.214	0.78	0.002
9	647	Tamakoshi	Busti	0.26	0.35	0.15
10	670	Dudhkoshi	Rabuwa Bazar	0.261	0.5	0.24
11	690	Tamur River	Mulghat	0.262	0.5	0.4
12	448	Tadi Khola	Belkot	0.1	0.45	0.25
13	460	Rapti River	Rajaiya	0.07	0.55	0.1
14	440	Chepe Khola	Garambesi	0.07	0.6	0.3
15	415.1	Andhi Khola	Borlangpol	0.08	0.45	0.3
16	339.5	Jhimruk Khola	Tigra gaon	0.07	0.52	0.3
17	169.8	Surnaya Gad	Gujar Gaon	0.22	0.4	0.2
18	225	Sinja Khola	Diware	0.27	0.75	0.2
19	286	Sarada Khola	Daredhunga	0.25	0.72	0.2
20	120	Chamelia	Karkale Gaon	0.26	0.71	0.2
21	256.5	Budhi Ganga	Mangalsen	0.28	0.5	0.2
22	220	Tila Nala	Nagma	0.29	0.7	0.6
23	330	Mari Khola	Nayagaon	0.38	0.6	0.5
24	350	Rapti River	Bagasotigaun	0.21	0.48	0.2
25	570	Kulekhani Khola	Kulekhani	0.2	0.7	0.4
27	470	Lothar	Lothar	0.2	0.5	0.35
28	465	Manahari	Manahari	0.001	0.8	0.55
29	695	Saptakoshi	Chatara	0.26	0.35	0.15
30	450	Narayani	Narayanghat	0.07	0.55	0.1
31	280	Karnali	Chisapani	0.25	0.72	0.2

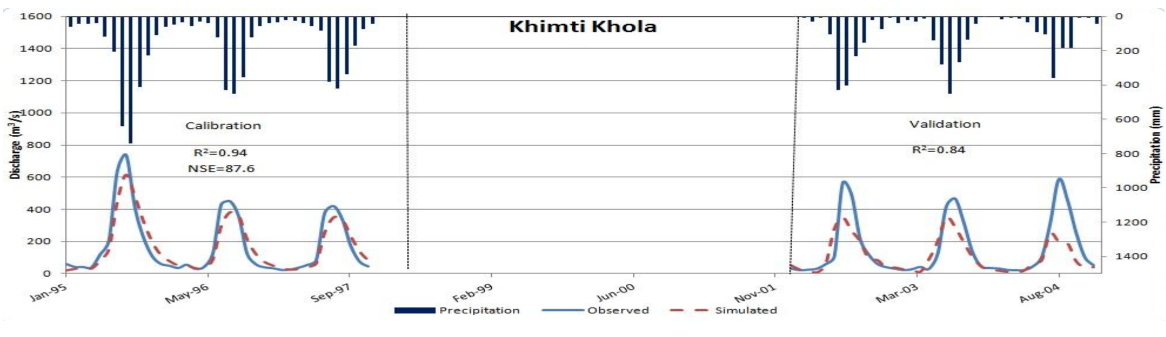


Figure 4-12: Calibration and Validation of the model for Khimti River

Simulation of changes in river flows in response to changes in climatic variables

Assessment of flow variation in river systems are carried out for four seasons viz., Season 1 (December, January and February), Season 2 (March, April and May), Season 3 (June, July, August, and September) and Season 4 (October and November). The calibrated parameters C, Psub, GWF of water balance model for various river systems are used to project the seasonal changes in stream flows in response to mean decadal change in climatic variables. Changes in spatial variations of stream flows for different seasons are presented in Figure 4-13 and in Table 4-13.

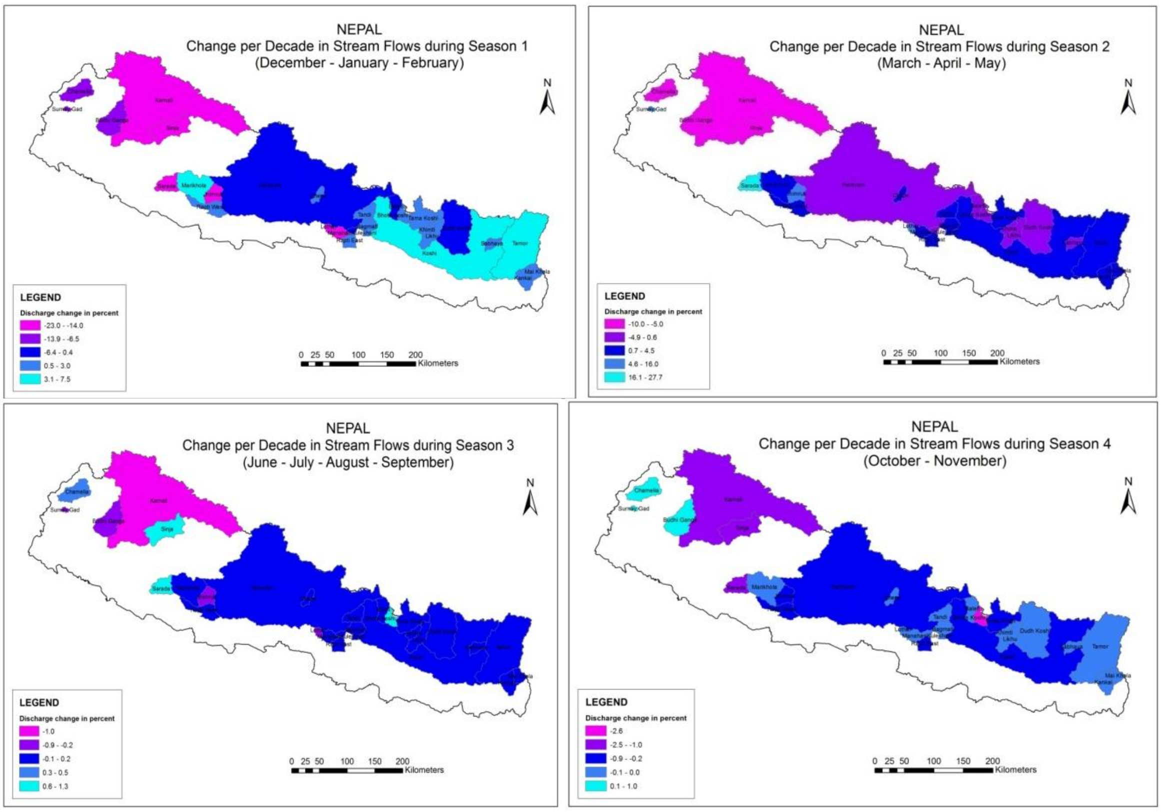


Figure 4-13: Change per decade in stream flows during Season1 (top left), Season 2 (top right), Season3 (bottom left) and Season4 (bottom right)

Note: Season 1 – Dec, Jan and Feb; Season 2 – March, Apr, May; Season3 – June, July, Aug, Sep; Season 4 – Oct, Nov.

Table 4-13: Change in seasonal volume of flow per decade of various river systems of Nepal (in m^3)

River	Location	Season 1	Season 2	Season 3	Season 4	Annual
Khimti Khola	Rasnalu	991154 (2.1%)	260602 (0.6%)	25057 (0.00%)	-854 (0.0%)	1275958 (0.2%)
Sabhaya Khola	Tumlingtar	1529813 (3.0%)	-746017 (-1.0%)	462110 (0.10%)	-115415 (-0.1%)	1130491 (0.2%)
Maikhola	Rajdwali	1269434 (2.7%)	711181 (1.2%)	459398 (0.08%)	-119411 (-0.1%)	2320603 (0.3%)
Bagamati River	Khokana	782927 (2.1%)	488529 (2%)	-193810 (-0.05%)	-31231 (-0.1%)	1046415 (20.0%)
Balephi Khola	Jalbire	425411 (0.4%)	350446 (0.3%)	-324199 (-0.03%)	-117518 (-0.1%)	334140 (0.0%)
Likhu Khola	Sangutar	1158050 (1.0%)	-759774 (-0.7%)	379005 (0.03%)	-76748 (0.0%)	700532 (0.0%)
Kankai River	Mainachuli	1479925 (1.5%)	904810 (0.8%)	339516 (0.02%)	-56287 (0.0%)	2667964 (0.1%)

River	Location	Season 1	Season 2	Season 3	Season 4	Annual
Bhote Koshi	Barhbise	3427067 (1.8%)	148894 (0.1%)	166144 (0.90%)	-82574 (-2.6%)	3659531 (15.0%)
Tamakoshi	Busti	5443768 (2.3%)	4009171 (1.5%)	3049909 (0.09%)	-924280 (-0.2%)	11578568 (0.3%)
Dudhkoshi	Rabuwa Bazar	-8899589 (-2.5%)	-6642973 (-1.7%)	3463719 (0.07%)	-732487 (-0.1%)	-12811330 (0.2%)
Tamur River	Mulghat	42285204 (7.5%)	11437897 (1.4%)	2742854 (0.03%)	-261378 (0.0%)	56204578 (0.5%)
Tadi Khola	Belkot	1462912 (1.9%)	1061763 (2.0%)	-529648 (-0.06%)	-107254 (-0.1%)	1887773 (0.2%)
Rapti River	Rajaiya	640898 (0.8%)	635481 (1.1%)	587886 (0.10%)	-213101 (-0.2%)	1651165 (0.2%)
Chepe Khola	Garambesi	-794535 (1.6%)	495772 (1.2%)	-196683 (-0.03%)	-31694 (0.0%)	-527140 (-0.1%)
Andhi Khola	Borlangpol	-38798085 (-22.1%)	-24209136 (-1%)	-9604273 (-2.38%)	-1547642 (-4.2%)	-74159135 (-15.5%)
Jhimruk Khola	Tigra gaon	-8422590 (-17.4%)	5255507 (16.0%)	-2084970 (-0.32%)	-335974 (-0.3%)	-5588026 (-0.7%)
Surnaya Gad	Gujar Gaon	-1452142 (-12.3%)	1202432 (12.1%)	-744830 (-0.34%)	186026 (0.8%)	-808514 (-0.3%)
Sinja Khola	Diware	-7769905 (-15.3%)	-6433792 (-7.8%)	3985323 (0.89%)	-995359 (-1.2%)	-11213733 (-1.2%)
Sarada Khola	Daredhunga	-7694469 (-23.0%)	6371328 (27.7%)	3946630 (1.34%)	-985695 (-1.6%)	1637794 (0.4%)
Chamelia	Karkale Gaon	-10843921 (-6.5%)	-8979200 (-5.0%)	5562040 (0.51%)	1389153 (0.6%)	-12871927 (-0.8%)
Budhi Ganga	Mangalsen	-14860887 (-10.7%)	-12305408 (-0.1%)	-7622414 (-0.4%)	1903744 (1%)	-32884964 (-1.3%)
Mari Khola	Nayagaon	7427417 (5.6%)	2165625 (2.4%)	-290039 (-0.02%)	-14502 (0.0%)	9288501 (0.5%)
Rapti River	Bagasotigaun	4946525 (2.3%)	4095921 (3.0%)	-2537161 (0.10%)	-633671 (-0.2%)	5871614 (0.2%)
Kulekhani Khola	Kulekhani	-201184 (-0.1%)	-88154 (0.0%)	-19394 (0.00%)	-1843 (0.0%)	-310575 (0.0%)
Lothar	Lothar	-2452878 (-15.9%)	1294840 (10.3%)	-402715 (-0.19%)	-50536 (-0.1%)	-1611289 (-0.6%)
Manahari	Manahari	-8514212 (-17.3%)	1964704 (4.5%)	-188906 (-0.04%)	-6442 (0.0%)	-6744856 (-1.0%)
Koshi	Chatara	150773778 (5%)	84292561 (2.3%)	64124147 (0.2%)	-19432920 (-0.4%)	279757565 (0.6%)
Narayani	Narayanghat	-34424755 (-1.1%)	-34133805 (-1.1%)	-31577309 (-0.10%)	-11446338 (-0.2%)	-111582207 (-0.2%)
Karnali	Chisapani	-404431114.7 (-14%)	-334885120 (-8.4%)	-207439921 (-1%)	-51809385 (-1%)	-998565541 (-2.3%)

Note: Figure in parenthesis shows percentage change.

Tables 4-14 and 4-15 show predicted percentage change in monthly flow during 2011-2040 and 2041-2070 respectively, as compared to the 1981-2010 period.

Table 4-14: Percentage change in monthly flow during 2011-2040 (predicted) as compared to 1981-2010 period

Name of Rivers	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bagmati	-3.8	-3.2	-2.8	1.8	0.7	0.2	0.0	0.0	0.0	-0.1	0.1	0.1
Balefi	-1.3	-1.8	-1.1	1.0	0.4	-0.1	0.0	-0.1	-0.1	-0.3	0.3	0.9
Bhote Koshi	-1.4	-1.7	-0.8	0.7	0.2	0.0	0.0	-0.1	-0.2	-0.1	-0.1	1.4
Budhi Ganga	-19.2	-13.7	-11.1	9.4	5.3	2.2	-0.4	-0.2	0.3	0.6	-1.0	1.3
Chamelia	-10.6	-9.3	-7.3	-5.1	3.3	1.5	-0.5	-0.3	0.3	0.6	0.7	0.8
Chepe	-3.2	-2.7	-2.2	1.4	0.7	0.1	0.0	0.0	0.0	0.0	-0.1	0.2
Dudh Koshi	-7.2	-8.3	-4.2	3.7	2.1	0.3	0.1	-0.2	-0.3	-0.4	0.5	-1.4
Kankai	-2.8	-2.3	-1.7	-1.0	0.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Karnali	-22.2	-19.6	-15.0	9.3	4.6	1.8	-0.7	-0.4	0.5	-0.9	-1.4	1.6
Khimti	-0.8	1.4	-0.8	1.7	0.4	0.5	0.0	0.0	0.3	-0.4	-1.7	5.1
Koshi	-6.1	8.4	-4.8	5.4	1.9	1.4	0.2	-0.4	0.6	-0.8	-4.1	7.8
Kulekhani	-3.6	2.4	-1.5	0.9	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Likhu	-1.5	1.8	-1.3	1.6	0.6	0.4	0.1	-0.1	0.1	-0.2	-0.8	1.8
Lothar	-30.7	24.4	-17.5	11.0	5.0	1.2	0.2	0.1	0.1	-0.1	-0.2	0.2
Mai Khola	-3.0	3.5	-2.4	1.5	1.4	0.2	0.1	-0.1	0.1	0.2	-1.1	0.6
Manahari	-76.1	81.0	-43.4	50.8	30.8	9.4	2.8	0.8	4.7	-6.2	-26.9	61.8
Marikhola	-11.8	7.1	-4.1	2.5	1.9	0.4	0.0	0.0	0.0	0.0	-0.2	0.7
Narayani	-1.7	1.9	-1.7	1.4	0.7	0.2	0.1	0.1	0.1	-0.2	-0.3	0.6
Rapti East	-1.1	1.1	-1.2	1.1	0.9	0.3	0.1	0.1	0.1	-0.1	-0.2	0.3
Rapti West	-5.1	3.8	3.7	3.5	2.3	0.5	0.1	0.1	0.1	-0.1	-0.2	0.3
Sabhaya	-2.5	3.9	-2.7	2.0	0.5	0.4	0.1	-0.1	0.2	-0.2	-1.3	1.9
Sarada	-36.4	33.0	-32.7	30.4	20.5	7.8	1.5	0.8	0.7	-1.2	-2.3	2.8
Sinja	-25.7	22.2	-13.5	7.6	4.8	2.7	-0.9	-0.5	-0.6	-1.0	-1.6	1.8
Surnay Gad	-21.1	17.5	-12.3	13.5	10.4	0.8	0.3	0.2	-0.3	0.7	1.2	1.4
Tama Koshi	-4.1	5.9	-3.2	5.2	2.2	1.0	-0.1	-0.2	0.4	-0.8	-3.9	11.3
Tamor	-4.7	3.5	-2.1	0.9	0.3	0.1	0.0	0.0	0.0	0.0	-0.1	0.1
Tandi	-3.4	3.4	-3.5	2.8	1.1	0.3	-0.1	0.0	0.0	-0.1	-0.2	0.4

Table 4-15: Percentage change in monthly flow during 2041-2070 (predicted) as compared to 1981-2010 period

Name of Rivers	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bagmati	-3.8	3.2	-2.8	1.8	0.7	0.2	0.0	0.0	0.0	-0.1	-0.1	0.1
Balefi	-0.9	1.5	-0.7	1.9	0.5	0.3	-0.1	-0.1	0.1	-0.2	-1.1	2.3
Bhote Koshi	-0.7	1.3	-0.4	1.7	0.6	0.5	0.0	-0.1	0.3	-0.5	-2.5	6.2
Budhi Ganga	-19.2	13.7	-11.1	9.4	5.3	2.2	0.4	0.2	-0.3	0.6	-1.0	1.3
Chamelia	-10.6	9.3	-7.3	5.1	-3.3	1.5	0.5	0.3	-0.3	0.6	0.7	0.8
Chepe	-3.1	2.7	-2.0	1.5	0.7	0.2	0.0	0.0	0.0	0.0	-0.1	0.3
Dudh Koshi	-4.3	4.1	-3.2	2.2	0.9	0.2	0.1	-0.1	0.1	-0.1	-0.3	0.5
Kankai	-2.8	2.3	-1.7	1.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Karnali	-22.2	19.6	-15.0	9.3	-4.6	1.8	0.7	0.4	-0.5	-0.9	1.4	1.6
Khimti	-0.4	0.5	-0.4	0.4	0.2	0.1	0.0	0.0	0.0	-0.1	-0.2	0.3
Koshi	-6.1	8.4	-4.8	5.4	1.9	1.4	0.2	-0.4	0.6	-0.8	-4.1	7.8
Kulekhani	-3.6	2.4	-1.5	0.9	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Likhu	-1.5	1.8	-1.3	1.6	0.6	0.4	0.1	-0.1	0.1	-0.2	-0.8	1.8
Lothar	-30.7	24.4	-17.5	11.0	5.0	1.2	0.2	0.1	0.1	-0.1	-0.2	0.2
Mai Khola	-3.0	3.5	-2.4	1.5	1.4	0.2	0.1	-0.1	0.1	0.2	-1.1	0.6
Manahari	-76.1	81.0	-43.4	50.8	30.8	9.4	2.8	0.8	4.7	-6.2	-26.9	61.8
Marikhola	-11.8	7.1	-4.1	2.5	1.9	0.4	0.0	0.0	0.0	0.0	-0.2	0.7
Narayani	-1.7	1.9	-1.7	1.4	0.7	0.2	0.1	0.1	0.1	-0.2	-0.3	0.6
Rapti East	-1.1	1.1	-1.2	1.1	0.9	0.3	0.1	0.1	0.1	-0.1	-0.2	0.3

Name of Rivers	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rapti West	-5.1	3.8	3.7	3.5	2.3	0.5	0.1	0.1	0.1	-0.1	-0.2	0.3
Sabhaya	-2.5	3.9	-2.7	2.0	0.5	0.4	0.1	-0.1	0.2	-0.2	-1.3	1.9
Sarada	-36.4	33.0	-32.7	30.4	20.5	7.8	1.5	0.8	0.7	-1.2	-2.3	2.8
Sinja	-25.7	22.2	-13.5	7.6	4.8	2.7	-0.9	-0.5	-0.6	-1.0	-1.6	1.8
Surnay Gad	-21.1	17.5	-12.3	13.5	10.4	0.8	0.3	0.2	-0.3	0.7	1.2	1.4
Tama Koshi	-6.1	-7.3	-3.9	3.7	1.8	0.3	-0.1	-0.2	-0.3	-0.7	-0.8	0.8
Tamor	-4.7	3.5	-2.1	0.9	0.3	0.1	0.0	0.0	0.0	0.0	-0.1	0.1
Tandi	-3.4	3.4	-3.5	2.8	1.1	0.3	-0.1	0.0	0.0	-0.1	-0.2	0.4

Trends in glacier retreat and glacial lake outburst flood (GLOF): A comparison of the 1992 glaciers with those of 1958 in Gunsa Khola basin of Kanchanjunga area, east Nepal revealed that out of 57 glaciers, half of them have retreated in the period from 1958 to 1992. Also, 30% of the glaciers are under stationary conditions, and 12 % are advancing (Asahi et al., 2000). The rate of upward shift of ELA in east Nepal (Kanchanjunga, Khumbu, Rolawaling, Langtang) between the Little Ice Age (1815) and 1959 was 0.38 m per year and between 1959 and 1992 was 0.76 m per year (Kayastha and Harrison, 2008). The higher rate of shifting of ELA in the recent past was mainly due to increase in air temperature in the recent decades.

Glacier AX010 in the Shorong Himal (27º42' N, 86º34' E) is one of the most studied glaciers in Nepal. Changes in glacier terminus have been monitored since 1978 to 2004. The aerial extent of the glacier was measured intermittently in 1978, 1996 and 1999 by topographic survey (Fujita, 2001). The terminus retreat from 1978 to 1989 was 30 m (-2.7 m a-1), which is equivalent to 12 m thinning of the glacier surface. Similarly, the terminus retreat rates from 1989 to 1995, 1996 to 1999 and 1999 to 2004 were -6.7 m a-1, -30 m a-1 and -14 m a-1, respectively.

Khumbu Glacier is a large debris-covered valley glacier in the Khumbu Region. The surface of the glacier lowered about 10 m throughout the debris-covered ablation area in the period 1978-1995 (Kadota et al., 2000). Majority of glaciers have retreated in the range of 30 to 60 m during 1970-1989 (Yamada et al., 1992). Studies of Yala Glacier in the Langtang Valley, Rasuwa district in 1994 and 1996 has shown an accelerated retreat and surface lowering (Fujita et al., 1998 and 2001). Rikha Samba Glacier in Hidden Valley, Mukut Himal, Mustang has retreated by about 200 m from 1974 to 1994 (Fujita et al., 1997). The areal average of the amount of surface lowering and the volume loss of the glacier was estimated to be 12.6 m ice equivalent and 13% of the total mass, respectively. The annual mass balance of – 0.55 m water equivalent was obtained as an average for 20 years, which is one of the largest negative values amongst small glaciers of the world.

Imja Glacial Lake in Solukhumbu district has increased from 0.4 sq km in 1984 to 1.01 sq km in 2009; Tsho Rolpa Glacial Lake in Dolakha district from 0.23 sq km in 1957 to 1.54 sq km in 2009; Thulagi Glacial Lake in Gorkha district from 0.22 sq. km. in 1958 to 0.94 sq. km. in 2009. A total number of 14 glacial lake outburst floods (GLOF) events have been recorded in Nepal causing substantial losses of lives, properties, infrastructures and ecosystem to a distance of more than 100 km downstream.

4.5.2 Efforts for Reducing Vulnerability

Measures such as non-conventional irrigation (e.g. sprinkler/drip irrigation), rainwater harvesting, solar water pumps, and river training works are already being practiced. Activities like the establishment of a national disaster preparedness and management agency, the creation of village-level early warning systems for floods, landslides, building decentralized emergency response capacity, enforcing design standards for buildings and infrastructure that take into account site-specific risks, investing in better weather prediction systems are few coping measures adopted by Nepal Government in the context of climate change. Besides, reorientation of supply driven

approach, institutional strengthening, and capacity building of Water Users Associations (WUA) are some other government initiatives.

The development of micro- and small hydro is already in line with Nepal's development priorities, and is being encouraged by both the government and development partners. Introduction of multiple units in power plant, alternate sources of energy supply, and better demand side management are some noted approach adopted by Nepal in coping the adverse effect of climate change in hydro power sector. In addition to that the initiation of Optimum Sediment Exclusion (OSE) research in Jhimruk and Khimti hydro power plants is a step forward in adaptation measure in the context of climate change. Working on OSE research will improve the performance of the existing as well as the planned hydropower projects. Increasing performance means maximizing the benefit from existing hydropower plants. This will lead to minimization of the construction costs and overall environmental effects caused by the construction of new projects to meet an equivalent energy demand.

In Nepal, the Kulekhani is the only storage project generating electricity. By efficient utilization of Run-off River (RoR) hydropower plants, equivalent water can be saved in the Kulekhani reservoir to generate power at peak hours. This can help in reducing the duration of the present load shedding. As an example, 2 % increase in performance of existing power plants in Nepal can generate the equivalent of 11 MW of extra power, which is equivalent to 264,000 units per day. In the dry season, equivalent amount of energy in the form of water can be stored in the Kulekhani reservoir and supplied during the peak hours. Intra basin water transfer projects like Sunkoshi-Kamala diversion, Bheri-Babai diversions and several multipurpose high dam projects as envisaged in Government policy are some of the efforts in order to address stream flow fluctuations as a result of current seasonal as well as climate variability.

Lowering the lake water level, establishment of early warning system and installation of micro-hydro were carried out in order to reduce the GLOF risks from Tsho Rolpa Glacial Lake. Likewise, Community-based Flood and Glacial Lake Outbrust Risk Reduction Project (CFGORRP) is being implemented for reducing disaster risk from Imja Glacier Lake.

4.6 Forestry and Biodiversity

4.6.1 Impacts of Climate Change on Forest and Biodiversity

Forest is one of the major areas where impacts of climate change are clearly visible. Climate change has increased vulnerability on forests and biodiversity of Nepal due to rise in temperature, decrease in snow fall, untimely rain, and increased dryness. These all have impacts on flowering and fruiting, ultimately threating the survival of plant species in forests.

In the context of climate change, there is a possibility that the winter rain will decrease and thus increasing the frequency and magnitude of forest fire events in future. For example, in late 2008 and early 2009, a larger part of Nepal faced severe drought due to lack of winter rain. During this period massive forest fire was recorded. The forest fires destroyed thousands of tons of forest biomass and wildlife. Change in flowering and fruiting phase of the plant is related with survival of fauna or wildlife. Plants are the ultimate food for the wild animals and their life cycle is related with availability of food and climate. For example, wildlife hibernates during winter when there is adverse climate and less food available. If seasonal availability of food is changed, then natural life cycles of animals such as reproduction, migration and hibernation do not match with their existing physiology. These are natural or biological process, which takes time for changing.

Nepal has already observed some changes in the distribution of some species, particularly invasive alien species viz. *mikenia micrantha* and *parthenium hysterophorus*. In Nepal, changes in forest boundaries have been reported, particularly in hills and at tree line. Tropical plants and animals are now seen in the warm temperate region of mid-hills.

Some of the impacts of climate change on forest and biodiversity are: early sprouting, flowering, fruiting, forest fire, pest attack, and degradation of species. Some of the discernible examples reported are:

- Reduction of dormant winter days has been experienced by all communities in the villages. Thus growing period is increased and dormant period decreased. Similarly, earlier flowering of Rhododendron Arboreum (laligurans) species and increase in growing season period were observed. The same phenomenon was observed for some plants across the Europe by about 11 days from the years 1959 to 1993.

- Changes in phenology are expected to occur for many species. Changes are seen in date of bud break, hatching and migration. This will continue for more species.

- Climatic change brings deviation from existing practices and uncertainty, which are difficult to tackle for plant, birds, animals and other biodiversity. Livelihood of indigenous people who depend on biodiversity will be adversely affected.

- Climate change is likely to provide favorable condition for the growth and distribution of invasive alien species because of their adaptability to disturbance.

Nepal Biodiversity Strategy, 2002 has identified following five ecosystems in Nepal: forests, rangelands, wetlands, mountain, and agro-ecosystems. The impacts at ecosystem level are discussed below.

A. Forest Ecosystems

Increased dryness and fire: One of the strong impacts of climate change experience in Nepal is drought during the spring season. Although, forest fire is caused by human, dryness of forest floor and wind are great contributing factors to spread fires and increase damages of all forest products such as timber, fuel wood, non-timber forest products (NTFP), wildlife, plants and small micro-organisms.

Physical disturbance from erratic rain, landslides and erosion: Heavy rains results landslips and landslides. Once there is land disturbance, additional rain cause erosion in the forest ecosystems. These physical disturbances also cause damage to overall forest ecosystems.

Altered natural life cycles: Short winters due to increase in temperature results, reduced dormant period for plants. As a result, there has been early sprouting, flowering and fruiting. This has impact on species which depends upon flower and fruits of the particular species.

Encroachment by alien species: Due to rise in temperature, drought and other unknown climatic factors, certain alien species are spreading rapidly in forests such as Mikania species in Terai forests, Lantana and blue Ageratum conyzoides in hill forests.

Disease and pests: Due to continuous rainfall after conventional monsoon period, rise in temperature, and other unknown factors various pests and diseases are seen increasing in forest ecosystems.

Degradation of species diversity: Degradation of forest ecosystems from physical disturbance, erosion, and rise in temperature, short dormant season, forest fire, encroachment by alien species, insects and pests cause damage to existing species diversity in forest ecosystems.

B. Rangeland Ecosystems

More grass due to rise in temperature in high altitude: It is also observed that wild life which normally comes down in low altitude in winter due to lack of grasses is thriving in high altitude due to rise in temperature which favors growth of grasses in winter.

Less grass due to drought in lower altitude: Due to drought, the areas which normally support grasses are devoid of grasses. As a result, livestock, wild lives and local communities depending on those resources are facing problems.

Reduced availability of non-timber forest products: Due to drought and rise in temperature, in high altitude grass land, local communities have experienced availability of less herbs and non-timber forest products in grasslands.

Damage by fire: Drought and fire have caused destruction of physical resources and reduction in species diversity in high altitude grasslands.

C. Wetland Ecosystems

Degradation of species: Due to drought, water level is reduced in wetlands especially in terai and some hill districts like Kaski. Many species of aquatic plants and fishes are destroyed in the wetlands. In Rupatal area of Kaski, it is claimed that the number of plant species like white lotus, oryza (*navo dhan*), Karaute *dhan*, *kadhe* fish, etc has reduced.

Encroachment by alien species: Exotic species such as water hyacinth is spread well beyond its conventional territory.

Degradation of livelihood resources: Degradation of wetland species like plants and fishes also reduces availability of direct products to neighboring indigenous peoples and local communities and reduces their employment and income.

D. Agriculture Ecosystems

Reduced production: Erratic rainfall and drought both are reducing agricultural yield, especially paddy (NAPA, 2010). Similarly decline in rainfall from November to April also reduces agricultural production.

Loss of local crop diversity: In the context of producing drought varieties, there has been loss of local land race and species.

E. Mountain Ecosystems

Risk of glacial lake outburst flood: There are more risks of glacial lake outburst floods which can affect mountain ecosystem and even the downstream communities and ecosystem.

Damage due to landslide and flood: In last ten years, more than 4000 persons died and properties worth $ 5.34 billion are lost, which include loss of land and crops, livestock etc (NAPA, 2010).

Spread of diseases: With rise in temperature, mosquitoes are also common in mountains, which are spreading diseases such as malaria, kalaazar, and Japanese encephalitis. In addition, there is also increased incidence and risk of other vector-borne tropical diseases such as typhoid.

4.6.2 Vulnerability Assessment

Forest and biodiversity are being more and more vulnerable in all the ecological regions due to changing precipitation pattern and increasing temperature. A study done by ICIMOD for Eastern Himalayas also shows an increase in temperature at 0.01 ^{0}C, 0.02 ^{0}C and 0.040 ^{0}C in the altitudinal range of less than 1000 meter, 1000-4000 meter and greater than 4000 meter respectively (ICIMOD, 2009). According to the report, the Terai-Dun tract from southeast Nepal to eastern Bhutan and Koshi Tappu Wildlife Reserve is most vulnerable to climate change. In addition, the area has also pressure for land and other natural resources, habitat fragmentation, species destruction through poaching and no potential for habitat extension.

Out of 39 life zones categorized by Holdridge (1967), Nepal has 15 types of life zones under existing condition. There may be only 12 types of vegetation in the double CO_2 climatic condition. Jha (2006) analyzed the vegetation under existing climatic condition and under projected double CO_2 condition. Under such condition, the tropical wet forest and warm temperate rain forest may disintegrate, and cool temperate vegetation at many places may turn to warm temperate vegetation.

Warming effect may be significant in the subalpine and alpine regions. In alpine regions, where the moisture regimes change, quite unexpected effects might also be seen. The vegetation may move up as much as 500m. Mountain plants will be affected by overall warming, associated with change in precipitation pattern and snow cover. Most sensitive areas are below tree line, as significant growth stimulation occurs here. Species of narrow thermal ranges (often rare species) will be affected first. Temperature increase at alpine sites may have little vegetative effect (growth, biomass production), but substantial phonological acceleration occur. Invaders from lower elevations can create pressure for upward movement of alpine species.

Vulnerability of forest and biodiversity across ecological regions is discussed below.

A. High Mountains

Snowline trees: Due to rise in temperature in higher elevations, snowline trees like Birch (*Betula utilis*) and Taxus (*Taxus baccata*), Cedar (*Cedrus deodara*) are becoming highly vulnerable as there are new trees competing and for existing trees to move up there is no favorable soil above the area.

The projected climate scenario indicates that the location and area of some habitats for many tree species and communities are likely to be influenced, particularly in mountains. The general effect of projected human-induced climate change is that the ecosystem boundaries of many species will move upward from their existing locations, and the composition of some ecosystems is likely to change (IPCC 2002). Mountain plants will be affected by overall warming with changes in precipitation pattern.

- **Major change in vegetation may occur in Trans-Himalayan region.**
- **Fir and hemlock forest may shift upward in the north.**
- **Fir-blue pine forest in central Nepal may convert to fir forest.**
- **Oak may reduce in fir-oak-rhododendron forest in western Nepal**
- **Magnolia may reduce in deciduous maple-magnolia-sorbus forest in eastern Nepal**

- **Tropical sal (*shorea robusta*) forest may convert into mixed forest.**
- **Species assemblages of some of the forests may alter as a result of warming in mountains.**

Fringe forests: Fringe forests are more vulnerable to landslides. Vulnerability increases with high intensity and short duration rainfall, which makes the upper layer of soil heavier and results in landslips, especially in areas where there is no large root system of trees.

High altitude medicinal plants: Due to climatic stress such as less water, and change in weather patterns, herbs in high altitude are more vulnerable and availability of medicinal plants like Yarshagumba (*Cordeyseps sinensis*), Jatamansi (*Nordostachys grandiflora*), Kutki (*Neopicrorhiza scorphularifolia*) and Sughadhawal (*Valerina wallichii*) have decreased. Similarly, unpalatable unidentified thorny grasses have been found in large quantity in high altitude, where they were not predominantly found before. Increase in such grass is reducing forage availability.

Less availability of herbs has direct impact on local indigenous communities, poor people and women who regularly collect herbs and non-timber forest products in high altitude. Vulnerability of herbs not only makes the local biodiversity vulnerable, but poor, women and indigenous people are also at risk due to slash in earnings which are used to buy foods and other basic goods.

High altitude birds and migratory birds: Due to erratic rainfall and less surface water, wetlands, and water sources are decreasing in and around high altitude forests. This decrease in water is also affecting trees, shrubs, and herbs, water plants in ponds and lakes, and fishes. All of these are important part of food and habitat for the local and migratory birds like danphe pheasant (*Lophophorus impijanus*). As a result, migratory birds like domicile crane (*Anthropodis virgo*) and other birds like pheasants are seen less.

High altitude animals: There has been migration of high altitude animals as well. For e.g., Pikas (*Ochotona spp.*), which used to reside mostly in 2800 m in the past, have now migrated up to 3200 m altitude. Similarly, leopards are now seen at higher altitude, which was not the case in the past.

<u>B. Mid-hills</u>

Tree species: As experienced by local communities, trees species such as banjh (*Quercus lanata*), kharsu (*Quercus semecarpifolia*), katus (*Castenopsis indica*), champ (*Michelia champaca*) are becoming more vulnerable due to rise in temperature. Upward shifting has also been experienced in trees like utis (*Alnus nepalensis*).

Similarly, local communities have also experienced diseases such as stem borer (benikira) and aijeru (fungus). Every year, fodder trees (mainly *Ficus nerlitolia*) in farmlands have been infested by defoliator resulting ultimate death of trees. Another insect named guheykira also infested in banjh (*Quercus langta*) and painyu (*Prunus cerasosdes*). Farmers are now lacking fodder and forages which were available plentiful in the past. Sal (*Shorea robusta*) trees have been infested by caterpillar during March-May. Due to prolonged dryness, incidences of forests fires are increasing. Plants with broad-leaves are very much prone to fire and cannot thrive in stress conditions. Alien and invasive species such as *Lantana camera* and invasive species such as banmara (*Chromolena adenophora*) are increasing posing threat to all plants in the locality.

Medicinal plants: Due to erratic rainfall and reduction in moisture, herbal fruits like amala (*Phylanthus emblica*), ritha (*Sapindus mukrossi*), timur (*Zanthoxylum armatum*), bel (*Aegle marmelos*) are found less and less every year. Likewise, satawari and sugandhakokila (*Cinnamomum glaucescens*) are also found less. Similarly, production of non-timber forest products like nigalo (small bamboo), bamboo, mushroom, etc. has diminished.

Wetland, water source and water bodies: Availability of water in wetlands, springs/sprouts and water bodies has been declining. Due to increased dryness, incidence of forest fire is increasing which destroys not only trees but also whole ecosystems in the area.

Birds: Due to water stress condition, the numbers of local bird species such as dove, bhyakur (bablar), ducks, vulture, eagle and bat are decreasing. Migratory birds like malchari, crane are also decreasing. Whereas, hill dhukur (*stereptopelia chinensis*), terai dhukur (*Stereptopelia orientalis*) are appearing here and there. Early flowering and early fruiting in plants are also making birds vulnerable due to change in food availability.

Wild animals: Due to shortage of water, the number of deer, monkey, porcupine, and pangolin is decreasing. Red monkeys earlier found in Churia range are now seen in Mahabharat range. Similarly, due to change in food availability, wild animals are more vulnerable.

C. Terai

Trees: Trees such as khair (*Acacia catechu*), sissoo (*Dalbvergia sissoo*), simal (*Bombax ceiba*) are seen decreasing due to change in water conditions in the streams. Trees like satisal (*Dalbergia latifolia*) and bijayasal (*Pterocarpus marsupium*) have become scarce in the forests due to over-exploitation and rise in temperature. Diseases are seen even in wild Sissoo trees. Forests are becoming drier. There is more incidence of fire in Terai forests.

Invasive species such as *Lantana camera*, *Eupatorium spp.*, *Mikania micrantha*, etc are increasing, thus making all plants in the locality vulnerable. An extreme example is found in Chitwan National Park where *Mikania macrantha* has spread extensively affecting original vegetation of shrubs and trees, which are important food for many wild animals.

Herbs: Due to changes in temperature and water related characteristics, herbs like kurilo (*Asparagus recemosus*), pipala (*Piper longum*), dalchini (*Cinamomum zeylanicum*), kaulo (*Cinamomum grandiliferum*) are decreasing in the forests and making them more vulnerable.

Water source and wetlands: The wetlands are more vulnerable to climate change as increase in temperature would enhance evapo-transpiration. Due to less rainfall, water is decreased in water sources in forests. Similarly, small ponds and lake are being dried such as Kalkij, Salgaudhi and Ranital in Kanchanpur and change in amount and pattern of rainfall would also affect the existence of the wetlands.

The production of some fishes living in fresh water bodies may be vulnerable to climate change. In aquatic species such as fish, rising water temperature increase metabolic requirements for oxygen while decreasing its solubility (Daweon, 1992).

Birds: Due to increased water scarcity, numbers of peacocks, waterducks, and mynah are decreasing in forests. Birds like Kilhat and migratory birds like Malchari are being more vulnerable and decreasing in and around forests. Similarly, due to early flowering, fruiting time of food availability have changed, making birds more vulnerable.

Animals: Availability of food for herbivores like deer is decreasing due to less quantity of grasses. Due to less deer, prey animals like tigers are also decreasing in number. Due to change in availability of food, behaviors of wild dogs have changed in Suklaphanta Wildlife Reserve, Kanchanpur. Water stress has also increased vulnerability.

4.6.3 Efforts to Reduce Vulnerability

Government of Nepal has been initiating a number of efforts to reduce the impacts of climate change on forests and biodiversity. Various awareness raising programs have been launched. Community forest user groups are managing about 28.3% of total forest contributing greatly to conservation of forest and biodiversity. The forest of 12 buffer zones has also been handed over to community user groups which is directly attributing to conservation and protection of endangered and protected wildlife. These community groups are also being supported by the government to formulate and implement appropriate adaptation action plan. Government has enlisted more wetlands in Ramsar list with a view to develop and protect these wetlands with priority. Government has formulated and implemented Nepal Biodiversity Strategy and Action Plan, 2014, National Wetland Policy 2013, Herbs and NTFP Policy 2004, Working Policy on Construction and Operation of Development Projects in Protected Areas, 2008 Forest Fire Management Strategy, 2009, Forest Encroachment Control and Management Strategy, 2010.

Herbs development program has been implemented in 12 districts of Midwestern Development Region which are in high altitude. Watershed management program has been implemented in 57 districts of the country to reduce the impact of soil erosion, landslides and floods. Forest fire control program has been implemented in all 75 districts. Integrated Churia Conservation Program has been initiated to reduce the vulnerability of the area. Various in-situ and ex-situ conservation activities have been undertaken to protect endangered, threatened and rare wild life. Mountain landscape management program and terai landscape management and conservation programs have been initiated to promote biodiversity conservation at ecosystem level both on protected and productive areas by involving local institutions. Leasehold forestry and livestock development program have been implemented in 22 districts of mid-hills to improve the livelihood of poor people living below poverty line and improve status of degraded forest.

Activities to cope with the changes in biodiversity and forest ecosystem include: management of forests for protection of soil and conservation of water, with inclusion of socio-economic factors; preparation and implementation of forest fire management plan; monitoring of forest health through management of landscape-level ecosystem and corridor, improved ecological connectivity, restored ecosystem and species, and control of invasive species; landscape conservation providing more flexibility for species by ensuring horizontal and vertical connectivity to enable movement of species due to climate change; increased understanding of changes in habitat; emphasis on management of herbs; ex-situ conservation of threatened species; afforestation/reforestation and reduction of deforestation; improved protected areas in mountains; reduced anthropogenic stresses; provision of minimum flow water requirement in river for fish and aquatic species; and incentive for private landowner to join conservation talks.

4.7 Public Health

4.7.1 Impacts of Climate Change on Public Health

A number of climate change-related impacts can be expected to occur on human health. Variation in monsoon rainfall pattern has affected ecosystem, resulting into loss of biodiversity, threatening to food security through adverse impacts on winter and spring crops, shifting of hydrograph cycle (including drying up of water resources, increased flash floods, possible droughts, and glacial lake outbursts), and changed environmental conditions, which eventually affect human health through the emergence of different types of new diseases (MOPE, 2004; NAPA, 2010).

Table 4-16 shows that the number of mortality due to heat stroke- hyperthermia was greater than that of cold stroke- hypothermia (DOHS 2009). The impact of the extreme weather conditions are seen increasing which is related to climate change (Kjellstrom, 2000, IPCC 2007). The phenomenon of heat waves has also been recognized by the communities during summer in most of the districts of Terai region but studies on its impacts are limited.

Table 4-16: Mortality due to extreme temperature events

Stroke\year	2004	2005	2007	2008
Heat	20	80	60	75
Cold	9	10	18	30

Source: DOHS (2004-2009)

During heat wave different symptoms of heat stress have been shown. They are hyperthermia, heat stroke, heat exhaustion, heat syncope, heat cramps, and heat rash. The impacts of heat wave were observed only from the last few decades (Figure 4-14)

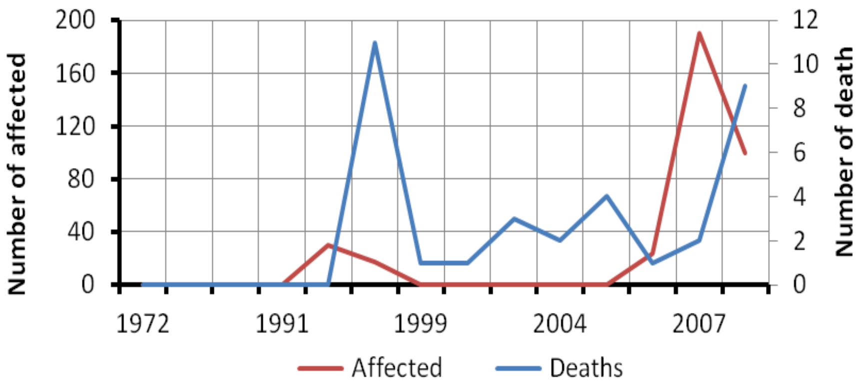


Figure 4-14: Trend of impacts of heat wave

The impact of heat stress has been observed in Terai region of Nepal where average summer temperature remain to 33°C and maximum temperature goes up to 45°C. The severity of heat wave varies as shown in Figure 4-15.

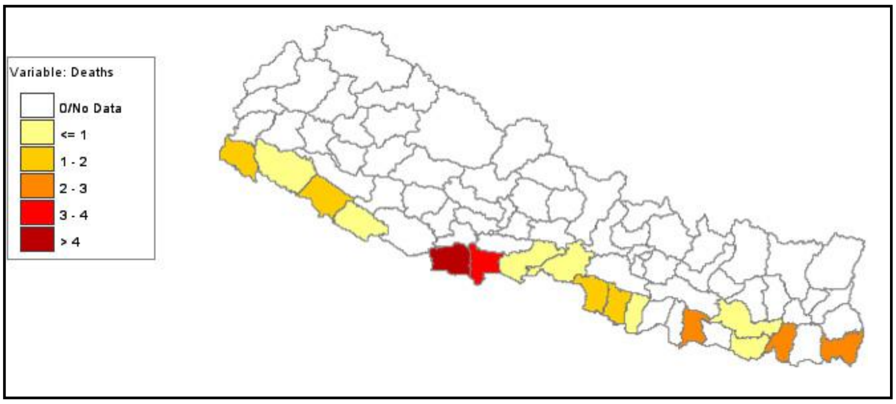


Figure 4-15: Heat wave affected districts in Nepal

Similarly the extreme cold weather has also been observed from the last few decades. The morbidity and mortality due to cold wave is shown in Figure 4-16. Cold wave causes different types of health impacts including respiratory problems such as cough, throat infection, chronic obstructive pulmonary disease (COPD), bronchitis, asthma, pneumonia, chronic bronchitis, rotavirus diarrhea, skin diseases etc.

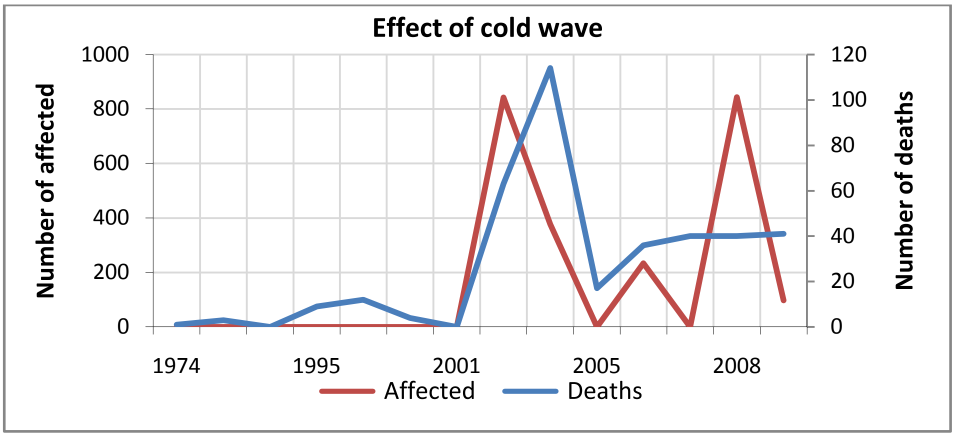


Figure 4-16: Trend of impacts of cold wave

The impacts due to cold wave are seen throughout the country. However the degree of impact varies as shown in Figure 4-17.

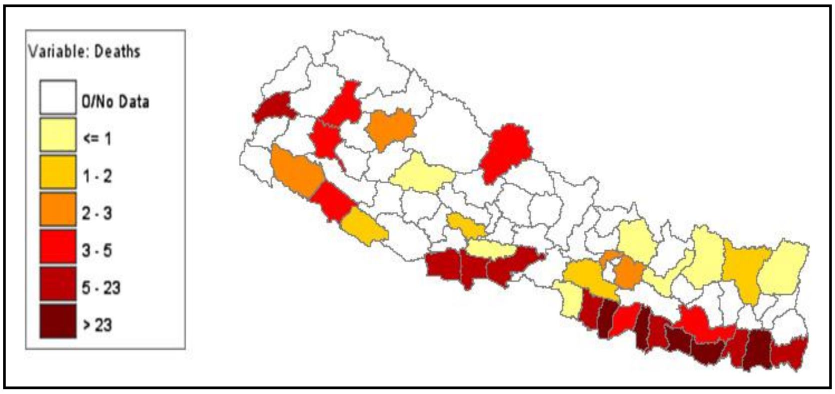


Figure 4-17: Degree of cold wave affected districts

Vector-borne diseases: Vector-borne diseases – encephalitis, Japanese encephalitis, leishmaniasis, malaria and kala-azar (Visceral leishmaniasis) – are more common in the warmer districts of Nepal (Figure 4-18).

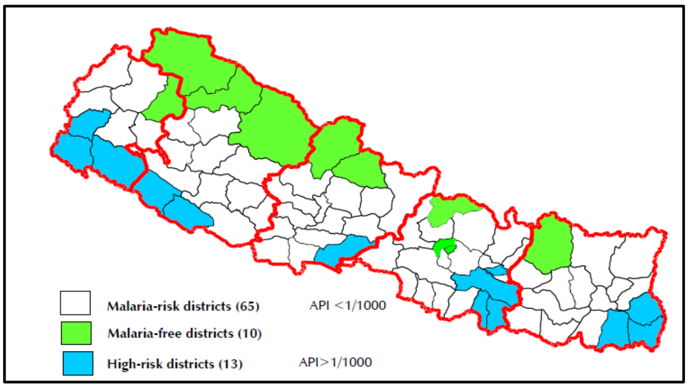


Figure 4-18: Spatial distribution of Malaria by region

Source: EDCD, Nepal. Note: API - annual malaria parasite incidence.

The most common species of malaria parasites are *Plasmodium vivax* and *Plasmodium falciparum* (DoHS, 2009). The proportion of *Plasmodium falciparum* type is in increasing trend which is relatively virulent compared to *Plasmodium vivax* (see Figure 4-19). The increment of *Plasmodium* *falciparum* is linked with increased temperature (WHO, 2005). Warmer temperature shortens the life cycle of mosquito, which generally takes 10-14 days for completion.

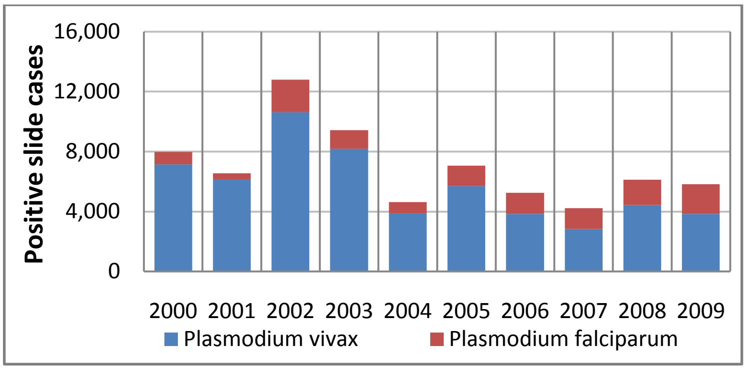


Figure 4-19: Trend of positives slides and types of malaria parasites

Data Source: EDCD, 2003-2008; DOHS 2010.

People have felt that mosquitoes are shifting to higher altitudes of Chitwan and Dhading districts where no occurrence of mosquitoes were noticed before (NHRC, 2009). The first outbreak of dengue occurred in Nepal in 2006. The cross- sectional entomological survey conducted in 2006 identified the presence of *Aedes aegypti* in 5 major urban areas of Terai regions bordering with India i.e. Biratnagar (Morang), Birganj (Parsa), Bharatpur (Chitwan), Tulsipur (Dang) and Nepalganj (Banke). Similarly, entomological survey conducted in Kathmandu valley in 2009 has revealed the presence of *Aedes aegypti* in Kathmandu (Gautam et.al, 2009). Previously *A. aegypti* was not recorded in Nepal. One of the reasons for increasing the disease and geographical spread might be because of climate change. The increased temperatures may create conducive environment to mosquitoes breeding. Highest abundance of the Aedes mosquito is in mean temperature above 20ºC at clean accumulated rainfall (150 mm). The egg laying capacity decreases if the monthly mean temperature decreases from 16.5ºC. If the temperature decreases below 14°C, mosquito cannot lay eggs.

Water-borne diseases: Water sources such as springs, rivers and groundwater are being reduced or dried up due to exposure to extreme heat. Water shortage is one of the causes for poor sanitation and water-washed diseases like skin disease, worm infestation, eye infections, etc. Limited and poor quality drinking water is responsible to spread water borne disease like typhoid, diarrhea, dysentery, cryptosporidiosis, giardiasis, amoebiasis, gastritis and infectious hepatitis (IPCC, 1996; 2001). Available studies indicate that heavy rainfall events transport terrestrial microbiological agents into drinking water sources, resulting in outbreaks of those infectious diseases (Pradhan, 2007). Incidence of diarrheal diseases per 1000 new cases children under 5 years of age has increased consistently from 131 in 1995 to 498 in 2011, while case fatality rate has decreased remarkably from 0.6/1000 new cases in 1996 to 0.01 in 2011. Further, morbidity with an average of over 3.3 episodes per child has been recorded. Likewise, there has been an increased trend of typhoid fever, from over 400 cases in 2001 to nearly 1000 cases in 2005. A hospital record in 2005 has shown a close relationship between temperature and precipitation and typhoid cases; both climatic phenomena have risen during four months (June-September) and meanwhile typhoid cases of children under 5 years of age were among the highest (ranged from 270 to 193/1000 new cases), while in the winter months, the cases have lowest along with low temperature and rainfall (Shrestha et al 2007, Regmi et al 2007). A total of 282 people died in May – August 2009 due to the outbreak of diarrhea and cholera in mid-western development region of Nepal which is mainly due to the consumption of contaminated water and poor sanitation due to the lack of adequate water. Most of the local water sources have been dried up due to long drought which may be due to variation in the climate (DoHS 2011).

Diarrhea lies in the top five common diseases listed in the OPD visits. The occurrence of this disease shows a definite monthly pattern, which has positive relation with the amount of precipitation. The highest diarrhea occurrence is recorded in the months of June and July (Figure 4-20). Figure 4-21 shows incidence of water borne diseases and diarrheal death by districts.

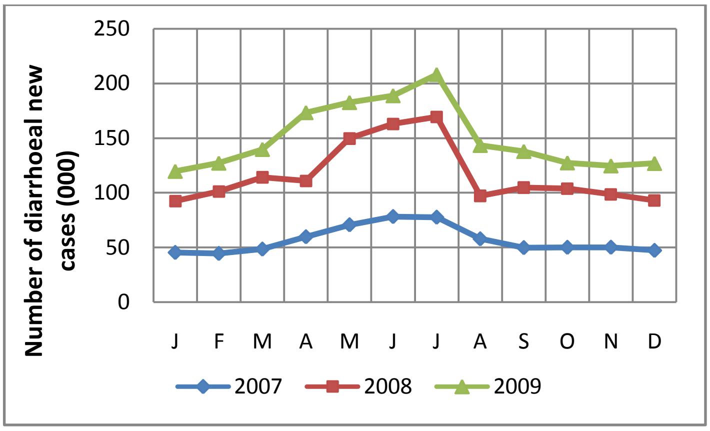


Figure 4-20: Monthly trend of diarrheal new cases

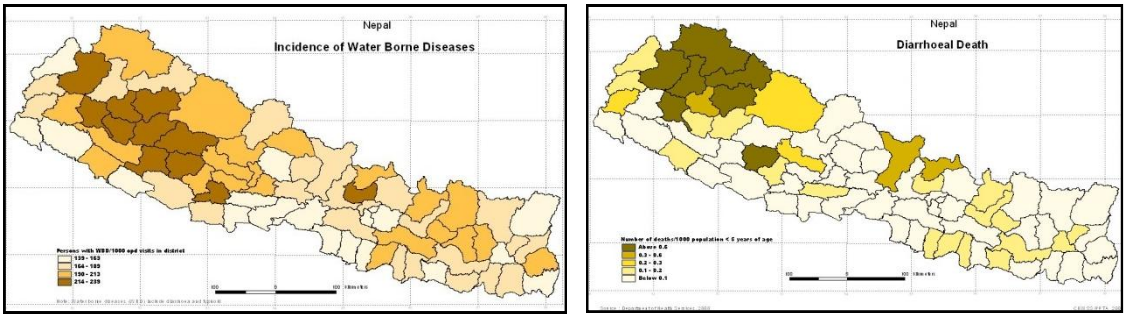


Figure 4-21: Incidence of water borne disease (left) and diarrheal morbidity (right)

4.7.2 Vulnerability Assessment

Generally, vulnerability of population to a health risk depends on the local environment, the availability of local resources, the effectiveness of governance and civil institutions, the quality of the public health infrastructure and the access to relevant local information on extreme weather threats. These factors are not uniform across the country. Individual, community and geographical factors determine vulnerability. Thus, people residing in the mountain and the hills are more vulnerable in terms of access to infrastructure and facilities including health. Potential vulnerable population varies with population characteristics, geographical location, settlement types, and occupational groups, social, political and cultural situations. The identified vulnerable groups of Nepal are as follows: children and women (especially pregnant), squatters – large cities, slum dwellers– large cities, dwellers of flood plain and river banks and hill slopes, internally displaced persons (IDPs), rag pickers, street children and child workers, commercial sex workers, prisoners, and refugees.

The potential vulnerable population is estimated by risk assessment method. The risk assessment is a process of determining the probability and magnitude of harm to human life and welfare or environment potentially caused by the release of hazardous chemical, physical or biological pollutants. The estimation of potentially vulnerable population and the districts in terms of climate sensitive diseases in Nepal are shown in Table 4-17. The trend of morbidity pattern for each disease is increasing. Similarly, coverage of the diseases is also increasing. The districts which were not vulnerable especially for the vector borne diseases are vulnerable at present. It is seen that the vulnerable population to climate sensitive diseases ranges from 100 percent to as low as 30% (Table 4-18).

Table 4-17: Potential vulnerable population in terms of climate sensitive diseases in Nepal

Diseases	Disease Coverage by District	Potential Risk Population (%)
Malaria	65	91.6
Lymphatic filariasis	60	87.0
Japanese encephalitis	24	53.9
Kala-azar	12	29.7
Water and food borne diseases	75 (all)	100
Non-communicable diseases	All districts	100

Source: DOHS (2010).

Table 4-18: Vulnerable population as per the demographic characteristics

Vulnerable people	%
All population from Terai region (13.3 million)	50.1 % of total population (26.6 million)
Elderly people	4. 4 %
Pregnant women	2.6 % of Terai women (6.7 million)
Neonates	2.8 % of Terai

4.7.3 Efforts to Reduce Vulnerability

The government has recently made efforts to address climate and health issues. Nepal Health Sector Program (NHSP-II) has addressed various environmental issues, including climate change and its impacts on the health of the people and other areas. Training manual for mainstreaming climate change and health issue from grassroots level to the district level has been prepared.

The MOHP/NHEICC (2011) has prepared information booklet on climate change and health for dissemination throughout the country. The Centre has also prepared radio jingle and documentary on climate change and health. The Centre has provided training to the media personnel on how to report climate change and health issue. The first national workshop on Climate Change and Human Health: Potential Impact, Vulnerability and Adaptation in Nepal was organized by NHRC in 2007 (NHRC 2007).

4.8 Climate-Induced Disasters

4.8.1 Background

Nepal is prone to a multitude of climate-induced hazards such as floods, flash-floods, glacial lake outburst floods, landslides, windstorms, hailstorms, heat and cold-waves, cloudbursts, forest fire, drought, famine and epidemics. Among the major hazards, floods and landslides are the most recurrent natural hazards in Nepal. As a result of increased glacier melt, 20 glacial lakes are at the risk of bursting, six of which have been identified as 'critical' (MOE, 2010a).

One of the obvious effects of global warming is the rapid melting of snow and ice as a consequence, glaciers are retreating very fast and glacial lakes are expanding. As a result, the risk of potential glacial lake outburst flood damaging far downstream areas is increasing. Similarly, the incidence of flash floods, landslides and debris flow is likely to increase in the context of increasing frequency of heavy precipitation due to global warming. The frequency and magnitude of drought events is also likely to increase.

In its 4th Assessment Report, the Inter-governmental Panel on Climate Change (IPCC) projects that rising global temperature will increase the frequency and severity of atmospheric extreme events such as tropical rain, flash floods, heat waves, droughts, bush trees, tropical and extra tropical cyclones, hailstorms and storms surges in many parts of the world. It also predicts monsoon pattern changing rainfall in large areas over Asia and other parts of the world and anticipates more extensive damage, economic, social, and environmental impacts from weather-related disaster. In addition endemic morbidity and mortality due to diarrheal disease primarily associated with floods and droughts are expected to rise in South Asia. Also, glacier melt in the Himalaya is projected to increase flooding and rock avalanche from destabilized slopes and to affect water resources (IPCC, 2007).

Disaster can have impact on all levels of development process and undermines developmental gains. It leads to destruction of fixed assets, loss of production capacity, market access or material inputs, damage to infrastructure and erosion of livelihoods, savings and physical capital. Indeed, poor people are affected most by disasters as they have limited capacity to adapt. Disasters have a devastating effect on achieving both short- and long-term goals including millennium development goals. More than 4000 lives have been killed in the last 10 years due to climate-induced disasters causing an economic loss of US$ 5.34 billion and more than one million people are susceptible to climate-induced disasters (MOE 2010). Floods and landslides alone claim about 200 lives every year. The scale of property loss by disasters from 2000 to 2009 by districts is shown in Figure 4-22.

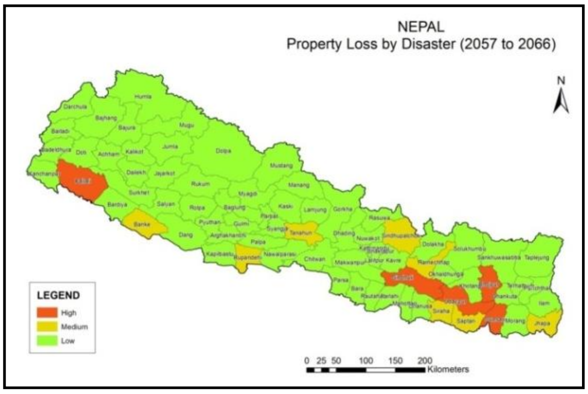


Figure 4-22: Property loss by disaster (2000 - 2009)

Besides human lives, the huge amount of private and public properties are being damaged and destroyed by floods and landslides every year. The private properties damaged mainly include agriculture lands, livestock and private houses whereas the public properties damaged include physical infrastructures such as roads, buildings, bridges, culverts, irrigation canals, hydropower plants etc. Damages to private properties are directly affecting the livelihood of common people and weakening their adaptive capacity. Similarly damages to physical infrastructures are not only incurring huge costs to the nation for repair and maintenance but also affecting other sectors impacting the economy as a whole. Climate change is likely to pose threat for the sustainable development and functioning of the infrastructures. The government is spending over 50 percent of development budget in infrastructures, in order to make the investment more efficient, sustainable, and resilient (NPC, 2010).

Nepal is committed to implement the Hyogo Framework of Action, 2005 and Incheon Roadmap on DRR 2010 and has been making various efforts in the field of disaster prevention/mitigation, mainstreaming of DRR, emergency preparedness and effective response measures (NPC, 2010). In 2009, the Government of Nepal approved National Strategy for Disaster Risk Management (NSDRM)

and the government has recently decided to amend the Natural Calamity Act 1982 to mainstream the provisions of the Strategy. In 2009, GoN launched the comprehensive Nepal Disaster Risk Consortium (NRRC) which identified five flagship areas of immediate action for disaster risk management in Nepal that included integrated community based disaster risk reduction/management and flood risk management activities (structural and non-structural measures for flood mitigation and flood forecasting and early warning systems). The current periodic plan requires a systemic risk assessment for natural hazards to be carried out for major development projects including key infrastructure projects.

4.8.2 Vulnerability Assessment

Nepal is ranked as the forth most vulnerable country to climate change, thirtieth with respect to water-induced disasters and twentieth with respect to multiple hazards (NPC, 2010). Although no systematic vulnerability assessment of the entire country has been conducted in relation to climate induced-disasters, but few flood and landslide vulnerability assessments of some places have been done.

Nepal Country Vulnerability Study Team (NCVST) in 2009 projects that the current frequency of hydro-meteorological extreme events such as droughts, storms, floods, inundation, landslides, debris flow, soil erosion and avalanche will increase due to projected climate change (MOE, 2009). Extreme precipitation events are likely to increase. One day precipitation amount has shown an increasing trend and there has been increasing trends in consecutive dry days (maximum number of consecutive days with rainfall less than 1 mm) and decreasing trends in consecutive wet days (maximum number of consecutive days with rainfall equal or more than 1 mm).

According to the study "Climate Change Vulnerability Mapping for Nepal" (MOE/NAPA, 2010), out of 75 districts, 29 districts have been found highly vulnerable to natural hazard such as landslides, 22 districts to drought, 12 districts to Glacial Lake Outbursts, and 9 districts to floods (MOE, 2010). Study shows that 15 districts have very high disaster risk exposure. Women in particular are more affected by climate change as they have less access to early warning and climate information and lack skills to survive extreme events.

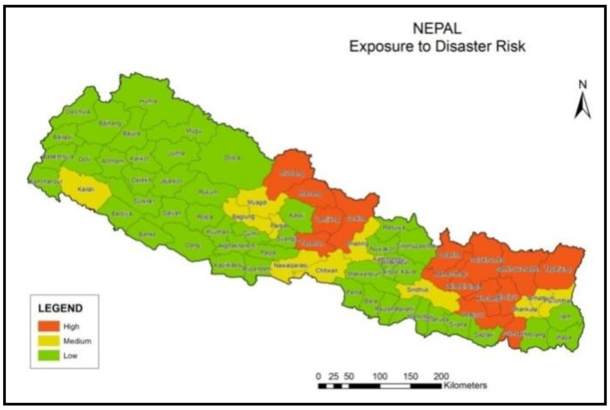


Figure 4-23: Disaster Risk Exposure Index

Note: Low (below average index value) <0.1978; medium (between value of average index and average index + standard deviation of index) = 0.1978 - 0.4530; high (Above average index + standard deviation of index value)>0.4530.

4.8.3 Efforts to Reduce Vulnerability

The institutional response to disasters management in Nepal began only after the promulgation of Natural Calamity Relief Act in 1982 which is relief and response centric in terms of Disaster Risk Management. Disaster Risk Reduction (DRR) has been considered as a climate change adaptation

strategy. Recognizing the growing importance of the need for disaster risk reduction, the Government of Nepal has been implementing National Strategy for Disaster Risk Management (NSDRM) since 2009 that envisages the reorganization and development of disaster management institutions, the creation of enabling legal environment for DRR and preparedness planning at all levels including strategies for mainstreaming DRR into the country's national development and poverty alleviation agenda.

Various structural and non-structural adaptation measures have been adopted to reduce the impacts of climate-induced disasters. These include: construction of embankments, check dams and spurs, emergency protection, development of early warning system, awareness raising programs, rehabilitation works, GIS development, provision of insurance, piloting of flood forecasting system, provision of irrigation facility etc (MOE 2010). Similarly, a number of practices have been adopted in agricultural sector such as rain-water harvesting and soil moisture retention through conservation farming (water harvesting ponds, soil mulching, planting fodder/forage grasses and legume plant/tree species and agro-forestry system), river embankments by planting bamboo and fodder/forage grass, slope stabilization and management by planting fodder trees, coffee on terraces and hedge roe planting. Priority has been accorded specifically to community-led DRR programmes and initiatives.

National Adaptation Program of Action (NAPA) has selected two projects-community-based disaster management for facilitating climate adaptation, and GLOF Monitoring and Disaster Risk Reduction-to be implemented as a most urgent and immediate priority adaptation need of the country in order to reduce the impact of various types of disasters, including a number of adaptation options such as hazard/vulnerability mapping and zonation, strengthening of early-warning and forecasting system, enhancing capacity of governmental and non-governmental organizations, implementation of structural measures, promotion of afforestation and reforestation programs and bio-engineering techniques, resettlement of vulnerable communities, among others.

4.9 Human Settlement and Infrastructure

4.9.1 Vulnerability Assessment

Climate change impact on human settlement and infrastructure is primarily due to extreme weather changes than gradual climate changes (IPCC, 2007). Impacts on human settlements from climate change may be direct due to extreme events, as well as indirect through effects on other sectors like changes in water supply, agriculture productivity, and human migration (IPCC, 1996). Climate change may increase the vulnerability of infrastructure due to increased vulnerability to flooding and landslides. Detailed modeling of frequency and intensity of rainfall events in the context of global warming has been linked to increased intensity and frequency of flooding, with considerable damage to infrastructure (IPCC, 2001).

Increased instances of drainage congestion, scouring, inundation, slope instability, landslides, erosion, and collapse of structures are likely to happen (NPC, 2011). Floods, landslides and debris flows will affect hydropower, roads, bridges, community and public buildings, and schools, irrigation, settlements, water supply and sanitation, while the drying up of water sources will impact drinking water and sanitation, irrigation, and micro-hydro plants. This will also increase the risk of isolation of human settlements especially if it is accompanied with broken telecommunications and traffic connections.

Global warming can be expected to affect the availability of water resources. An extended drought often results in crop failures, a drop in the production of hydropower, a reduction in milk and meat production, and a shortage of domestic water supply in downstream areas. Water resources and biomass – the major energy sources in Nepal – are already under stress as a result of rising demand. Increasing human population and prosperity provide a rising energy-demand baseline against which the adverse impacts of changing climate will be exacerbated. Energy demand will be affected by warming, but the direction and strength of the impact will depend on the extent of demand for space heating or cooling and the role of climate-sensitive sources of demand, such as irrigation pumping.

Irreversible glacial melt, unpredictable precipitation patterns, flash floods in the hills and downstream flooding, temperature fluctuation, extreme rainfall events, dwindling agricultural outputs, and degraded ecosystem services will affect the state of human settlement and of physical infrastructures. Since infrastructures such as transport, hydropower, irrigation, water supply and sanitation, housing, and communication are the lifeline of socioeconomic development, it is not surprising that about half of Nepal's annual development budget is spent on their development and maintenance.

In addition, damaged infrastructures impede the functioning of other economic sectors-sometimes for long periods causing huge economic loss. A damaged road hinders the movement of people and goods and adversely affects industry, business, markets, and all other associated activities. When a hydropower plant is damaged, it is not only the production of electricity that stops, but all output of industries that rely on electricity from that plant is adversely affected.

Most vulnerabilities and impacts of human settlement and infrastructure to climate change are cross thematic in nature and are largely related to climate induced disasters. The impacts are mainly associated with municipal water and energy resources and also adversely affected human health. Human settlement planning process has increasingly become more challenging due to climate-induced rural urban migration (MOE, 2010).

Higher temperatures and extended heat waves can result in a more rapid degradation of asphalt and materials of roads, airports, bridges and buildings. The dense and unsafely built human settlements are one of the major causes of climate vulnerability. The ongoing land use change, new buildings, land transaction and land fragmentation, decreasing open space in the urban areas are adding vulnerability of human settlement to climate change (MOE, 2010). Climate resilient human settlements and infrastructure require improved, effective and pro-poor structures of governance.

4.10 Environmental and Socio-Economic Vulnerability by Districts

4.10.1 Vulnerability Mapping

Realizing the necessity for identification and characterization of the vulnerable regions, communities and sectors for addressing climate change adaptation in Nepal, the then Ministry of Environment prepared and published climate change vulnerability map for the first time in 2010 at district level (MOE, 2010b). In addition to the review of NAPA vulnerability mapping exercise, this study for SNC carries out further assessment of environmental and socio-economic vulnerability with slight modification in selecting and categorizing key indicators/indices using the following methodology.

Hahn, Riederer and Foster (2009) have developed the following livelihood vulnerability index. This study has also incorporated environmental factors in order to develop overall vulnerability index.

$$\text{Livelihood Vulnerability Index } (LVI_d) = (e_d - a_d) * s_d$$

where e_d = exposure index of the district; a_d = adaptive capacity of the district; and s_d = sensitivity index of the district.

The value of a district were aggregated and normalized to a scale of 0 to 1 range using the following formula. For the purpose of aggregation, the indicators were grouped into two groups: Group A and Group B. Group A consists of those indicators whose values increase with the decrease (from better to worse) in the level of performance among districts. Group B consists of those indicators whose values increase with the increase (from worse to better) in the level of performance among the districts.

Group A: $Z_{i,j} = (X_i^{max} - X_{ij})/(X_j^{max} - X_j^{min})$

Group B: $Z_{i,j} = (X_{i,j} - X_j^{min})/(X_j^{max} - X_j^{min})$

where $Z_{i,j}$ = standardized indicator index of type i of district j; $X_{i,j}$ = non-standardized indicator index of type i of district j; X_j^{max} = maximum value of the indicator index over district j; and X_j^{min} = minimum value of the indicator index over district j.

The normalized values are further divided in to three scales of High, Medium, and Low categories. Below the average index value are categorized as Low. The index value between average and sum of average and 1 standard deviation are categorized as Medium, where the value above the sum of average and 1 standard deviation are categorized as High. Table 4-19 list the indicators used in this study for calculating index value of exposure, sensitivity and adaptive capacity.

Table 4-19: List of indicators for vulnerability assessment

Particulars	Indicator	Data Sources
<u>Exposure</u>		
Climate	Mean annual temperature trend	Calculated based on time series data obtained from DHM
	Mean annual precipitation trend	Calculated based on time series data obtained from DHM
Disaster	Property loss due to disaster	DNCDM, MOHA, 2011
	GLOF Risk	Climate Change Vulnerability Mapping for Nepal, MOE, 2010
<u>Sensitivity</u>		
Socio-Economic	Population density	CBS, 2011
	Health facilities (health institutions)	Annual Report 2066/67, DOHS, 2011
	Food balance	Department of Agriculture and Cooperatives, 2009/10
	Drinking water facility	Nepal WASH Sector Status Report 2011
	Irrigation facility	Department of Agriculture and Cooperatives, 2002/3
	Road facility	Statistics of Strategic Road Network SSRN2009/10
Environment	Steep slope (> 30 degree)	LRMP, 1986
	Sloping terraces	LRMP, 1986
	Forest coverage	JAFTA, 2001
<u>Adaptive capacity</u>		
Development	Human Development Index	Nepal Human Development Report 2004, UNDP, Nepal, 2004
Livelihood Strategies	Economically active people engaged in non-farm activities	National Census Report 2001, CBS
Social Network	Number of working NGOs	Social Welfare council (1978-2009)

Exposure: The composite level of exposure (climate and disaster risk) map is presented in Figure 4-24. It shows that 13 districts are in high level of exposure, 21 in medium and rest in low level of exposure.

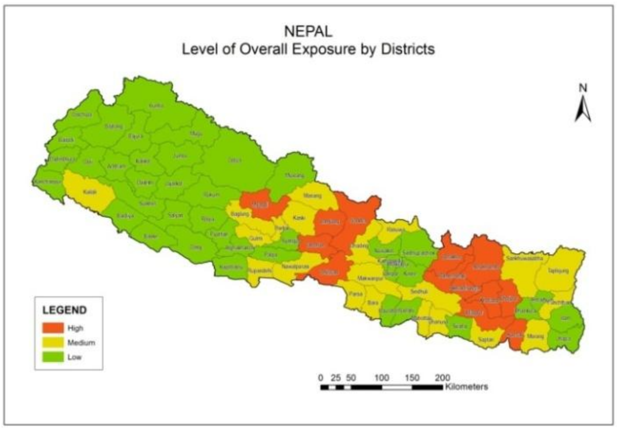


Figure 4-24: Level of overall exposure by districts

Note: Low (below average index value) <0.3598; medium (between value of average index and average index + standard deviation of index) = 0.3598 to 0.5758; and high (above average index + standard deviation of index value)>0.5758.

Sensitivity: Population density, number of health institutions, food balance, percentage of population with safe drinking water facilities, percentage of area under irrigation facility, density of road length were taken as indicators of sensitivity to climate change. Similarly, percentage of area above 30 degree slope, percentage of area under sloping agriculture, percentage of area covered with forest were taken as indicators of environmental sensitivity. Figure 4-25 shows level of sensitivity in terms of environmental condition. It shows that 15 districts are in high, 23 in medium and 37 in low level of sensitivity.

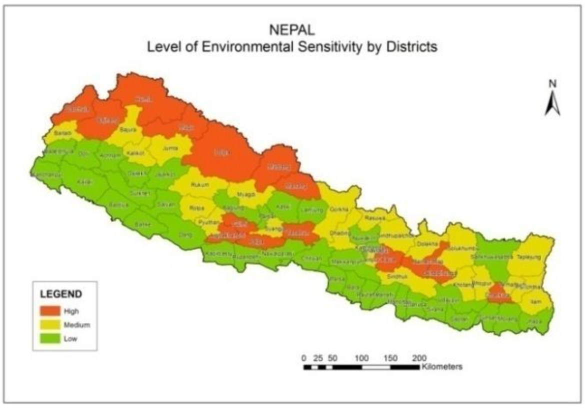


Figure 4-25: Level of environmental sensitivity by districts

Note: Low (below average index value) <0.5622; medium (between value of average index and average index + standard deviation of index) = 0.5622 to 0.7925; high (above average index + standard deviation of index value)>0.7925.

Similarly, Figure 4-26 shows socio-economic sensitivity. Out of 75 districts in the country, 12 are in high level of socio-economic sensitivity, 17 in medium and rests in low level of sensitivity.

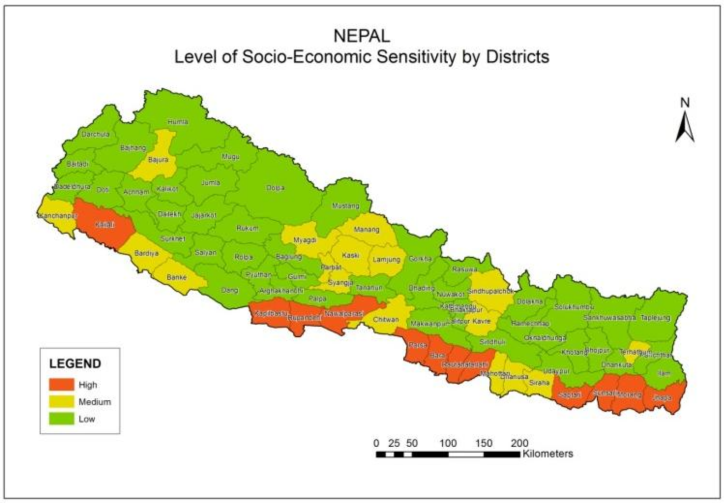


Figure 4-26: Level of socioeconomic sensitivity by districts

Note: Low (below average index value) <0.4486; medium (between value of average index and average index + standard deviation of index) = 0.4486- 0.6352; high (above average index + standard deviation of index value)>0.6352.

Figure 4-27 shows overall sensitivity in combination of environmental and socio-economic indicators. It shows that 13 districts are in high level of sensitivity, 24 districts in medium and rest in low level of sensitivity.

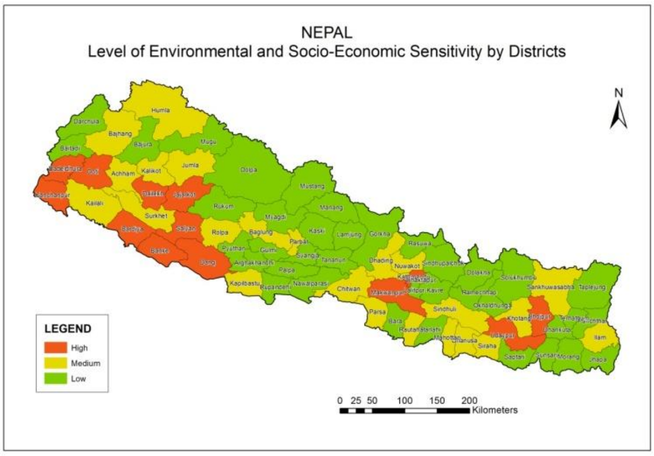


Figure 4-27: Level of environmental and socio-economic sensitivity by districts

Note: Low (below average index value) <0.5064; medium (between value of average index and average index + standard deviation of index) = 0.5064- 0.7161; high (above average index + standard deviation of index value)>0.7161.

Adaptive capacity: Human development index, percentage of people engaged in non-agricultural sectors (off-farm activities), and availability of social network (number of I/NGOs working in the district) have been taken as key indicators of adaptive capacity. Figure 4-28 shows classification of district based on composite index of adaptive capacity. Nine districts have been found with high level of adaptive capacity, 15 districts of medium and 51 districts with low level of adaptive capacity. Those having high adaptive capacity are Lalitpur, Kathmandu, Bhaktapur, Banke, Jhapa, Mustang, Morang, Sunsari and Kaski.

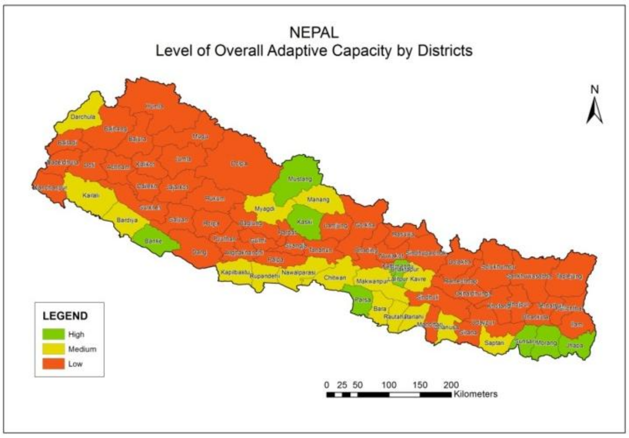


Figure 4-28: Level of overall adaptive capacity by districts

Note: Low (below average index value) <0.3374; medium (between value of average index and average index + standard deviation of index) = 0.3374 - 0.5340; high (above average index + standard deviation of index value)>0.5340.

Overall socio-economic and environmental vulnerability: Figure 4-29 shows overall socio-economic and environmental vulnerability to climate change in the country. Nine districts (Bhojpur, Khotang, Udaypur, Dolakha, Sindhuli, Chitwan, Gorkha, Lamjung and Baglung) are identified as highly vulnerable. 27 districts are in medium level of vulnerability. 39 districts are in low level of vulnerability. Note that Ranking of districts in terms of vulnerability differ from that in an earlier study done in 2010 (MOE, 2010b). Such differences arise partly due to selection, categorization and use of the different indicators, and partly due to incorporation of updated climate and socio-economic data. With future updates in population data, forest survey data, downscaling of climate projections data and other relevant data, it becomes necessary to re-assess vulnerability in future studies.

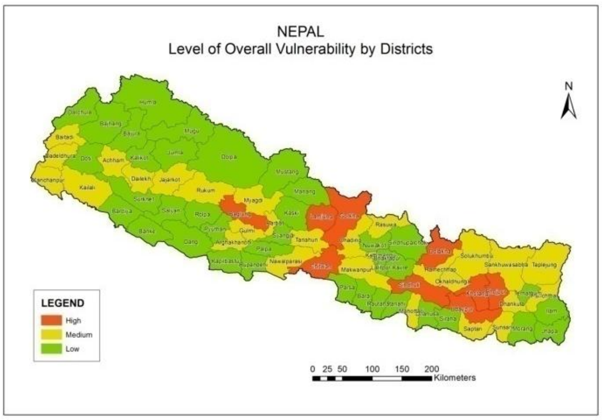


Figure 4-29: Level of overall vulnerability by districts

Note: Low (below average index value) <0.4038; medium (between value of average index and average index + standard deviation of index) = 0.4038 - 0.5419; and high (above average index + standard deviation of index value)>0.5419.

4.10.2 Efforts to reduce vulnerability

Prioritized districts for adaptation planning: The Government has prioritized districts for adaptation planning considering specific climate change exposure (MOE, 2010b). A total of 16 districts have been prioritized for adaptation planning in the field of ecology out of which 6 districts have been recommended for the first phase. Similarly, a total of 26 districts (6 for the first phase) in the hills and mountains have been prioritized for landslide risk management. A total of 12 districts (6 for the first phase) in the Terai have been prioritized for flood risk management. Likewise, a total of 20 districts (7 for the first phase) for drought risk. Finally, a total of 12 districts (6 for the first phase)

are selected for GLOF risk. Figure 4-30 shows prioritized districts for adaptation planning for the first and second phase.

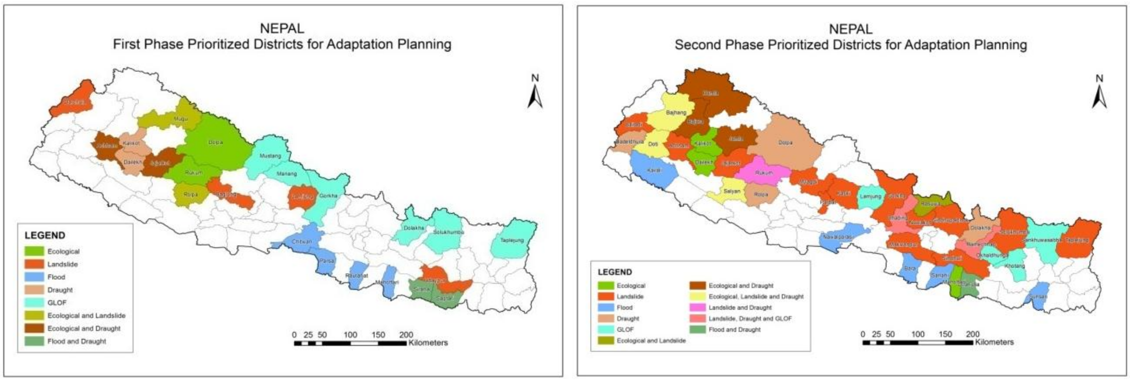


Figure 4-30: Prioritized districts for adaptation planning for first (left) and second phase (right)

Source: MOE, 2010b.

4.11 Environmental Management

4.11.1 Impacts of Climate Change on Environment

Water Management

Flooding and its Impacts: Flooding will inevitably result in additional water pollution from a large variety of sources. It could increase turbidity and sedimentation that will result in loss of reservoir storage. In addition, for the most part, wastewater treatment plants and combined sewer overflow control programs have been designed on the basis of the historic hydrologic record, taking no account of prospective changes in flow conditions due to climate change. As a result, it is conceivable that water suppliers will face a continually increased influent challenge from sewage overflows producing high concentrations of coliforms and other pathogenic microbes.

Water Shortage: The alteration in precipitation and consequent change in water availability could result water distribution problems and reduced quantities of water available to recharge groundwater aquifers.

Water Contamination: The decreased water availability enhances water contamination. Similarly, the increased temperature favors microbial growth deteriorating the water quality and there would be increased evaporation and eutrophication in surface sources. Thus, these factors will affect water quality and quantity of the areas stressing water quality management.

Air Quality Management

Alteration in Meteorology: The wind system may be altered in magnitude and direction that will alter the air pollution meteorology.

Alteration in Particulate Matter Concentration: Climate change could increase biogenic emissions (including wild fires). Loss of visual range and increased morbidity and mortality due to higher concentrations of fine particulate matter (PM) are likewise probable. In addition, high temperature increases the evaporation of volatile organic compounds (VOCs) from fossil fuels such as gasoline vapor that acts as a precursor to PM and ozone. Increased temperatures from the urban heat island effect are well documented and could exacerbate these effects.

Rise in pollutants: Similarly, certain trees emit biogenic VOCs such as terpenes from pines, isoprene from oaks and both from sweet gum. These compounds react with man-made pollutants to generate smog and haze. Also, higher temperatures and higher CO_2 concentrations accelerate emissions with degrading the air quality.

<u>Solid Waste Management</u>

Alteration in waste decomposition rate: Higher temperature could alter waste decomposition rate due to changed rate of biological processes such as composting and anaerobic digestion.

Alteration in leachate production: Increasing temperature could lead to reduced water availability that will alter site hydrology and leachate production. However, intense precipitation could increase flooding occurrence on site due to saturated waste and rising groundwater increasing leachate production.

Disease transmission: Higher temperature will give rise to increased vermin eg flies and enhance disease transmission.

Odor nuisance: Increasing temperature could cause increased risk of odor nuisance from solid wastes.

Reduced labor productivity: Higher temperature may reduce outdoor workers productivity.

Instability on waste management sites: Waste management is generally done in unused barren land and increased precipitation intensity could affect slope stability of such waste management sites.

4.11.2 Adaptation Measures

Water management: The upgrading and improvement of water supply lines would bring losses to acceptable limits. Further, the efficient use of water would reduce treatment and distribution costs and monitoring should be done to control and repair household leaks. Water management can be achieved through the following measures.

- **Improved management of existing irrigation system**
- **Rehabilitation of traditional ponds**
- **Incentives could be given in the form of tariff reduction for households and businesses who install rainwater tanks, re-use their grey water and install low-flush toilets.**
- **Building codes/regulations can be made that new buildings be installed with water saving devices, such as low-flush toilets and rainwater tanks.**
- **Rainwater harvesting in homes and commercial buildings for use on gardens, in swimming pools and sewage could be encouraged and incentivised.**
- **Regular monitoring of capacity of water distribution and treatment systems**
- **Develop additional reservoir capacity**
- **Capture and reuse rainwater for irrigation and other uses**
- **Prepare high resolution flood hazard/risk mapping to identify high risk areas to floods**

- **Implement sustainable urban drainage systems including permeable pavements and increased use of stormwater retention ponds, constructed wetlands and swales**
- **Create natural eco-system buffers for vulnerable water bodies, low-lying areas**
- **Expand capacity of storm sewers to manage extreme weather events**
- **Regulate land-use planning and zoning to avoid buildings and infrastructure in flood or landslide prone areas**
- **Flood-proof buildings in vulnerable locations can be constructed**
- **Use of early warning system for impending disaster risks with the help of the meteorological and hydrological monitoring stations.**
- **Regular maintenance of storm-water drains to clear them of sand build-up an rubbish.**
- **Floodproofing such as structure raising, sacrificial first storey and watertight doors**
- **Flood insurance and reinsurance**
- **Awareness raising for restricting the use of water for some activities to specific times and disallowing other activities to reduce the demand on the limited water resources.**
- **Flood education can be given to the general public**

Air quality management: Adaptation measures include

- **Implementation of warning systems on air pollution at community level**
- **Awareness raising and capacity building to the professionals in the public health sector such as health care workers, emergency doctors and general public**
- **Strengthening treatment / public health care system**
- **Average person should be advised to avoid exercise on days with high levels of air pollution and susceptible person should reduce physical activity in the afternoon**
- **Coordination among concerned stakeholders**
- **Interventions to reduce heat island effects including increased street trees and tree canopy coverage, increased parks and green spaces, green roofs, high albedo (reflective) building and road surfaces, heat response systems (cooling centres, water distribution, etc.)**
- **Construction of forest fire line and collection of dry leaves from forest ground should be done**
- **Education, awareness and training to the community people on control of forest fire should be given**

Solid Waste Management: Adaptation measures include

- **Establishment of sanitary landfill site and its environment friendly management to protect from contaminating our land and waterways**

- **Establishment of municipal compost plant**
- **Establishment of biogas systems in hotels, colleges, army barracks, police posts and households**
- **Interventions to prevent impacts from expansion of vector-borne diseases such as early detection and warning systems, spraying to control infestations, control of other factors that support the expansion of disease-carrying insects (e.g. standing water)**
- **Improved sanitation**
- **Conduct public education on climate-related health threats (vector-borne diseases, heat) and prevention**
- **These adaptation options as well as infrastructure construction of development program should be climate proofed as mentioned below**

Climate-Proofing Environmental Infrastructures: In the context of long-term climate change, previous concepts of 'weather-proofing' or 'hazard-proofing' of infrastructure investments that rely on past records as an indication of future hazards are no longer sufficient. It is necessary to adapt to current and future hazards and climate conditions.

Integrating climate change risks and opportunities into the design, operation and management of infrastructure is climate proofing (UNDP, 2011). The climate proofing of environmental infrastructures identifies the risks to the infrastructures as a consequence of climate variability and change, and ensures that those risks are reduced to acceptable levels through long lasting and environmentally sound, economically viable, and socially acceptable changes implemented at one or more stages of the project cycle: planning, design, construction, operation, and decommissioning. The possible approaches are mentioned below.

Research and development on climate projection: In the context of long-term climate change and infrastructure, decision makers should be aware of a range of emerging concerns. Relying on past records as an indication of the future is not a viable option. A sophisticated array of information with up-to-date scientific projections of how precipitation, temperature and wind patterns might change, will be necessary to inform and guide decisions concerning investment on infrastructure as well as decisions on management. This requires a research and development on projections of future climate at local scale of how precipitation, temperature and wind patterns might change, as this will influence the location and operations of infrastructure such as hydropower plants, roads, bridges, settlements and so on.

Climate responsive EIA: A possible approach in order to achieve climate proofing infrastructures could be the inclusion of climate change impact study as a part of the Environmental Impact Assessment (EIA) process by including an expert on climate change in the present panel of experts. Therefore, EIA can be strengthened towards climate change impact analysis so that they give adequate recognition to climate-related risks of the infrastructure project and also the effects of the project on climate-related risks.

Climate resilient building codes and standards: Government should define and enforce the appropriate building codes and standards intended to control aspects of the design, construction, materials, use and maintenance of infrastructure that are necessary to ensure human safety and welfare, including resistance to natural hazards and climate change. It will enhance the sustainability of infrastructures at risk to climate change. However, it will normally require an investment that is small relative to the additional maintenance and repair costs incurred over the

lifetime of the infrastructures. Even the retroactive climate proofing is likely to be considerably more expensive than that undertaken at the design stage of a project.

4.12 Gender and Social Inclusion

4.12.1 Impacts on Gender and Social Inclusion

Women and men have different and changing gender roles which are bounded with relations of unequal power. Women are often the primary users of water in domestic consumption, subsistence agriculture, health and sanitation. Power relations arise between the sexes, caste and gender roles in livelihood generation, influence vulnerability and adaptive capacity of individuals, households and communities, because women have less influence in decision making, less secure resource rights and are more likely to experience poverty and hence, gender and power dynamics are key concern areas influenced by exposure and adaptive capacity. The IPCC (2007) notes that: "Climate change impacts will be differently distributed among different regions, generations, and age classes, income groups, occupations and genders. The impacts of climate change will fall disproportionately upon developing countries and the poor persons within all countries, and thereby exacerbate inequities in health status and access to adequate food, clean water and other resources".

For gender and climate change discourse, the key issue is whether women and men are impacted by climate change in the same way or women and their specific concerns are left out. Because of this, the issue of gender and social inclusion is thus emerging as an important and extremely urgent aspect of climate change policy and programs, now becoming the focus of many international deliberations. Women's status and activities make them experience poverty differently from men, and they are often more vulnerable than men to climate change and its effects. Therefore, there is certainly a gender dimension to climate change (Denton, 2000). It is not only large-scale disasters that affect women's lives and livelihood. Other less dramatic problems might occur as a result of a heavy rainy season or a drought that would have a negative impact on women's daily roles and tasks, and thereby increase their burdens (Dankelman, 2010). Socially excluded groups, women and children are in a greater need of adaptation strategies with regard to turbulent weather patterns and consequent environmental phenomena, climate change may, in fact, worsen gender inequalities by creating extra work for women, and aggravating their vulnerability in poor and socially excluded households.

Climate change vulnerability impacts the following key areas which are an integrated and integral portion of the major developmental sectors of the nation that needs to be analyzed from gender and social inclusion perspective. An attempt has been made here to discuss climate change impact in different sectors and its vulnerability from Gender and Social Inclusion Perspective.

Agriculture and food security: According to census 2001, women contributing 60.5 % in agriculture production where they have only 10.83 % ownership on land in Nepal. Almost 90 percent of women producers have access to land as users but do not have the decision making power regarding what to grow, which land to allocate for which crops or what share of foods to be allocated for family consumption and access to other means of production.

Some of the major impacts of climate change on agriculture and food security reported are: i) crop failures and livestock deaths; ii) damage of crops by floods and drought; iii) food insecurity and malnutrition; iv) increased unemployment and rate of migration; v) decreasing seasonal labor in agriculture; and vi) over exploitation of natural resources, impairing livelihood of indigenous groups, specially fishermen/women, herb collector etc. These impacts have the following implications on GSI:

- Women often produce, process, manage and market vegetables and are also responsible for raising livestock. Crop failures and livestock death due to extreme climatic events cause women to sacrifice for her family by eating less, resulting in under-nourishment and putting the family at a greater risk of unmanaged resources.

- The marginalized or indigenous groups, particularly Majhi, Rautes, Chepang, Satar, are more vulnerable to food insecurity due to disasters like floods, landslides and fire.

- Women are compelled to consume less food due to food shortage which affect their health specially during pregnancy and lactating period

- Women have indigenous knowledge, skill and practice in production, seed preservation and other related activities. Due to harsh climatic condition they are losing their practices and skills.

Forest and biodiversity: Among the poor and marginalized people, women are highly responsible to manage the household need like fuel wood and water collection and fodder for livestock. Climate change vulnerability impacts on forestry seem additional burden in household activities for women because of their social and cultural roles and responsibilities towards families and communities.

Some of the noted climate change impacts on forest and biodiversity include: i) reduced and destroyed water sources in forest; ii) increased chance of prevailing insects and diseases; iii) change in plant behavior like early flowering and fruiting; iv) increased dryness, forest fire and increased soil erosion, landslides in fringe forests; v) decreased non timber forest product like fodder, medicinal plant, wildlife and wild food; vi) increased conflict among or between communities for forest products; and vii) reduced availability of small plant products such as herbs. Its implications on GSI are:

- Women often have to bear physical risks to collect water, fuel wood and fodder as they have to walk a long distance.

- Increased risks of livelihood of forest dependent indigenous people who depend on herbs and non timber products for their survival, especially wild food, water, fuel wood, fodder and herbs

- Women have very limited access to information and communication

- Policy/strategy formulation in the forest sector may neglect women's needs and interests.

Water and energy: Women are largely responsible for water collection in their family. Some of the impacts of climate change on water and energy sector are: i) decreasing groundwater and affect in availability of water; ii) low access of water and decreasing quality of drinking water; iii) worsening access to water supplies for agriculture production and livestock farming; and iv) increased variability and new climate floods and drought. As a result, the GSI aspects of these impacts are the followings:

- Women are primarily responsible for water use (cooking, health and hygiene, kitchen garden and livestock etc.). So, they have to walk long distances to collect water and fuel, exposing women and girls to harassment or sexual assault.

- **Increased work burden due to scarcity of water resources which results in increased physical and mental stress and reproductive health especially during the pregnancy and lactating period resulting in prolapsed uterus, incontinence of urine, infertility and abortion.**

- **Girls have to drop out of school to help gather fuel-wood and water, with long-term consequences for their education and future livelihood.**

- **The scarcity of water and energy often leads to conflict; as a consequence, the women may suffer from violence, anxiety and depression.**

- **There is an increased risk of water borne disease outbreak due to inadequate and safe drinking water. Evidences showed that around 70% of the disease burden occurs among the women and children and marginalized groups.**

Health: Women are more prone to malnutrition as they are the last to eat and are also the primary caretaker of children, sick, disabled and the elderly members of the family. Some of the impacts of climate change on human health are: declining water and air quality; increased risk of water borne and vector borne disease; social physical and mental stress and workload; cold and heat related injuries and respiratory illness (heat stress and heat waves); lack of access to health services during severe weather condition in rural communities; skin damage and skin cancer due to exposure to ultraviolet rays; and epidemic and outbreak of diseases.

Respiratory disorders and allergy problems, asthma and other respiratory diseases are more common in women, children and disadvantaged people. Likewise, increased work burden results in prolapsed uterus and other reproductive problems of women. Women are more exposed to agriculture, livestock, taking care of children, old age and sick and other household activities so they are prone to disease and other health related problems.

4.12.2 Efforts to Reduce Vulnerability

The tenth five year plan and three year interim plan have emphasized gender equality as a guiding principle for development. At the same time, natural disaster policies and the others that relate to climate change, and the responsible agencies, are not addressed in legislative and policy frameworks for gender, including the Law on Gender Equality.

Table 4-20: Progression of women inclusion in national periodic development plans

Plans	Development in Women Inclusion Aspect
6th periodic plan (1980-1985)	Conceptualization of women inclusion in development programs
7th periodic plan (1985-1990)	Active participation of women and quota for women, ensuring at least 10 percent of women participation
8th periodic plan (1992-1997)	Women specific sub-sector program (e.g., group formation, training)
9th periodic plan (1997-2002)	Women in decision making, post harvesting programs
10th periodic plan (2002-2007)	Gender mainstreaming through capacity building and entrepreneurship
Three year interim plan (2007-2010)	Inclusive development and targeted programs
Three year plan (2010-2013)	Inclusive development and targeted programs

4.12.3 Adaptation Measures

Gender and Social Inclusion (GSI) is a cross-cutting issue, and thus should be embedded in all sectoral adaptation action plans. Therefore, separate action plan for GSI with budget has not been proposed in this study for SNC. However, considering the importance of GSI in adaptation to climate

change, the following elements should be considered in the sectoral adaptation plans in order to ensure meaningful participation of women and socially excluded groups in the decision making in the meeting, campaign, training/workshop, interaction etc. as well as planning and implementation of adaptation activities.

Socio-Economy: Awareness raising and capacity building of community people from GSI perspective; promotion of GSI sensitive policies and programs, and to ensure women's ownership on land; promotion of social/financial safety nets (such as micro-credit facilities and services, health schemes, grain banks, livestock insurance); and promotion of GSI friendly infrastructure are some of the measures to adapt to climate change.

Technology: Adaptation measures include: introduction and promotion of women friendly and drudgery reducting tools and technology and agricultural extension services; promotion of women's indigenous knowledge, skill and practices for enhancing adaptive capacity; empowerment of women and socially excluded groups with knowledge, providing life skill trainings and equipments to cope with the weather related risks and hazards; and promotion of gender sensitive early warning and forecasting system and established relief or protective shelters after disaster.

Infrastructure: Structural measures which refer to physical construction to reduce or avoid possible impacts of hazards. This includes engineering measures and construction of hazard-resistant and protective structures or infrastructures like health service centers, rural road, relief shelters and other service centers for emergency need responses. Limited exposure to market and communication is crucial factor of vulnerability impact on women. Women's access to communication means and services increase their adaptive capacity.

4.13 Adaptation Action Plan

An adaptation action plan for major sectors has been prepared with clear distinction of responsibility among the relevant stakeholders, timeframe for fulfillment/implementation of the adaptation measures, financial means for implementation of the measures and identification of the possible barriers and risks. The action plan for each sector is given below.

Table 4-21: Adaptation action plan: Agriculture

S. N.	Adaptation Actions/Measures	Timeframe	Financial Means	Responsible Agencies	Potential Barriers and Risks
1	Development of drought resistant varieties				
	Identification of crops to develop drought resistant varieties	1 year	Government	NARC	Underutilized crops are likely to get ignored
	Screening of local varieties for drought resistant genomes	3 years	Government	NARC	Some crops like rice and maize have very large number of local varieties and variations
	Development of stress-tolerant crop varieties and identification of landraces tolerant to biotic and abiotic stresses	Continuous	Government	NARC	Varieties are domain-specific. Efforts are on but time taking. Scientists without enough motivation. Landraces have low productivity.
2	Development and extension of agronomic practices				
	Development of agronomic management practices for irrigation management	2 years	Government	NARC	Irrigation is not available for 46% of the farmland.
	Development of agronomic management practices for integrated plant nutrient management	4 years	Government	NARC	Limited access to chemical fertilizers limits the management
	Develop and standardize agronomic management practices for integrated pest management	1 years	Government	NARC	Organic pesticides are more costly and less effective than inorganic pesticides.
	Develop institutional strategy for technology demonstration	1 year	Government	NARC, DOA	Poor coordination between NARC and DOA limits this practice
	Demonstrations of stress reducing technologies	Continuous	Government	NARC+DOA	Technologies are agro-ecology specific. Detraction of youths from agriculture limits technology adaptation.
3	Extension of soil and water conservation technologies				
	Extension of sustainable agriculture soil and water conservation	10 years	Government	DOA	Insufficient number of technicians. Low level of training of village level workers.
	Developing legislation for cultivation of riverbeds and shrub lands	3 years	Government	DOA, MOFSC	Riverbed technology labour intensive. Not suitable for hills. Forest law is hurdle for shrub land cultivation.
4	Improvement in rangeland management and fodder production				
	Develop technologies for rangeland improvement and forage improvement and increased production of fodder and forage crops	5 years	Government	DOLS, MOFSC	Rangelands are less accessible. Secondary users of the forest excluded from community forest.

S. N.	Adaptation Actions/Measures	Timeframe	Financial Means	Responsible Agencies	Potential Barriers and Risks
5	Reducing heat stresses in livestock				
	Develop schemes for livestock shed improvement for reducing heat stress	3 years	Government	DLSO	Scattered livestock holding. Large number of less productive animals.
	Develop strategies for promoting alternate bio-energy using agricultural residues	2 years	Government	WECS, MOAD	No central agency with clear mandate. Scattered production of varieties of crop residues.
6	Disaster risk reduction				
	Train farmers in disaster risk reduction in agriculture	10 years	Government	MOAD, MOHA	High risks of disaster in agriculture. Uncertainly of the level of impact. Low resiliency of the poor community.

Table 4-22: Adaptation action plan: Water resources

S. N.	Adaptation Options/Measures	Time Frame	Financial Means (indicative)	Responsible Agencies	Potential Barriers & Risks
1	Promoting adaptation through implementation of water induced disaster management policy & plan	10 years	$ 20 million	DWIDP	Capacity development. Development of infrastructures.
2	Community-level disaster preparedness program	5 years	$ 10 million	DWIDP	Capacity development
3	GLOF monitoring and Disaster Risk reduction	15 years	$ 55 million	DHM, WECS	Inadequate Funding
4	Empowering Vulnerable communities through sustainable IWRM	15 years	$ 15 million	WECS, DOI	Insufficient and weak coordination among local communities
5	Develop and implement Watershed management policy and plan	15 years	$ 5 million	DSCWM	Mainstreaming climate change adaptation into key organizations
6	Integrate irrigation planning and management with agricultural development	15 years	$ 10 million	DOI, MoA	Coordination among line agencies. Mainstreaming climate change adaptation into planning and management.
7	Improve management of existing irrigation systems and implementation of alternative irrigation techniques	5 years	$ 25 million	DOI	Inadequate technical skills, operation and maintenance funds
8	Develop year round irrigation in support of intensification and diversification of agriculture	25 years	$ 25 million	DOI	Inadequate funds. Incorporation of climate change aspect in design of system
9	Improve ground water development/ management with legislative provisions	15 years	$ 10 million	DOI	Inadequate assessment
10	Develop multipurpose cost effective storage projects	25 years	$ 30 million	DOED, NEA	Funds and political instability
11	Program to improve power system planning	5 years	$ 5 million	DOED, NEA	Poor decision making capability
12	Extension of hydrological and meteorological networks of DHM in Himalayan, Bhabar and Terai belts.	5 years	$ 10 million	DHM	Inadequate human resources, operation and maintenance funds

Table 4-23: Adaptation action plan: Forestry sector

S. N.	Adaptation Options/Measures	Time Frame	Financial Means (indicative)	Responsible Agencies	Potential Barriers & Risks
1	Community based forest fire control: Preparing fire management plan as part of forest management plan and its implementation, including fire fighting equipments and training	5 years	$ 160,000	DOF/DNPWC	If forest fire is not detected in early stage, its control is not possible.
2	High altitude NTFP management	5 years	$ 160,000	DOF/DPR/DNPWC	Difficult to access the site and continue its management due to harsh climatic conditions. Natural physical damage such as wind and snow.
3	Terai wetland management	5 years	$ 140,000	DOF /DNPWC	
4	Integrated forest management in Churia	5 years	$ 280,000	DOF and/or DSCWM	
5	Forest management for water	5 years	$ 280,000	DOF	It is new activity for Nepal. Will be more challenging in the beginning.
6	High altitude range land conservation	5 years	$ 180,000	DOF and/or DOLS	Difficult to access the site and continue its management due to harsh climatic conditions. Natural physical damage such as wind and snow.
7	Management of birch forest to reduce encroachment by fir. This will include preparation of conservation plan and its implementation in pilot sites.	5 years	$ 110,000	DOF and/or DNPWC	Difficult to access the site and continue its management due to harsh climatic conditions. Natural physical damage such as wind and snow.
8	Conservation of forests with lichens through reduce interference	5 years	$ 110,000	DOF and/or DNPWC	Difficult to access the site and continue its management due to harsh climatic conditions. Natural physical damage such as wind and snow.

Note: The above estimates are tentative only. These costs can be many fold more depending upon number of sites. The cost will also depend upon size of the site. DOF: Department of Forest, DSCWM: Department of Soil Conservation and Watershed Management

Table 4-24: Adaptation action plan: Public health

S.N.	Adaptation actions/measures	Time frame (years)	Financial Means (US$)	Responsible Agencies	Potential barriers and risks
A	Extreme weather heat wave and cold wave				
	<u>Personal level</u>				Resource and technical knowledge. Implementation of urban housing standard (lack of rural housing standard).
	Aware about the heat stress and cold stress	3	300,000	NHEICC/FCHV	
	IEC materials	Interruption			
	Improvement in indoor environment during extreme cold and heat	5	1,300,500	DUDBC	
	Warm environment and warm cloths	2			
	<u>Community Level</u>				Resource
	Awareness	5	1,000.000	NHEICC	
	More greenery/shading	5	5,000,000	Municipality, DDC/ VDC	
	<u>Policy level</u>				Resource
	Implementation of housing standard	2		DUDBC	
	Working environment standard	3		MPPW	
	Occupational safety	2	100,000	MoHP	
	Effective surveillance mechanism	3			
B	Diarrheal disease				
	<u>Personal level</u>				Resource, technology, and knowledge
	Water quality management – point of use and source protection,	5	5,000,000	DWSS	
	Enforcement of drinking water quality and wastewater quality standard	5	50,000,000	DWSS/WASH	
	Support community led total sanitation for declaring open defecation free area (ODF)	3	1,000,000	DWSS, NHEICC	
	Enable sustainable, massive and effective critical hand washing Program	3	1,000,000	NHEICC/DWSS	
	Improve personal hygiene and sanitation				
	<u>Community level</u>				Resource, technology, and knowledge
	Water source protection	5	5,000,000	DWSS, MLD	
	Water supply improvement	5	5,000,000	DWSS	

S.N.	Adaptation actions/measures	Time frame (years)	Financial Means (US$)	Responsible Agencies	Potential barriers and risks
	Implementation of community led total sanitation for declaring open defecation free area (ODF)	5	10,000,000	DWSS/WASH	
	Awareness program on water sanitation and hygiene	3	100.000	DWSS/NHEICC	
	Advocacy	3	10,000	DWSS/NHEICC	
	<u>Policy level</u>				Resource, technology, and knowledge
	Implementation of WASH program throughout the country	5	10,000,000	DWSS	
	Enforcement of awareness program	3	50,000	DWSS/NHEICC	
	Monitoring and evaluation of WASH program	5	50,000	MoHP	
	Water quality surveillance as per the National Drinking Water Quality Standard 2005	5	1,000,000	MoHP	
C	Vector borne disease				
	<u>Personal level</u>				
	Keeping nets in windows and doors	5	1,000,000	Personal level	Resource – financial, technical, human
	Awareness on the biting time of the mosquitoes and precautionary measures	3	50,000	NHEICC	
	Environmental sanitation	3	1,000,000	DWSS/WASH	
	<u>Community level</u>				
	Strengthen sanitation program	5	5,000,000	DHO/DPHO	Resource – financial, technical, human
	Effective awareness programs	3	3,000,000	MPPW, MLD,	
	Facilitation on early diagnosis and treatment	3	10,000	MOE and MOHP, other stakeholders	
	Reduce the stagnant water bodies/vector breeding area	5	5,000,000		
	Environmental friendly ways to eradicate the vectors –larva	5	1,000,000		
	Waste water management comply with the national standard provided	3	5,000,000		
	<u>Policy level</u>				Resource. Challenge in the implementation.
	Integrated management plan for control of vector borne disease	2	1,000,000	MOHP	
	Enforcement for compliance with policy, acts and rules	1	50,000	DoHS/EDCD, DP/HO	
	More emphasis on surveillance of vectors and diseases	2	1,000,000	DP/HO	

Table 4-25: Adaptation action plan: Climate induced disaster

S.N.	Adaptation Options/Measures	Time Frame (years)	Financial Means (indicative) (US$ million)	Responsible Agencies	Potential Barriers and Risks
1	Community-based disaster management	6	60	MOHA, MOSTE, MOLD, MOPPW, MOI, DHM, DWIDP, local bodies	Finance, availability of technology, public participation
2	GLOF monitoring and disaster risk reduction	5	55	MOE, DHM	Finance, availability of technology and capacity of DHM
3	Public awareness	5	2.5	MOHA, MOE, MOFALDLD, MOPPW, MOI, DHM, DWIDP, local Bodies	Finance, capacity of GOs and NGOs
4	Strengthening capacity of concerned governmental and non-governmental agencies	5	2.8	MOE, MOHA, MOI, MOFALD, MOPPW, DOI, DOR, DHM, MOFSC, MOEd, MOH, MOAD, DWIDP, DOE, DOH, local bodies	Finance, capacity of training institutions
5	Hazard /vulnerability Mapping and Zoning	5	2	MOI, DWIDP	Finance, technical capacity of DWIDP
6	Strengthening early warning system and forecasting	10	12.5	MOE, MOI, DHM, DWIDP	Finance, availability of technology, number of hydro-meteorological stations, technical capacity of DHM
7	Reforestation/afforestation program including bio-engineering techniques	10	23	MOFSC, MOFALD	Finance, people's participation
8	Improvement of degraded land	15-20	23	DOFS, DWSC	Finance, people's Participation
9	Development of crops and promotion of agriculture practices	10	12.5	MOAD, DOA	Finance, development of new practices
10	Crop and livestock Insurance	5	1	MOAD, DOA, DOLS, insurance companies	Finance, willingness of farmers and insurance service providers
11	Implementation and promotion of water harvesting system and conservation ponds	5	28	MOI, MOFALD	Financial capacity and awareness level of people and local bodies
12	Conservation of Churia/ Siwalik regions	15-20	62	MOFSC, MOFALD, DOF, Local Bodies	Finance, promotion of conservation practices, public participation
13	Implementation of structural measures	15-20	25	MOPPW, MOI, MOFALD, MOEd, MOH, DOI, DWIDP, DOR, DOE, DOH, local bodies	Finance, availability of technology, technical capacity of concerned agencies
14	Resettlement of the vulnerable communities	15-20	12.5	MOHA, MOFALD, local bodies, DAOs	Finance, participation of people and local bodies

Table 4-26: Adaptation action plan: Human settlement

S. N.	Adaptation Options/Measures	Time Frame (years)	Financial Means (indicative) (US$ million)	Responsible Agencies	Potential Barriers and Risks
1	Formulate human settlement development strategy and policy with due consideration of climate change	5	0.5	MOAD, DOA, DOLS, MOFSC, NPC, MOWPP,	Finance, political consensus, political commitment,
2	Improve settlement quality	20	40	MOWPP, MOFALD	Finance, political consensus/ stability, political commitment
3	Formulate and implement resettlement plan for the vulnerable settlement	20	50	MOWPP, MOFALD	Finance, political consensus/ stability, political commitment,
4	Construct modern infrastructures such as roads, streets, avenues, boulevards and expressways	20	60	MOWPP, MOFALD, DOR,	Finance, political consensus/ stability, political commitment,
5	Protect and conserve built-up heritage and develop viewpoints over admirable landscapes	5-15	20	MOAD, DOA, DOLS, MOFSC, NPC, MOWPP,	Finance, political consensus/ stability, political commitment,
6	Formulate and enforce infrastructure codes incorporating climate change dimension	5	0.5	MOAD, DOA, DOLS, MOFSC, NPC, MOWPP,	Finance, political consensus, political commitment,

Chapter 5

Technology Transfer and Development

5.1 Background

With the support of the UNEP acting as the Implementing Agency (IA) of the Global Environment Facility (GEF), the Ministry of Science, Technology and Environment (MOSTE) has prepared Technology Needs Assessment (TNA) as a part of the activities included in the UNFCCC. One of the components of the TNA was to identify, analyze, and prioritize technology needs, which can form the basis for a portfolio of environmentally sound technology (EST) and projects and programs to facilitate the transfer of, and access to, the ESTs and know-how in the implementation of Article 4.5 of the UNFCCC. Under Article 4.5, Annex I Country Parties have an obligation to support and facilitate development and transfer of environment- friendly technologies to Non-annex I Country Parties. The UNFCCC has developed a framework for meaningful and effective actions to enhance the implementation of Article 4.5 of the Convention since 2000.

Technology transfer encompasses the broad set of processes that cover the flow of knowledge, experience, and equipment for mitigating and adapting to climate change among different stakeholders. These include governments, international organizations, private sector entities, financial institutions, NGOs and research and/or education institutions (IPCC 2002). Technology does not only refer to the application of science and scientific methods and machines as most people often think of. The term ‘techno’ also refers to “art, skill and craft”. Thus, the term technology in the SNC includes not only scientific knowledge and applications such as machines, infrastructure and equipment but also the art and management such as domestic wisdom and practices.

Technology transfer is an important mechanism to assist Nepal in addressing climate change. Nepal is using both traditional (indigenous) and modern technologies to address climate change.

5.2 Indigenous Knowledge, Skill, Technologies and Practices in Reducing Climate Change Risk

Climate Change poses a great threat to many indigenous and marginalized societies due to their continuing reliance upon resources-based livelihoods. Indigenous people, who are vital and active parts of many ecosystems, are often found helping to enhance the resilience of ecosystem by interpreting and reacting to the climate change impacts in creative ways, drawing on traditional knowledge as well as new technologies to find solution which helps the society at large to cope with the impending changes (Jan and Anja, 2007). This is true in Nepal's case as well.

Indigenous agriculture practices: Indigenous coping strategies range from simple methods such as maintaining hardy wild foods (e.g. consumption of wild fruits and vegetables that survive during droughts) to more complex methods of reducing grain staple, mixed land use, intercropping and mixed cropping and agro-forestry system. Indigenous agriculture techniques commonly include many different varieties of crops even in non-crisis times. If a crisis occurs, new crop varieties or species are planted, and unusual resources are harvested. Diversity in the crops and food is often matched by similar diversity in field location.

Local varieties, which are highly acclimated to withstand harsh climate, is one innovative strategy. Farmers in the mountainous region are now taking advantage of higher temperature to try crops like corn and vegetables, which would not have been possible without the use of greenhouses (Manandhar et al., 2010; Chapagain, Subedi and Paudel, 2009; and Tiwari, et al., 2010). Likewise, Tharu farmers in the plains of Nepal are replacing rice crops with sugarcane to cope with uncertain rainfall.

Traditional knowledge against erosion control in terraced fields are practiced by farmers in Eastern Nepal by building dams to control water flow. In the mountainous regions of Nepal, sloping lands are ploughed, following a bottom-to-top approach in a sword-like pattern to check sudden runoff and to minimize soil erosion.

Indigenous soil fertility management practice: Indigenous farmers often classify soil on the basis of color, texture, fertility and other physical properties. Production of farm yard manure, green manure, and in-situ manure, use of nitrogen fixing plants, crop rotation, fallowing, slash and burn technique, use of forest soils and black soils, burying of dead animals are some of the common indigenous techniques for soil management in Nepal. Using bio-fertilizer also helps in maintaining soil fertility.

Indigenous water resource management practices: Examples of indigenous knowledge and technology on water resource management include underground canals, water storage by tank system, and water transfer by gravity. The art of rainwater collection has been practiced in Nepal since ancient times, whereby a small pond is built nearby the house for storing waste water, which later is used for watering the kitchen garden or watering the cattle.

Parallel water diversion from the same stream at different elevation along the slope is a popular method of water delivery in the hills of Nepal. Farmers often design and construct channel head diversion using simple technologies and locally available materials, preferably bamboo and shrubs. However, where sources of water are available, a bamboo split and a drain, locally called *kulo*, is used to carry water by gravity as a method of water abstraction. Use of loose boulders to reduce cutting effects of streams locally called *bhakari* is used by farmers in the hills to protect their paddy fields. Appropriate tree species are grown along the river bank, which act as buffer to improve the quality of river water.

Traditional water mill (*pani ghatta*) used for grinding wheat, maize, millet etc. is a fine example of indigenous technology.

Indigenous forest management practice: Ban on cutting certain type of trees on religious beliefs, and declaring certain species as scared species help in maintaining ecosystem health and to cope with unpredictable climates. Local people also have special knowledge of varieties of trees that can resist drought and extreme heat. Agro-forestry is one of the practices found very effective in carbon sequestration.

Indigenous pest management practices: Indigenous people often use locally available plant materials for pest management. Instead of using pesticide, the use of *titepati* juice, *neem* powder, ash, or oilcake can effectively safeguard crops from pest attack. Traditionally, the drying of maize cobs was done by keeping them on the top floor where kitchen heat would be available.

Studies on Indigenous Knowledge, Skill, Technologies and Practices

Government of Nepal has prepared a draft on National Legislation 2002 regarding biodiversity and traditional knowledge (access to genetic resource right and benefit sharing). IUCN Nepal has completed community registration and documentation program on traditional knowledge about biodiversity in more than 20 districts in historical territories of indigenous people. International Centre for Integrated Mountain Development (ICIMOD) World Wildlife Fund (WWF) and several NGOs are working with indigenous people in the field of conservation, climate change, sustainable development and sustainable livelihoods of people.

A research report prepared by WWF Nepal on understanding indigenous people's perception on climate change impact on floral and faunal species in the Kanchenjunga-Singalia complex (Eastern Nepal) examined ways by which indigenous people perceive climate change impacts on natural resources, assessed the effect of climatic parameters on livelihood of the people and identified indigenous people's adaptation and mitigation strategies. Likewise, Livelihoods and Forestry Program prepared a report titled Practice of Community Adaptation to Climate Change: A Case of Community Forestry User Groups of Nepal, which dealt with various indigenous adaptation practices.

Reasons for Integrating Indigenous Knowledge in Climate Change Adaptation Policy

There are number of reasons for integrating indigenous knowledge in climate change adaptation policy is a logical act. The reasons can be summed up as follows.

- Indigenous knowledge is a powerful asset in many developing countries. Such knowledge is widely acceptable in the long run.
- Indigenous coping strategies often resemble scientific methods due to the reliance on systematic observation of natural phenomenon.
- Indigenous technology in climate change adaptation plans fits well in the framework of sustainable development with the 3E criteria – environmentally sound, socially equitable and economically efficient.
- Indigenous knowledge is generally user-friendly.

5.3 Status of Technology Use in Climate Change Adaptation

5.3.1 Water Resources

Despite the fact that Nepal is rich in water resources, the problem with this vast resource is "too much and too little". This means the temporal and spatial variability on the availability of water resources highly varies. Almost 80 % of the precipitation is received only during monsoon season while the remaining eight months receive only the remaining 20 % of precipitation. The situation is further exacerbated by the current climate change. This ultimately results into higher degree of chances for flood and landslides including drought events. Similarly the balance between water availability and water supply cannot be met leading to water scarcity. At such condition, wise use of available water and preparing for the water induced disasters are the only reliable answers to the problems of water in the context of Nepal.

In this context, the available technologies that fit best to overcome the burgeoning pressure of climate change can be categorized as water conservation, preparation of extreme weather events and diversification of water supply. Existing technologies in this area are listed below.

Water conservation: Increasing the use of water efficient fixtures and appliances e.g. drip irrigation, sprinkler irrigation; leakage management e.g. detection and repair in canal/pipe system.

Preparation of extreme weather events: Bio-engineering; flood forecasting system; bore holes as drought intervention; use of permeable spurs.

Diversification of water supply: Rain water harvesting from roofs; water reclamation and reuse.

5.3.2 Agriculture

Despite the fact that almost two-third population is involved in agricultural practices, the commercial farming system is yet to flourish. Subsistence farming is more in common. Fulfillment of water requirement for crop production is mainly based on the rainfall with only 17 % of cultivated area receiving year round irrigation. The fulfillment of water demand for crop cultivation under dire climatic variability is possible only with the water conservation measures (as discussed in water resources sector). In such situation, the technology requirement can be assessed based on two priorities namely resource management and niche-based farming.

Resource management: Integrated farming systems (IFS)-crop and livestock; minimum tillage; biochar.

Niche-based farming: Organic nutrient management; stress-tolerant crops and varieties; poly-cropping.

5.3.3 Public Health

Access to safe and clean drinking water is the indicator of the development status of the country and this directly links with the health status of the citizens. Majority of the rural areas are in the shadow of the health facilities as the full health services are mainly city centered. Efforts have been made to improve and increase the access of people to health support centers, however, the development has not been sufficient.

Water borne diseases: Healthcare liquid waste management; drinking water quality surveillance; water and sanitation (WASH) practice.

Vector borne diseases: Mosquito nets; bacillus thuringiensis israeliensis (Bti); breeding area reduction.

5.4 Technology Prioritization in Adaptation Sector

5.4.1 Criteria for Technology Prioritization

An expert panel selected by MOSTE identified a set of criteria for assessing priority adaptation technologies in each sector, including cost (capital, operation and maintenance) and benefit (environmental, social and economic). In each sector, technologies were scored and weighted for each criterion and arranged in priority order. The more the point, higher the rank was.

5.4.2 Technology Prioritization for Water Resources Sector

Based on prioritization criteria, sprinkler irrigation was ranked as first priority, followed by borehole/tube well irrigation, and leakage management under irrigation subsector. Similarly, flood forecasting and warning was ranked first in water resources subsector, followed by bioengineering and permeable spurs.

Table 5-1: List and assessment of prioritized adaptation technologies in water resources sector

Availability/ Scale	Technology	Adaptation Potential in 20 Years	Estimated Investment Cost
Short-term/ Small-scale	Sprinkler irrigation	High	US$ 600-US$2500/ha (depending on the type of materials used and the amount of labor contributed by rural producers)
Short-term/ Medium-scale	Flood forecasting and warning	High	US$ 125000/basin (for basin size<1000sq km, however the cost differ widely depending on the level of sophistication of monitoring and forecasting technologies.

Sprinkler Irrigation

Technology description: Sprinkler Irrigation is a method of applying irrigation water which is similar to rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air and irrigated entire soil surface through spray heads so that it breaks up into small water drops which fall to the ground. Sprinklers provide efficient coverage for small to large areas and are suitable for use on all types of properties. It is also adaptable to nearly all irrigable soils since sprinklers are available in a wide range of discharge capacity.

Contribution to adaptation: This technology is very important at the brink of climate change as it utilizes the water resources effectively and efficiently. It is for almost all field crops like wheat, gram, pulses as well as vegetables, cotton, soya bean, tea, coffee, and other fodder crops. The most important thing about this technology in relation to country's physiography, it can be used in sloppy hill areas as well where less water can irrigate the field with effective utilization of fertilizer and soil.

Flood Forecasting and Warning

Technology description: It involves the detection of the flood warning level in the upper basin which triggers either the siren or alarm message to the authorized personnel of the basin such that preparedness activities can be initiated in advance to mitigate the losses of lives and properties. In this technology, telemetric system is involved in which the water level in the river is continuously measured with battery fed detecting instruments. This type of technology is beneficial in basins where rainfall – runoff relationship has been established and flood danger level has been assessed. Once these information are available, flood forecasting can be issued for timely alert.

Contribution to adaptation: With increase in the extreme precipitation events, there is greater possibility of weather induced floods and resulting losses of lives. In today's context, 29 % of total loss of lives and 43 % of total loss of properties account to water induced disasters alone. Hence this technology can be added advantage in adapting to the burgeoning impact of climate change on flood events and save the essential lives.

5.4.3 Technology Prioritization for the Agricultural Sector

Based on prioritization criteria, minimum tillage was ranked as first priority followed by integrated farming systems and biochar under resource management subsector. Similarly, organic nutrient management was ranked 1st followed by cultivation of stress tolerant crops/varieties and mixed cropping system in niche based farming subsector.

Table 5-2: List and assessment of prioritized adaptation technologies in agricultural sector

Availability/ Scale	Technology	Adaptation Potential in 20 Years
Short-term/ Small-scale	Minimum tillage	High
Short-term/ Small-scale	Organic nutrient management	High

Minimum Tillage

Technology Description: Minimum tillage is a method aimed at reducing tillage to the minimum necessary for ensuring a good seed bed, rapid germination, satisfactory stand and favorable growing condition. It denotes the reduction of number of operation by planting directly after harrowing without any other soil related activities (such as deep ploughing) which are usually carried out to give a fine seed bed. The technology is imperative as it increases organic carbon and improves soil structure. Besides hydraulic conductivity of soil is enhanced and thus infiltration of soil. It also reduces soil compaction.

Contribution to adaptation: As the technology itself requires less human power and provides better yield than other conventional approaches, it can improve the adaptive capacity efficiently. Besides the technology reduces the risk from drought, minimizes tillage cost and limits soil erosion.

Organic Nutrient Management

Technology description: Organic agriculture/farming is a system of agriculture that encourages healthy soils and crops through such practices as nutrient recycling of organic matter (such as compost and crop residue), crop rotations, proper tillage and the avoidance of synthetic fertilizers and pesticides (IASA, 1990). Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 2008). As stated in the 2002 report of FAO, organic agriculture enables ecosystems to better adapt to the effects of climate change.

Contribution to adaptation: This technology emphasizes closed nutrient cycles, biodiversity and effective soil management providing the capacity to mitigate and even reverse the effects of climate change. Besides this, organic nutrient management decreases fossil fuel consumption by 33% and carbon sequestration takes CO_2 out of the atmosphere acting as the most effective strategies for mitigating CO2 emissions.

5.4.4 Technology Prioritization for Public Health Sector

Based on prioritization criteria, drinking water quality surveillance was ranked 1st priority followed by healthcare liquid waste management (HCLWM) and WASH under diarrheal disease subsector. Similarly, Bti was ranked first followed by reduced stagnant water bodies and then mosquito nets under vector borne disease subsector.

Table 5-3: List and assessment of prioritized adaptation technologies in public health sector

Availability/ Scale	Technology	Adaptation Potential in 20 Years	Estimated Investment Cost
Short-term/ Small-scale	Drinking Water Quality Surveillance	High	US$50,000 (in 5 districts)
Short-term/ Small-scale	Bti	High	

Water Quality Surveillance

Technology description: At national level water quality contamination is very common throughout the year and intensity of contamination is higher during monsoon period. Diarrheal epidemics occur every year in some parts of the county. National water quality standard with 27 parameters are available. MOHP is responsible for drinking water quality surveillance as per the drinking water quality standard 2005. For water quality surveillance, laboratory, equipments and trained human resource for analyzing all the required parameters at district level are required. The absence of drinking water quality surveillance at district level is due to lack of resources and laboratory.

Contribution to adaptation: Climate change is being experienced by the weather extremities especially temperature changes. The water resources are directly or indirectly affected by climate change which has been seen in decrease in water quality and quantity of the existing water supplies. On the other hand this changed temperature is very much favorable to the aquatic microorganisms to replicate faster and to enhance their virulent effects as water borne diseases to human beings. Water quality surveillance is an assessment tool concerned with the water quality supplied by the government to the people has complied with the National water quality standards or not. If it has not complied with the national standard then no doubt the diarrheal disease will always be in increasing trend.

Bacillus thuringiensis Israelensis (Bti)

Technology description: Bacillus thuringiensis (Bt) is a naturally occurring bacteria in the soil throughout the world. It is one of the microbial insecticides used in widespread. The strain of Bacillus thuringiensis israelensis (Bti) has been isolated to kill mosquito larvae. Bti acts on the mosquito larvae by producing proteins that reacts with the cells of the gut lining of susceptible insects and paralyzes the digestive system of the infected insects stopping feeding within hours and ultimately die. To control mosquito larvae, Bt formulation containing israelensis strain are placed into the standing water of mosquito breeding sites. For these applications, Bt usually is formulated as granules or solid, slow-release rings or briquettes to increase persistence. The quantity of Bti use is determined by the size of the water body.

Contribution to adaptation: Vector borne disease is climate sensitive disease. Despite the government's multiple efforts of curative and preventive measures such as treatment, insecticide spray, insecticide impregnated bednets etc., the types, coverage and mortality and morbidity due to vector borne diseases are in increasing trend. The Bti is an environmental friendly technology. Unlike most insecticides, Bt do not have a broad spectrum of activity, so they do not kill beneficial insects. Therefore, Bt integrates well with other natural controls. Bt is essentially nontoxic to people, pets and wildlife. It is well tested and more than two decades global experience of assessing its effectiveness.

5.5 Current Status of Technologies in Climate Change Adaptation Sectors

5.5.1 Energy Sector

In the energy sector, the status of technologies use in climate change adaptation can be summed up as follows.

Improving energy efficiency: Improved cooking stove (mud, metallic); metallic stove (with Space Heating); metallic stove (without space heating); energy efficient appliances; use of white LED for lighting.

Renewable energy: Electrical cooking; solar water heating; biogas for cooking; briquette; induction cooker/ hot plate cooker; solar PV for lighting.

5.5.2 Agricultural Sector

In the agricultural sector, the status of technologies use in climate change adaptation can be summed up as follows.

Livestock sector: Molasses-urea block; ammonia treatment of straw; straw silage; providing mineral blocks/MNB; chemical/mechanical feed treatment; diet quality and nutrient balance; selective breeding; modified rumen bacteria.

Rice cultivation: Fertilizer and manure management; alternate wetting and drying (AWD) technology; nitrification inhibitors- nimin application; tillage technology; mid-season water drainage; agriculture biotechnology; and selection of drought and flood tolerant varieties.

5.5.3 Forestry sector

Forest protection and management: Forest protection; improvement of harvesting techniques; improvements in the product conversion and utilization efficiency.

Sink enhancement: Analog forest; reforestation; afforestation; agro-forestry; urban forest; REDD.

C-substitution: Co-generation or gasification technology; biogas.

5.6 Technology Prioritization for Mitigation Sectors

5.6.1 Criteria of Technology Prioritization

The expert group agreed on a set of criteria for assessing priority mitigation technologies in each sector, including: cost (capital, operation and maintenance) and benefit (environmental, social and economic). In each sector, technologies were scored and weighted for each criterion and arranged in priority order. The more the point was, the higher was the rank.

5.6.2 Technology Prioritization for Energy Sector

Based on prioritization criteria, solar water heater for space heating was ranked as first priority followed by electric cooking stove, Biogas technology, improved cooking stove (mud and metallic) and bio-briquette for cooking and space heating under Residential subsector. Similarly, rapid transit (electrical train) was ranked first followed by bus rapid transit and biodiesel under transport subsector.

Table 5-4: List and assessment of prioritized technology in the Energy sector

Availability/ Scale	Technology	Mitigation Potential	Estimated Investment Cost in USD
Short-term/ Small-scale	Electric cooking stove	316.3	963
Short-term/ Small-scale	Biogas	54	111
Short-term/ Small-scale	Bus rapid transit	2.41	100

Table 5-5: Relevance of the prioritized technologies to the existing policy and strategies

National Initiatives	Strategies and Measures	Selected Technology	Objectives
Promotion of the Improved Cooking Stove (ICS) Nepal	Promotion of 24,000 mud improved cooking stoves (ICS) in Terai region and 3,000 metallic improved cook stove (MICS) in high hill region annually	Metallic cook stoves	To improve the energy efficiency, utilization of by-products
Establishment of Biogas Support Program (BSP) Nepal	Promotion of 25,000 biogas plant annually, BSP implementation (capacity building, promotions, data base management, quality control etc.)	Biogas for cooking	energy security, utilization of local resources
Vehicles and Transport Management Act	26-36 passengers including driver according to transport size.	Bus rapid transit	To move towards mass transportation and for energy efficiency

<u>Solar Water Heater for Space Heating</u>

Technology description: Solar water-heaters for domestic use are low-temperature devices that heat water up to 65 degrees. The average efficiency is 30 %, which depends on the materials used to make the collectors, coils and insulators. Copper sheets and pipes, and good insulators like glass-wool and thermocol, can push efficiency up to 40 %, while aluminum sheets and GI pipe can lower it to 20 %.

Contribution to mitigation: Along with the flourish of tourism industry, the existing utilization of fuel wood for space heating has increased into greater folds and thus the consumption of fuel woods. Hence the technology can be the added value being the clean energy with no additives of GHGs.

<u>Electric Cook Stove</u>

Technology description: Electric cook stove is comparatively new in Nepal. Classic stoves with coil elements and induction stoves are popular in Nepal. With a coil element stove they produce the heat that gets transferred to the pot, pan, cooker etc. and then to the contents of those, with induction it the other way around. When cooking on an induction stove, the pot or pan is the one generating the heat.

Contribution to mitigation: This is the cleanest form of energy that is imperative in the current anthropogenic climate change as electric source do not emit any forms of GHGs. Besides, it has potential to reduce the consumption of fuel woods as the residential sector highly consumes it mainly for cooking.

<u>Electric Train</u>

Technology description: Electric rail is a form of urban public transportation which generally has a lower capacity and lower speed than heavy rail and metro systems, but higher capacity and higher speed than traditional street-running tram systems. The term is typically used to refer to rail systems with rapid transit-style features that usually use electric rail cars operating mostly in private rights-of-way separated from other traffic but sometimes, if necessary, mixed with other traffic in city streets

Contribution to mitigation: Electric trains have zero tailpipe exhaust emissions.

Bus Rapid Transit System

Technology description: A bus rapid transit system (BRT) is a high-capacity transport system with its own right of way, which can be implemented relatively at low cost. It is a key technology in cities in developing countries, which can change the trend of modal shifts towards more private vehicles and public transportation, thereby bringing about a range of benefits, including reduced congestion, air pollution and GHGs and better service to poor people.

Contribution to Mitigation: Reduced GHGs pollution.

5.6.3 Technology Prioritization for Forestry Sector

In forestry sector, based on prioritization criteria, silviculture was ranked as first priority followed by short rotation forestry, agro-forestry, forest protection and enhanced natural regeneration.

Table 5-6: List and assessment of prioritized technology in the forestry sector

Availability/ Scale	Technology	Mitigation Potential in 20 Years	Estimated Investment Cost in USD/tCO_2
Long term/ small scale	Silviculture	1413	0.77
Long term/ short scale	Short rotation forestry	750	0.56

Table 5-7: Relevance of prioritized technology with the existing policy

National Initiatives	Strategies and Measures	Selected Technology	Objectives
Strategy for Land use and Land use change: ▪ Implementation of sustainable agriculture	▪ Promote agro forestry ▪ Promotion of organic farming	Silviculture	▪ Maintaining carbon stock in the future
Reduced deforestation and degradation of forest (REDD) strategy: ▪ Community forestry user groups ▪ Market based mechanism to reward forest conservation ▪ Stringent measures to curb deforestation	▪ Afforestation program ▪ Sustainable use of forest ▪ Annual growth targets ▪ Standard data bank ▪ Severe punishment	Short rotation forestry	▪ Increasing carbon sequestration ▪ Maintaining carbon stock in the future

Improvement of Harvesting Techniques (Silviculture)

Technology description: Silviculture system could be broadly divided into two systems, i.e. selection system (polycyclic) and shelter wood systems (monocyclic). The Selection System aims to keep all-aged stands through timber cuttings at shorter intervals. Many light cuttings are made. Seedlings will become established in small gaps. Under this system, two or more intensive harvests are possible during one rotation. The selective cutting of exploitable trees is done over an area at periodic intervals. The shelter wood system is introduced usually when it becomes necessary to harvest more intensively and regeneration is not assured under the selection system. Basically, the shelter wood system attempts to produce a uniform crop of trees from young regeneration through both heavy harvesting and broad Silviculture treatments. A new even-aged tree is established by applying preparatory and establishment cuttings to natural regeneration (i.e. seedlings and saplings) of the desired trees. At an appropriate time the remaining over-storey is removed.

Contribution to mitigation: It has mitigation potential of 49 tC/ha.

Short Rotation Forestry

Technology description: Short rotation forestry (SRF) consists of planting a site and then felling the trees when they have reached a size of typically 10-20 cm diameter at breast height (see http://www.biomassenergycentre.org.uk). Depending on tree species this usually takes between 8 and 20 years, and is therefore intermediate in timescale between SRC and conventional forestry. This has the effect of retaining the high productivity of a young plantation, but increasing the wood to bark ratio. It is currently proposed that the stem wood only would be removed from the site, with bark stripped during harvesting and left on site with other residues to return nutrients to the soil.

5.6.4 Technology Prioritization for Agriculture Sector

Based on prioritization criteria, urea molasses multi-nutrient block (UMMB) was ranked as first priority followed by use of local crop residue for feeding ruminants (LCR) under livestock management subsector. Similarly, alternate drying and wetting (ADW) in rice cultivation was ranked first followed by direct seeding in rice (DSR) cultivation under rice cultivation subsector.

Table 5-8: List and assessment of prioritized technology in the agriculture sector

Availability/ Scale	Technology	Mitigation Potential	Estimated Investment Cost in USD
Short-term/ Small-scale	Urea molasses multi-nutrient block (UMMB)	14(kg/head/yr)	43.8($/head/yr)
Short-term/ Small-scale	Alternate drying and wetting (ADW) in rice cultivation	11.67 tCO_2/yr	7.378($/$tCO_2$)

Table 5-9: Relevance of the prioritized technologies with the existing policy

National Initiatives	Strategies and Measures	Selected Technology	Objectives
Agriculture Perspective Plan	▪ Development of overall economy ▪ Commercialization of agriculture	Urea molasses multi-nutrient block (UMMB)	▪ Contribution to GHG mitigation ▪ Improvement in productivity
		Alternate drying and wetting (ADW) in rice cultivation	▪ Contribution to GHG mitigation ▪ Utilization of local resources ▪ Improvement in productivity

Urea Molasses Multi-Nutrient Block (UMMB)

Technology description: UMMB is a special preparation (15 part urea, 28 part molasses, 40 part bran, 1 part salt and 4 part lime) made into blocks of two kg weight. This type of block, upon feeding, has been proven to increase the milk production and reduce methane emission. This is a cost-effective feeding strategy and is being used by the farmers in Chitwan and Nawalparasi districts. Recently NARC has developed the equipment to produce UMMB and is being distributed to the District Livestock Service Offices and NARC stations. This may bring about economic and social co-benefits, particularly for the rural poor. The main barriers are the unavailability of the raw materials, time-taking preparation process, and lack of proper extension of this technology with appropriate modification according to the location in terms of its ingredients.

Contribution to mitigation: It has mitigation potential up to 14kg/head/yr along with increase in feed conversion efficiency, 25% increase in milk yield, CH_4 reduction by 27% and increase in animal productivity by 60%.

Alternate Drying and Wetting (ADW) in Rice Cultivation

Technology description: Water management is one of the most confounding factors affecting methane emission. The average emission in saturated soil was found to be 0.3 to 0.6 kg/ha/day while in intermittent wetting and drying it was 0.1 to 0.4 kg. Intermittent irrigation is an option for minimizing CH_4 emission. Increasing water percolation would add oxygen-rich water to the reduced soil layer and decrease methane production (Vivekanandan and Jayasankar, 2008).

Contribution to mitigation: ADW technology can reduce the number of irrigations significantly compared to farmer's practice, thereby lowering irrigation water consumption by 25 per cent, reducing diesel fuel consumption for pumping water by 30 liters per hectare, and producing 500kg more rice grain yield per hectare. The visible success of ADW has dispelled the concept of yield losses under moisture stress condition in non-flooded rice fields. Adoption of ADW technology reduced water use and methane emissions, and it increased rice productivity. It can reduce methane emissions by 50% as compared to rice produced under continuous flooding.

Chapter 6

Other Relevant Information

6.1 Research and Systematic Observation

6.1.1 Researches and Projects on Climate Change

6.1.1.1 Government Initiatives

Ministry of Science, Technology and Environment (MOSTE): It has established a Climate Change Management Division to look after the overall climate change related issues. There are different programs and projects currently implemented and under pipeline. Some of the projects and programs under this Ministry to strengthen the climate change mitigation and adaptation strategy are as follows:

- National Adaptation Program of Action to Climate Change (NAPA)
- Strategic Program on Climate Resilience (SPCR)
- Second National Communication (SNC)
- Technology Needs Assessment (TNA)
- Mountain Initiative
- Nepal Climate Change Support Program (NCCSP)

The MOSTE is implementing capacity building component and the Department of Hydrology and Meteorology is implementing Building Resilience to Climate-Related Hazards component of PPCR. Climate Development Knowledge Network (CDKN – INGO) in collaboration with MOSTE also carried out the study on "Assessing the economic impacts of climate change in Nepal" – which assessed the economic impacts on agriculture, hydropower and disaster sector.

The Climate Change Management Division under MOSTE has developed various strategy, plan and policies, rules and regulation to cope with the climate change phenomenon. Some of the key publications related to the climate change are as follows.

- Climate Change Policy, 2011
- National Adaptation Program of Action to Climate Change, 2010
- Climate Change Vulnerability Mapping in Nepal, 2010
- National Framework on Local Adaptation Plans for Action, 2011
- Status of Climate Change in Nepal, 2011

Ministry of Agricultural Development (MOAD): There are basically two organizations under the Ministry to carry out research: Nepal Agricultural Research Council (NARC) and National Agricultural Research and Development Fund (NARDF). MOAD also has Agriculture Environment and Biodiversity Section under the Gender Equity and Environment Division to do research and studies on environment and climate change. The Ministry is implementing small sub-component of PPCR basically on developing Agricultural Management Information System for the benefit of farmers, researchers and other stakeholders.

Nepal Agriculture Research Council (NARC) primarily conducts basic research. It was established as an autonomous organization under "Nepal Agriculture Research Council Act 1991" with the prospect of having an efficient, effective and dynamic agriculture research system in the country to uplift the socio-economic level of the people through productivity enhancement by optimal use of available means and resources without depletion of the environment.

There are various divisions and units working under the NARC. Among them, Agriculture Environment Division is related with climate change. Current research activities are as follows:

- Regional collaborative research on the application of CO_2 enrichment technology in rice.
- Application of Effective Microorganisms (EM) technology to increase efficiency of nutrient management on field crops.
- Enabling activities for the preparation of initial national communication related to UN Framework Convention on Climate Change (UNFCCC).
- Prepared the inventory of meteorological database of different ecological belts of Nepal and analyze in relation to agriculture production system.
- System approach to address the Rice-Wheat production system using simulation models.

NARDF is governed by a seven person Fund Management Committee (FMC) chaired by the Secretary of the MOAD. NARDF is responsible to carry out the applied researches of shorter duration (not more than 3 years). It has targeted to support the Government, non-government, educational, private sector, civil society, cooperatives and community based organizations to conduct agricultural research and development works. There are many researches done by various institutions on climate change and agriculture through this Fund.

Ministry of Forests and Soil Conservation (MOFSC): Ministry of Forests and Soil Conservation was established with the objectives of sustainable management of forest resources, conservation of the wetlands, biodiversity and utilization of the forest resources etc. The conservation and management of the forest itself is a mitigation option to climate change. Government of Nepal has established the REDD Forestry and Climate Change Cell under this Ministry for further strengthening of the climate change related activities through conservation and management of the forest. The MOFSC is implementing Multi-stakeholder Forestry Program supported by DFID, SDC and the Government of Finland, where the climate change is one of the focused area.

REDD Forestry and Climate Change Cell: The vision for Nepal's REDD strategy is to reduce greenhouse gas emissions resulting from deforestation and forest degradation by forest conservation and enhancement, by addressing the livelihoods concerns of poor and socially marginalized forest dependent people, and by establishing effective policy, regulatory and institutional structures for sustainable development of Nepal's forests.

The REDD Working Group (RWG) is chaired by the Secretary, MOFSC, which guides the implementation of REDD related programs and activities. Trainings, workshops and interaction programs have been organized at the national and the regional level for the capacity building and a forest carbon measurement guideline has been prepared to maintain consistency in carbon inventory method at local level. The Emission Reduction Project Idea Note (ER-PIN) has been approved by the Carbon Fund and the preparation of Project Document is underway.

Besides, Department of Forest Research and Survey contributes directly towards conducting research and systematic optimization of the forest data of Nepal. Similarly, the Department of Forest is mandated to manage the country's forest resources for the conservation of the natural environment and to supply the forest products to the people. There are many projects and programs completed and ongoing. These programs and projects directly and indirectly form a part of the climate change mitigation. The DOF is implementing Ecosystem-based Adaptation Project – regional Project with the financial support from Germany. The Department of Soil Conservation and Watershed Management is implementing watershed management in the mountain ecosystem, one of the components of Pilot project on Climate Resilience.

Alternative Energy Promotion Center (AEPC): Alternative Energy Promotion Centre (AEPC) is a Government institution established on November 3, 1996 under the MOSTE with the objective of developing and promoting renewable/alternative energy technologies in Nepal.

AEPC has various publications, researches and documents related to policies and programs. For strengthening of climate change related programs it has established Climate and Carbon Unit (CCU) in July 2010 with financial support from UK Department for International Development (DFID) and the technical assistance of SNV Nepal. Since its establishment, the unit has been catalyzing the renewable energy programs in order to better address climate change issues.

The CCU supports government to formulate climate change sensitive RE policy and plan and to develop a Guideline for Local Level Climate Change Initiatives and support District Development Committees to prepare climate and gender sensitive energy plans and to implement them. CCU is working on Development & management of RETs carbon projects feasible in the country. It has succeeded in registering 5 Clean Development Mechanism (CDM) Projects; 4 biogas projects consisting about 60 thousands biogas plants, and one Micro hydro project with total 448 mini/micro hydro projects. CCU has developed the District Climate and Energy Plans preparation Guidelines and developed District Climate and Energy Plans (DCEPs) for three pilot districts namely; Ilam, Makawanpur and Mustang. Capacity building of DDC-DEEU/S to coordinate climate change activities at local level and ensure coordination and cooperation between the AEPC and the wider climate change sector are the other activities being conducted by the unit.

National Trust for Nature Conservation (NTNC): The National Trust for Nature Conservation (NTNC) was established in 1982 by a Legislative Act as an autonomous and not-for-profit organization, mandated to work in the field of nature conservation in Nepal. For over two decades, the Trust has successfully undertaken over 200 small and large projects on nature and biodiversity conservation, cultural heritage protection, ecotourism, and sustainable development.

Though NTNC has not involved directly into the large scale climate change projects, as a new initiative, the Trust has established an Energy and Climate Change Unit to address the emerging issues of climate change through mitigation and adaptation approach and renewable energy technologies. The Trust has also started work on urban environment conservation with the Bagmati River Conservation Project and has published books and journals, and formulation of policies to address the climate change issues in Nepal through the perspectives of conservation and technology transfer. The NTNC also has performed various activities in climate change management in Nepal.

Some of the major programs and projects of the trust are:

- Kyoto projects
- Climate change awareness campaign

- **Publications**
- **Cabinet meeting in kalapatthar**
- **Copenhagen campaign**
- **Save the Himalayas campaign, New York, USA**
- **Public dialogues**

Nepal Academy of Science and Technology (NAST): Nepal Academy of Science and Technology (NAST) is an autonomous apex body established in 1982 to promote science and technology in the country. The Academy is entrusted with four major objectives: advancement of science and technology for all-round development of the nation; preservation and further modernization of indigenous technologies; promotion of research in science and technology; and identification and facilitation of appropriate technology transfer.

Nepal Climate Change Knowledge Management Centre (NCCKMC) is collaboratively formed by NAST and the MOSTE. The MOSTE through the National Adaptation Program of Action (NAPA) project has developed a web-based community portal called Nepal Climate and Development Portal that serves as a platform for sharing knowledge products, experiences, and expertise amongst institutions and individuals who are working on climate change in Nepal (see http://www.climatenepal.org.np/main/). The portal is designed to allow collaborative management and provisioning of information by a community of users.

6.1.1.2 Non- Governmental Initiatives

World Wildlife Fund for Nepal (WWF-Nepal): In 2003, WWF Nepal initiated the Climate Change Program. Since then, it has initiated a network of I/NGOs called the Climate Change Network Nepal (CCNN), launched the Himalayan Glacier and River Project, and initiated the Climate Witness Project.

It has organized different awareness programs, carried out researches and developed learning tools on climate change useful to communities, teachers and students.

"Meltdown in Nepal", a documentary that highlights Nepal's vulnerabilities from global warming in the form of GLOF events. It has been instrumental in getting the attention of the global community at various occasions like the Conference of Parties (COP 10) for UNFCCC at Buenos Aires, Argentina, in December 2004. Climate witness brochure, prepared by WWF has enlightened the voice of the higher Himalayan people on reality and thoughts of climate change.

WWF Nepal in collaboration with the MOFSC has launched a Hariyo Bann program, the Steering Committee of this Program is chaired by the Secretary, MOFSC. One of the aims of the program is to increase the ability of targeted human and ecological communities to adapt to the adverse impacts of climate change.

International Center for Integrated Mountain Development (ICIMOD): ICIMOD is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush-Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal.

ICIMOD has been focusing on the following activities related to the climate change

- Working towards generating regional baseline data, particularly on cryosphere and climate change, and developing mechanisms for sharing of data and information.

- Updating the inventory of glaciers and glacial lakes in the region and extending to other areas; and a GLOF risk assessment.

- Documenting community adaptation strategies to climate related stresses, particularly too much and too little water; assessing the vulnerability of communities with the aim of helping to build their resilience to climate related hazards developing; a climate-induced risk mapping approaches.

- Monitoring carbon flux in six sites in India and Nepal to evaluate the role of community-managed forests in climate stabilization; and working with other partners at policy level to recommend recognition of community forestry as an important carbon sink in the new treaty that will replace the Kyoto Protocol.

- Carrying out an assessment of climate change vulnerability of the mountain ecosystems in the Eastern Himalayas, including an analysis of stakeholders' perceptions of climate change; and developing plans to strengthen the transboundary landscape and corridor development process and scale up transboundary cooperation and habitat connectivity to address the challenges of conservation of biological resources and human well-being using a more community-based and integrated approach.

CARE Nepal: Since 2000, CARE Nepal began working in partnership with local NGOs, networks, federations and community groups to address the underlying causes of poverty, conflict and vulnerability through the promotion of gender and social inclusion, rights based approach and social mobilization. CARE Nepal prepared Community-Based Adaptation Plan on the basis of Climate Vulnerability and Capacity Analysis in one of the VDCs of KCAP in collaboration with KCAMC.

Some of the programs that directly and indirectly address the climate change related issues are:

Jalaidh Integrated Watershed and Natural Resource Management Program: To contribute to improved and sustainable livelihood security and well-being of the poor and socially excluded people living in Jaladh watershed area through: a) improvement in natural resource management and economic activities; b) increased equality in power, capacities, access and control over resources within households, communities, the watershed and the district.

Sustainable Conservation Approaches in Priority Ecosystems: To address imminent threats to biodiversity while promoting social equity, good governance and sustainable livelihoods in partnership.

Practical Action Nepal: Around the world, Practical Action is working in different ways to tackle both the causes and effects of climate change. It has been working with communities, other organizations, national and international bodies, schools and teachers etc. so as to address the issues of climate change.

It has been launching and supporting campaigns designed to raise awareness of the impacts of climate change on vulnerable communities, and enabling them to take tangible action to support strong and urgent change at the local, national and international level.

Recent project work of Practical Action Nepal includes increasing community resilience to cope with impacts of climate change: Mainstreaming livelihood-centered approaches to disaster management, Scaling-up Early Warning Systems in Nepal (SEWIN) related to flood, and Coping with the climate change in Nepal.

6.1.1.3 Initiatives by Academic Sector

Tribhuvan University (TU): Tribhuvan University is the first national institution of higher education in Nepal. It was established in 1959 A.D. There are thirty eight central departments and four research centers located at Kirtipur.

Central department of hydrology and meteorology and environmental science are the major departments that produces the technically sound researcher and graduates with the knowledge of climate change, it is because the topics climate change has been introduced inside their curriculum deeply than other departments. These Departments have also carried out researches and studies related to climate change impacts on various sectors in Nepal.

Kathmandu University (KU): At present, the University offers various undergraduate, graduate and postgraduate programs in science, engineering, medicine, management, education, arts, pharmacy, environment, music, human and natural resources, information technology and biotechnology, through School of Science, School of Management, School of Engineering, School of Medical Sciences, School of Education and School of Arts. Kathmandu University has also carried out many researches related to climate change and has produced researchers and experts in the field of climate change.

6.1.2 Systematic Observation on Climate Change

6.1.2.1 Hydrological Network

Department of Hydrology and Meteorology (DHM) under Ministry of Science, Technology and Environment is the mandatory organization for systematic observation related to climate change. The department has been monitoring different aspects like river hydrology, climate, agro-meteorology, sediment, air quality, water quality, limnology, snow hydrology, glaciology, and wind and solar energy. General and aviation weather forecasts are the regular services provided by DHM.

DHM has been maintaining 170 gauging stations including 20 sediment monitoring stations. Based on instrumentation, the current status of these 170 stream gauging stations is as follows:

- 28 stations with staff gauge only
- 101 stations with staff gauge and cable-way
- 10 stations with staff gauge cable-way and water level recorder
- 8 stations with staff gauge cable-way water level recorder and wireless communication
- 1 station with staff gauge and wireless communication
- 1 station with staff gauge cable-way and wireless communication
- 21 stations with staff gauge and water level recorder
- 8 stations used for flood early warning through SMS and siren system

6.1.2.2 Meteorological Network

At present, DHM maintains 286 meteorological observation stations nationwide, mostly for climate study. Out of these, 16 sites are for synoptic (that is for weather forecasting), and 21 are for agro-meteorological applications. The network also includes 72 climatic stations, and 37 evaporation monitoring stations. These observational networks are in general well distributed in lower altitude regions of the country; however, the number of stations decreases at the higher altitude regions.

6.1.2.3 Observation Network

Existing Observational Network of DHM are as follows.

Table 6-1 shows existing manual stations.

Table 6-1: Existing manual stations

S.N	Manual Stations	No. of Stations
1	Precipitation stations	173
2	Climatic stations	72
3	Agro-meteorological stations	21
4	Synoptic	9
5	Aero-synoptic stations	7
6	Hydrometric stations	154
7	Sediment stations	20

Automatic Surface Observation systems

Table 6-2 shows existing automatic stations.

Table 6-2: Existing automatic observing stations

S.N	Automatic Stations	No. of Stations
1	Automatic weather stations near real time data (Air temperature, humidity, precipitation, atmospheric pressure, wind speed and direction, solar radiation)	14
2	Automatic stations near real time data (Air temperature, rainfall)	7
3	Automatic rainfall stations near real time (Data transmission through GPRS, CDMA system in every 10-30 minute depending on site)	51
4	Automatic weather stations offline	7
5	Automatic real time river gauge stations	31

Few automatic weather stations with iridium satellite data transmission facility are under installations in high altitude.

6.1.2.4 Parameters Observed at Existing Automatic Meteorological Stations

Table 6-3 shows parameters observed at the automatic observing stations (real time).

Table 6-3: Parameters observed at the automatic observing stations (real time)

S.N	Observed Parameter	No. of Stations
1	Rainfall	73
2	Air temperature and relative humidity	21

S.N	Observed Parameter	No. of Stations
3	Wind speed and direction	14
4	Atmospheric pressure	12
5	Global solar radiation	9

Automatic weather stations (offline): 7

- Data from all the automatic stations quality controlled in real time
- Web based new database system (PostgreSQL 9.0) in Linux based environment installed in 2011 with support from Finnish Meteorological Institute. Database server is installed at National Information Technology Center (NITC) Nepal.
- The database can handle both manual and automatic real time data from AWSs.

Quality control is done in real time (every 2 minutes).

6.2 Education, Training and Public Awareness

6.2.1 Education

Education is an effective measure to build knowledge, skills and attitude in fight against the harmful effects of climate change in the Least Developed Countries (LDC) and it requires lying emphasis on the education of children who are the future generation to mitigate with the climate change effects. It is pertinent to prepare children to adapt to climate change effects and enhance resilience to mitigate its effects.

Education represents an important strategic resource in the fight against climate change and preparation for its current and future impacts. Education policies and curricula need to promote strategies to address climate change, in terms of mitigation and adaptation by increasing knowledge and understanding of the causes and impacts. Additionally, it should enhance knowledge, skills, values and attitudes for effective mitigation using appropriate action-oriented pedagogies (UNESCO, 2011).

6.2.1.1 Review of Lower Secondary Level Curriculum

SNC reviewed the lower secondary level curricula with respect to climate change education, analyze whether the existing subjects / contents provide any knowledge on climate change issues and if provide, how and to what extent they provide. It is also recommended the possible ways to address the climate change issues in the curricula, and produced a concise recommendation report providing adequate analysis of inclusion of emerging climate change issues in various key subjects.

The issue of climate change and the contents are spread in different subject areas of lower secondary curriculum. All these level wise competencies indicate of having most of the contents of environment and climate. These competencies are symmetrical to national objectives and they have further specified the scope of the contents. Science and environment education and social studies and population education are the two major subjects that cover most of the contents related to climate change. Introduction to climate change, climate change and its effects, introduction to weather and climate, sustainable development, human contribution in environmental balance, biodiversity and sustainable development are some of the topics mentioned in this curriculum. There are other basic and fundamental contents appropriate for the level of these grades relating to environment and climate change. Besides, there are provisions for continuous improvement and updating of curriculum in the curriculum development policy.

However, the text books (students' reading material) developed by the Curriculum Development Centre (CDC) for the students of lower secondary level are not friendly to the level of students. The content presentation and the language presentation are not simplified as per the age level and knowledge level of these grades. There is preparation gap for the effective implementation of this curriculum that contains some new contents and concepts. Few programs for curriculum dissemination do not ensure teacher orientation / updating with the new concepts. Lack of teacher support materials and teacher orientation on the new contents has contributed poor delivery at the classroom level. CDC must develop a strong mechanism so that all the teachers have access to obtain a copy of CDC curriculum ensuring these manuals address the support needs of the teachers on the content areas of climate change issues. Similarly the presentation of contents and concepts of climate change issues given in the students' text book do not resemble the strategies of the curriculum. These text books must be revised and simplified to match with the students' age and level of learning

The review has recommended an orientation program on climate change issues for all the curriculum writers and the text book writers of lower secondary level so as to ensure fusion of the contents in the subjects like Nepali, English, Health Education, Moral Education, and CBT (Career, Business and Technology) subjects.

6.2.1.2 Integrating Climate Change Concepts into Secondary-Level Science Curriculum

A workshop on integrating climate change concepts into the science curriculum for secondary level education was organized by MOSTE from 8 - 9 November 2012 at Hotel Himalaya, Lalitpur. The objective of the workshop were to present the findings of the Academic Curriculum Review (ADB TA 7173) to Curriculum Officers (COs) and Textbook Writers (TWs), identify and recommend appropriate contents on climate change which is to be incorporated into the curriculum and provide relevant background information and reference sources on climate change to the COs and TWs and put them in contact with key experts on the topic. The workshop also held working sessions to identify how CC concepts can be appropriately introduced to curriculum of Compulsory Science and Optional Environmental Science for Grade 9 and 10 in the revised curriculums to be disseminated in 2013.

During the workshop, resource persons made presentations on climate science, climate change impacts on Nepal, strategies for climate change adaptation, synthesizing climate change content for secondary level education, best practices for introducing new topics into secondary school curriculum and priorities for continually updating climate change information in the future. Participants then held group working sessions to start the process of incorporating new learning about climate change into the curriculum materials.

The recommendations from the workshop will be used to update science curriculum and textbooks for secondary level education that are to be distributed in schools for upcoming years.

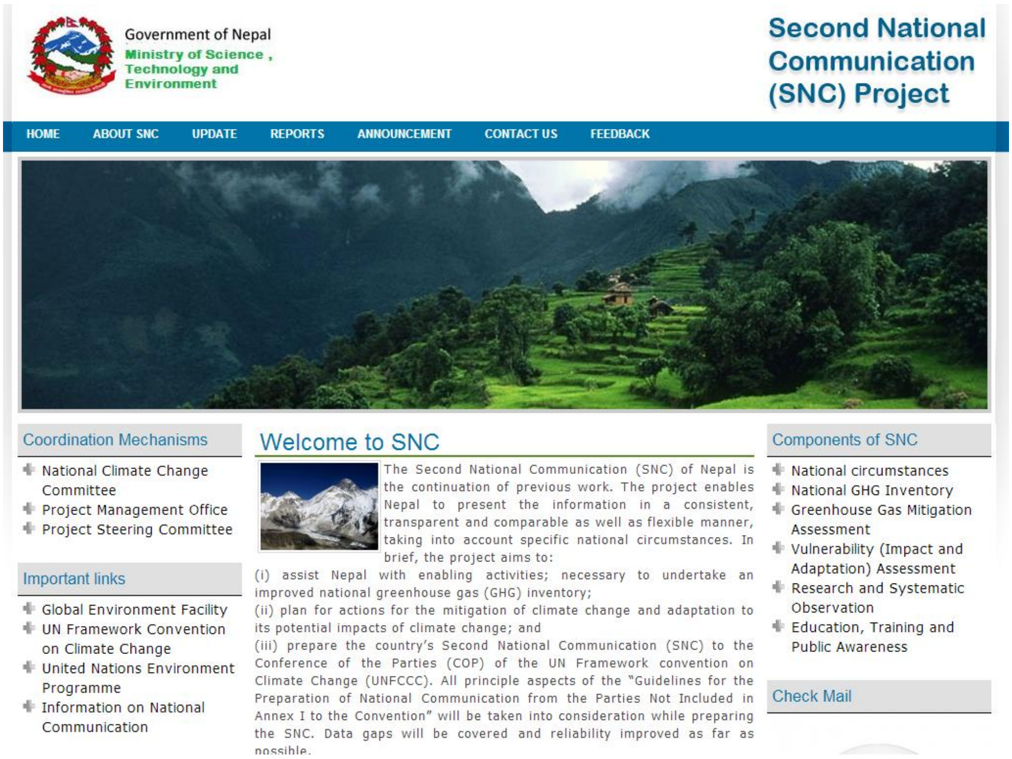
6.3 Capacity Building

The then Ministry of Environment Science and Technology (now MOSTE) implemented National Self Capacity Needs Assessment (NCSA) Project from March 2007 to December 2008 with the assistance of the GEF/UNDP, in which climate change featured as one of the major components. On the climate change front, the project prepared action plan on capacity building needs and implementation strategy (i) to strengthen the national policy and regulatory framework to adequately mitigate the impacts of and adapt to the effects of climate change; (ii) to improve institutional capacities of key agencies and organizations for carrying out climate change adaptation and mitigation activities; (iii) to strengthen public awareness and environmental education on the linkages between development and the impacts of climate change; and (iv) to catalyze the financing of climate change adaptation and mitigation programmes through both donor coordination and government budgetary allocations.

The Second National Communication (SNC) Project was initiated with an aim to strengthen the technical and institutional capacity of Nepal in mainstreaming climate change concerns into the country's sectoral and national development planning processes while preparing and submitting the country's SNC to the UNFCCC, thereby meeting its obligations to the said convention. As a part of developing and enhancing technical capacities and skills of national experts through training on negotiation skills, climate modeling, etc., and through regular participation in regional and international meetings, conferences and seminars for exchange of experiences and information, the key officials engaged with the project shared experiences on the National Communication processes in an international forum in Turkey, participated in a climate change workshop in Nairobi, Kenya, and in low carbon strategy workshop in Bangkok, Thailand.

6.4 Networking and Information Sharing

With growing public access to internet, online networking and sharing has become a very reliable way to facilitate knowledge transfer, sharing and dissemination. For networking and information sharing among stakeholders and partners including the public, the SNC Project has developed and hosted a dedicated website, viz. moste.gov.np/snc.



Through the website, the SNC Project shares information on the SNC process, and components such as National Circumstances; National GHG Inventory; Greenhouse Gas Mitigation Assessment;

Vulnerability (Impact and Adaptation) Assessment; Research and Systematic Observation; and Education, Training and Public Awareness. Nepal's Initial National Communication (INC) report is also available on the website. For easy online navigation, links are provided to the websites of GEF, UNFCCC and UNEP. The website also includes information on the SNC coordination mechanism including the organizational structure of National Climate Change Committee, Project Management Office, and Project Steering Committee. Relevant news and events are regularly updated.

Apart from the development of the dedicated website, the SNC Project has also published and distributed brochures containing information on the SNC in both English and Nepali languages in order to disseminate information to stakeholders and general public.

Chapter 7

Constraints, Gaps, and Financial, Technical and Capacity Needs

7.1 Constraints and Gaps

The SNC preparation process faced a number of challenges, the most significant of which is the unavailability of quality data. In order to overcome such shortcoming, logical assumptions have been made where/ when deemed necessary. In this report, almost all data used have been collected from the secondary sources. For authenticity, priority has been given to the government sources. However, government data sources alone could not provide sufficient background for required analyses at all times. In such case, data sources maintained by non-state agencies (including bilateral agencies) have been used with cross verification as far as possible. Although data quality was given high importance, a slim possibility of data inconsistency and inaccuracy cannot be denied. In case of slightly varied data at different data sources for the same subject matter, the simplest statistical concept of uncertainty analysis i.e., the arithmetic mean of the data, was used as per IPCC, 2000. Moreover, in case of data inadequacy, efforts were made to come up with realistic assumptions through discussion with and among expert panel members, and a thorough review of relevant literatures and best international practices.

7.2 Data Quality and Uncertainty in GHG Inventory

The Good Practice Guidance and Uncertainty Management in the National Greenhouse Gas Inventories (IPCC 2000) provide guidance on improved methods for the GHG estimation. The IPCC inventory methods for each gas-activity pair are stratified into tiers by the intensity of data requirements and model complexity. In GHG inventory, there are uncertainties associated with the emission estimates. These uncertainties are due to the degree of accuracy of the activity data and emission factors. The emission factors used in developing the inventory are IPCC default values.

Currently, there is a complete absence of Nepal-specific emission factors for the various emission-related activities. Therefore, emission factors suitable to Nepal have to be developed. Some of the current estimates, such as those for CO_2 emissions from energy-related activities and cement processing, are considered relatively accurate. For other categories of emission, lack of data has limited the scope of the inventory, particularly in the sectors of energy, agriculture, and forestry and land use. Therefore, efforts need to be made to improve data collection and management system.

Energy sector: The Water and Energy Commission Secretariat is the main source of fuel data for the energy sector. However, the available energy balance did not provide sufficient information for a thorough understanding of fuel consumption. For example, it did not include information on fuel consumption in the domestic aviation sector.

Quality control for the transport sector emission estimates was limited to checking the consistency of data trends as well as cross-checking data entries.

Agricultural sector: The inventory suffers both from non-availability of emission factors at the national level and activity data set as defined by the emission factor data base (EFDB) of the IPCC 1996. For example, Nepal has a unique type of traditional agriculture for which no suitable emission factor has been developed. Similarly, the activity data are not disaggregated as necessary for juxtaposing with the emission factors reported by the EFDB. For example, paddy area data in Nepal are available in aggregate. No disaggregated data are available for upland paddy and low land paddy. The upland paddy is not irrigated or flooded but grown as rain-fed. Even among the low land paddy, some areas have no irrigation and crop is grown based on flood water. In some other areas, irrigation is very limited and, most of the time, the field remains aerated. In some other cases, irrigation is available once a week or so in rotation from farmer to farmer or even plot to plot. There are still some paddy areas with continuous flooding with least chance of aeration. Such data limitation puts challenges on estimating the GHG emission in Nepal precisely. Moreover, the numbers of draft cattle and dairy cattle are not reported separately. No beef cattle are herded in Nepal.

Forestry and land use sector: There was difficulty in finding sufficient data for the estimation of the forestry sector's GHGs emission. The major data gaps include: rainfall and temperature data for categorization of forest types, district wise forest area, district wise forest area according to forest type, biomass or carbon data for each district according to forest type, forest encroachment annual figure, increase in forest biomass in hills from community forestry during the last one and half decade, and emission from forest soil.

7.3 Technology Gaps in Adaptation and Mitigation

Lack of appropriate technology and financial resources has seriously impeded Nepal's ability to implement adaptation and mitigation options. Adaptive and mitigation capacity is likely to vary, depending on availability and access to technology at various levels- from local to national and in all sectors. Many of the adaptive strategies identified as feasible in the management of climate change directly or indirectly involve technology, such as warning systems, protective structures, crop breeding and irrigation, settlement and relocation or redesigning flood control measures, improved irrigation techniques to cope with drought, and new plant varieties which are resistant to drought or to flood, etc. Similarly, mitigation technologies include use of energy efficient vehicles and equipments, use of alternative energies, short rotation forestry, methane recovery from organic waste etc. Most of these technologies are in continuous development and practice in Nepal. However, they warrant further development and refinement tailored to meet additional requirement in order to face further climate change variability and extremes.

7.4 Constrains and Gaps in Research, Systematic Observation and Networking

In the case of research and systematic observation, there is an inadequacy of the hydro-meteorological stations in the hilly and mountainous area of mid-western and far-western development regions. Similarly mountainous region of eastern development region also lacks such types of stations, which is prerequisite for analyzing and forecasting the climatic trends of the country. Likewise, most of the stations in high altitude are located at remote areas; and hence, in practice, poorly trained observer can inflict errors while handling and reading the instruments. There is an inadequate institutional capacity of DHM in producing and sharing research findings and early warning information dissemination, poor institutional coordination of HMS producer at inter- and intra-levels and inadequate flood and weather forecasts quality.

7.5 Constrains, Gaps and Financial needs in Technology and Capacity Development

Nepal is in the process of identifying its technological needs in the context of climate change. However, the public policies and strategies have not fully geared towards taking the opportunities associated with technology transfer for climate change adaptation and mitigation, and the level of

awareness and technological knowhow is also low. Given this situation, there are gaps in capacity building which can be filled through further investments.

Nepal, as a country with no fossil fuels deposits but having large potential of renewable energy (hydropower, and biomass), is in distinct position to demonstrate a low-carbon emission path for its economic development. However, Nepal suffers from the lack of sufficient technical human resource and lack of adequate financial resources for research and development. Institutional capacity of different governmental organizations engaged in climate change-related research and studies is found to be inadequate in producing, sharing and disseminating research findings.

Chapter 8

Conclusion

8.1 Conclusion

As a party to the UNFCCC, Nepal prepared Initial National Communication (INC) in August 2004, and has now prepared Second National Communication (SNC). The SNC is expected to contribute towards strengthening of the technical and institutional capacity of Nepal in mainstreaming climate change concerns into the country's national agenda and sectoral and national development planning process. The SNC comprises of four key components: national circumstances, national GHG inventory, vulnerability and adaptation, and mitigation assessment. The report includes inventory of GHG emission – and hence adaptation and mitigation measures – in the following five sectors: (i) energy, (ii) industrial process, (iii) agriculture, (iv) land use, land use change and forestry, and (v) solid waste as per the UNFCCC guidelines. This study also includes discussion on technology development and transfer, research and systematic observation, and capacity development through education, training and public awareness. Likewise, the study has identified constraints and gaps in the climate change initiatives undertaken by the country, and assessed financial and, technical aspects and capacity needs to overcome obstacles in future.

As part of the fulfillment of its obligation as a party to the Convention, Nepal has given high priority to the issues of climate change and a number of climate change-related initiatives have started including declaration of the right of every person to live in a clean environment as a fundamental right in the Interim Constitution of Nepal 2007, formulation of Climate Change Policy 2011, formulation of Environment Protection Act 1997 and Environment Protection Rules 1997, adoption of National Adaptation Programs of Action (NAPA) and Local Adaptation Plan of Action (LAPA), issuance of Kalapatthar Declaration through a Cabinet Meeting at Kalapatthar near the base camp of the Mount Everest, and launching of National Capacity Needs Self-Assessment (NCSA) Project, among others. Several Ministries and Departments are actively engaged in the formulation of adaptation and mitigation policies, strategies and programs against climate change and associated risks.

Preparation of SNC report further consolidates Nepal’s engagement in global effort towards making the world safer from climate change risks.

REFERENCES/ BIBLIOGRAPHY

ABPSD (2010), Statistical information in Nepalese agriculture. Agribusiness Promotion and Statistics Division, Ministry of Agriculture and Cooperatives, Kathmandu

ABTRACO (2008), Country Report on The State of the Nepal's Plant Genetic Resources for Food and Agriculture. Submitted to the Commission on the Genetic Resources for Food and Agriculture by Agri-Business and Trade Promotion Multi-Purpose Cooperatives Limited (ABTRACO), Kathmandu, Nepal, pp. 92.

ADB (2006), Kathmandu Valley Water Distribution, Sewerage, and Urban Development. Project feasibility study. Asian Development Bank, pp. 37.

ADB/ICIMOD (2006), Environment Assessment of Nepal: Emerging Issues and Challenges. Asian Development Bank/ International Centre for Integrated Mountain Development, Kathmandu, Nepal.

Amundson, J.L., Mader, T.L., Rasby, R.J. and Hu, Q.S. (2005), Temperature and temperature-humidity index effects on pregnancy rate in beef cattle. 17th International Congress on Biometeorology, Deutscher Wetterdienst, Offenbach, Germany.

Bajracharya, S.R. and Maharjan, S.B. (2010), The status of glaciers in the Nepal Himalaya. ICIMOD, Kathmandu, Nepal.

Bajracharya, S.R., Maharjan, S.B. and Shrestha, B.R. (2010), Second generation glaciers mapping and inventory of Nepal. Journal of Nepal Geological Society 41.

Baylis, M. and Githeko, A.K. (2006), The effects of climate change on infectious diseases of animals. Report for the Foresight Project on Detection of Infectious Diseases, Department of Trade and Industry, UK Government.

Burkett, V.R., Wilcox, D.A., Stottlemyer, R., Barrow, W., Fagre, D., Baron, J., Nielsen, J.L., Allen, C.D., Peterson, D.L., Ruggerone, G., Doyle, T. (2005), Nonlinear dynamics in ecosystem response to climatic change: Case studies and policy implications. Ecological Complexity 2: 357-394.

CBS (2001), Nepal Environmental Study Report. Central Bureau of Statistics, Kathmandu, Nepal.

CBS (2002), Population Census 2001, National Report. Central Bureau of Statistics, Kathmandu, Nepal.

CBS (2009), Report on the Nepal Labour Force Survey 2008. Central Bureau of Statistics, Nepal/ United Nations Development Programme/ International Labour Organization.

CBS (2009), Statistical Year Book of Nepal. Central Bureau of Statistics, Kathmandu, Nepal.

CBS (2011), Population Census Report. Central Bureau of Statistics, Kathmandu, Nepal.

Chapagain, B. K., Subedi, R., and Sharma Paudel, N. (2009), Exploring Local Climate Change Impact on Floral and Faunal species in the Kanchenjunga-Singalila Complex.

Chaulagain (2007), Impacts of Climate Change on Water Resources of Nepal: The Physical and Socio-economic Dimensions. Shaker Verlag, Aachen, pp.146.

Denman, K.L., Brasseur, G., Chidthaisong, A., Ciais, P., Cox, P.M., Dickinson, R.H., E., Heinze, D., Holland, C.E., Jacob, D., Lohmann, U., Ramachandran, S., da Silva Dias, P.L., Wofsy, S.C., Zhang, X. (2007), Couplings Between Changes in the Climate System and Biogeochemistry. In: Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Dercon, S. (2006), Vulnerability: A Micro perspective. In: Bourguignon, Pleskovic, and van der Gaag (eds.), Annual World Bank Conference on Development Economics Europe: Securing Development in an Unstable World. World Bank.

Devkota S.R., Neupane P. C. (1994), Industrial Pollution Inventory of the Kathmandu Valley and Nepal, Industrial Pollution Control Management Project, Ministry of Industry, Nepal.

DFRS (1999), Forest and Shrub Cover of Nepal 1994 (1989-1996). Department of Forest Research and Survey, Forest Survey Division, Kathmandu, Nepal.

DFRS (1999), Forest Resources of Nepal (1987-1998). Department of Forests and Soil Conservation, Kathmandu, Nepal.

DHM (1997), Proceeding of the workshop on climate change in Nepal. Department of Hydrology and Meteorology, Kathmandu, Nepal.

Dixon, R.K., Smith, J. and Guill, S. (2003), Life on the edge: vulnerability and adaptation of African ecosystems to global climate change. Mitigation and Adaptation Strategies for Global Change 8, 93-113.

DOF (2002), Hamro Ban. Government of Nepal, Ministry of Forest and Soil Conservation, Department of Forests, Kathmandu, Nepal.

DOHS (2010), Annual Report 2008/2009, Ministry of Health and Population, Government of Nepal, Kathmandu.

FAO (2006), Global Forest Resources Assessment 2005, Progress towards Sustainable Forest Management: Food and Agriculture Organization.

FAO (2010), Country Profile: Food Security Indicators, Nepal, Published by FAO.

FAO (2010): Forest and Climate Change in the Asia and Pacific Region, Forests and Climate Change Working Paper 7, Food and Agricultural Organization Rome.

FAO (2010): Global Forest Resource Assessment 2010 Nepal Country Report. p. 4.

Fujita, K., Nakawo, M., Fujii, Y. and Paudel, P. (1997), Changes in glaciers in Hidden Valley, Mukut Himal, Nepal Himalayas, from 1974 to 1994. Journal of Glaciology 42, 583-588.

Fujita, K., Nakazawa, F. and Rana, B. (2001), Glaciological observations on Rikha Samba Glacier in Hidden Valley. Nepal Himalayas, 1998 and 1999, Bulletin of Glacier Research 18, 31-35.

Fujita, K., Takeuchi, N. and Seko, K. (1998), Glaciological observations of Yala Glacier in Langtang Valley, Nepal Himalayas, 1994 and 1996. Bulletin of Glacier Research 16, 75-81.

Hanson, J.G., Baker, B.B. and Bourdon, R.M. (1993), Comparison of the effects of different climate change scenarios on rangeland livestock production. Agricultural Systems 41, 487-502.

Harvell, C.D., Kim, K., Burkholder, J.M., Colwell, R.R., Epstein, P.R., Grimes, D.J., Hofmann, E.E., Lipp, E.K., Osterhaus, A., Overstreet, R.M., Porter, J.W., Smith, G.W. and Vasta, G.R. (1999), Review: marine ecology - emerging marine diseases-climate links and anthropogenic factors. Science 285, 1505-1510.

Harvell, C.D., Mitchell, C.E., Ward, J.R., Altizer, S., Dobson, A.P., Ostfeld, R.S. and Samuel, M.D. (2002), Ecology - climate warming and disease risks for terrestrial and marine biota. Science 296, 2158-2162.

Hertel, T. W. and S. D. Rosch (2010), Climate Change, Agriculture, and Poverty. Applied Economic Perspectives and Policy, volume 32, number 3, pp. 355–385.

Holdridge, L.R. (1967), Life Zone Ecology.Tropical Science Center, San Jose, Costa Rica.

Hopkins, A. and Del Prado, A. (2007), Implications of climate change for grassland in Europe: impacts, adaptations and mitigation options: a review. Grass and Forage Science 62, 118-126.

ICIMOD (2001), Inventory of glaciers, glacial lakes, and glacial lake outburst floods: Monitoring and early warning systems in the Hindu Kush-Himalayan region - Nepal. ICIMOD, Kathmandu.

ICIMOD (2009), Climate Change Impacts and Vulnerability in the Eastern Himalayas. ICIMOD, Kathmandu.

Industrial Statistics, (2004/05), Department of Industries, Ministry of Industry, Commerce and Supplies, Nepal.

IPCC (1996), Climate Change 1995 Impacts, Adaptations and Mitigation of Climate Change. Scientific-Technical Analyses.

IPCC (1997a), Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. United Nations Environment Programme, Organization for Economic Cooperation and Development, International Energy Agency. Paris

IPCC (1997b), The Regional Impacts of Climate Change: An Assessment of Vulnerability, Summary for Policymaker. Intergovernmental Panel on Climate Change (IPCC).

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, National Greenhouse Gas Inventories Programme, May 2000

IPCC (2003), Good Practice Guidance for Land Use, Land-Use Change and Forestry. Institute for Global Environmental Strategies (IGES)/IPCC.

IPCC (2006), Guidelines for National Greenhouse Gas Inventories. IGES.

IPCC (2007), Summary for the policy makers, Climate Change 2007: The Physical Science Basic. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC.

IPCC (2012), Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 582.

IUFRO (2007), Adaptation of forest and people to climate change. IUFRO, HelsinkiJoshi, G.R. (2012). Clean Development Mechanism in the Context of Climate Change Mitigation. In: Bhattarai, T.N., Uprety, B.K. and Devkota, D.C. (eds.) - Chapter 5 (Pp 51-59). Climate Change and the UNFCCC Negotiation Process, Kathmandu: Ministry of Environment, Science and Technology (MOEST), 2012.

Kabubo-Mariara, J. (2009), Global warming and livestock husbandry in Kenya: impacts and adaptations. Ecological Economics 68.

Kayastha, R.B. and Harrison, S.P. (2008): Changes of the equilibrium line altitude since the Little Ice Age in the Nepalese Himalayas. Annals of Glaciology 48, 93-99.

LRMP (1986), Agriculture and Forestry report. Land Resources Mapping Project, Department of Survey, Government of Nepal, Nepal

Mader, T.L. and Davis, M.S. (2004), Effect of management strategies on reducing heat stress of feedlot cattle: feed and water intake. Journal of Animal Science 82, 3077-3087.

Malla, G. (2008), Climate change and its impact on Nepalese agriculture. The Journal of Agriculture and Environment 9, 62-71.

Manandhar S., Dietrich S. V., Sylvain R. P., and Futaba K. (2010), Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers perception and practices. Regional Environmental Change.

Minson, D.J. (1990), Forage in Ruminant Nutrition, Academic Press, San Diego.

MOAC (2006), Statistical Information on Nepalese Agriculture. Ministry of Agriculture and Cooperative, Kathmandu.

MOAC (2010), Statistical Information on Nepalese Agriculture. Ministry of Agriculture and Cooperative, Kathmandu.

MOE (2009), Strengthening National Capacity in Climate Change, Status Paper for COP15/CMP5 to UN Framework Convention and Climate Change and Kyoto Protocol.

MOE (2010a), National Adaptation Programme of Action (NAPA) to Climate Change. Ministry of Environment, Government of Nepal.

MOE (2010b), Climate Change Vulnerability Mapping of Nepal, Ministry of Environment, Kathmandu, Nepal.

MOEST (2008), Stocktaking and Stakeholder Consultation for the Preparation of the Proposal for Second National Communication Final Report for Non-Annex I Parties-Nepal. Ministry of Environment, Science and Technology, Government of Nepal, Kathmandu, Nepal.

MOF (2010), Economic Survey, FY 2009/10, Government of Nepal, Ministry of Finance, Nepal.

MOF (2011), Economic Survey: Fiscal Year 2010/11. Ministry of Finance, Government of Nepal.

MOFSC (2012), Community Forestry Database, Ministry of Forests and Soil Conservation, Nepal.

MOPE (2001), State of the Environment of Nepal, 2001. Ministry of Population and Environment, His Majesty's Government, Nepal.

MOPE (2004), Initial National Communication to the United Nations Framework Convention on Climate Change, Ministry of Population and Environment, Government of Nepal, Kathmandu.

MPFS (1989), Master Plan for Forestry Sector: Main report. Ministry of Forest and Soil Conservation, Kathmandu, Nepal.

NARC/MOAC (2008), Country Report on the State of Nepal's Plant Genetic Resources for Food and Agriculture. Commission on Genetic Resources for Food and Agriculture, Kathmandu. Nepal Agriculture Research Centre/Ministry of Agriculture and Cooperatives, Nepal.

NBSM (2004), Shield, Nepal Bureau of Standards and Metrology, Nepal.

NEA (2011), A Year in Review (2010/11). Nepal Electricity Authority, Kathmandu, Nepal.

NFI (1999), Comparison to the previous results: Forest resources of Nepal (1987-1998), p. 25.

NPC (2010a), Poverty Measure Exercise and the Number of Poor in Nepal. National Planning Commission, Nepal.

NPC (2010b), Three-Year Interim Plan: Approach Paper (2067/68-2069/70). Government of Nepal, National Planning Commission, Nepal.

NPC (2010c), Statistical Pocket Book Nepal 2010. Government of Nepal, National Planning Commission, Central Bureau of Statistics, Nepal.

NPC (2011a), Climate-Resilient Planning: A Tool for Long-Term Climate Adaptation (Working Document). National Planning Commission, Kathmandu, Nepal.

NPC (2011b), Three Year Plan (2067/68-2069/70). National Planning Commission, Kathmandu, Nepal

NPC/UNDP (2010), Nepal Millennium Development Goals: Progress Report 2010. National Planning Commission/ United Nations Development Programme, Kathmandu, Nepal.

Oli, B.N., Shrestha, K.M. (2009), Carbon Status in Forests of Nepal: An Overview. Journal of Forest and Livelihood 8 (1): 62-66.

Pant, G.B. and Rupa Kumar, K. (1997): Climates of South Asia. John Wiley and Sons, Chichester.

Pant, K.P. (2011), Economics of climate change for smallholder farmers in Nepal: a review. The Journal of Agriculture and Environment 12, 113-126.

Parry, M.L., Rosenzweig, C., Iglesias, A., Fischer, G. and Livermore, M.T.J. (1999), Climate change and world food security: a new assessment. Global Environmental Change 9, 551-567.

Patz, J.A., Campbell-lendrum, D., Holloway, T. and Foley, J.A. (2005), Impact of regional climate change on human health. Nature 438.

Patz, J.A., Confalonieri, U.E.C., Amerasinghe, F.P., Chua, K.B., Daszak, P., Hyatt, A.D., Molyneux, D., Thomson, M., Yameogo, L., Lazaro, M.M., Vasconcelos, P., Rubio-Palis, Y., Campbell-lendrum, D., Jaenisch, T., Mahamat, H., Mutero, C., Waltner-Toews, D. and Whiteman, C. (2005), Human health: ecosystem regulation of infectious diseases, Ecosystems and Human Well-Being, Current State and Trends, vol.1. The Millennium Ecosystem Assessment.

Poudel, K.P, Bhattarai, B., Sapkota, B., Kjeldstad, B. (2011), Total Solar Radiation Potential in different parts of Nepal. Journal of Institute of Engineering, Vol. 8: 189-197.

Regmi, B., and Adhikari, A. (2007), Human Development Report 2007: Climate Change and Human Development - Risk and Vulnerability in Warming World: Country Case Study-Nepal. UNDP.

Rotter, R. and van de Geijn, S.C. (1999), Climate change effects on plant growth, crop yield, and livestock. Climate Change 43.

SCA (1990), Feeding Standards for Australian Livestock: Ruminants. CSIRO Publications (Standing Committee on Agriculture), East Melbourne.

Shrestha, A.B.,et al. (1999), Maximum Temperature Trends in the Himalaya and its vicinity: An Analysis Based on Temperature Records from Nepal for the Period 1971-94. Journal of Climate Vol. 12, American Meteorological Society, pp.2275-2786

Shrestha, T.B. and Joshi, R.M. (1996), Rare, Endemic and Endangered Plants in Nepal. WWF Nepal Program, Kathmandu.

Stern, N. (2006), The Stern Review on the Economics of Climate Change. Cambridge University Press.

SWMRMC (2004), A Diagnostic Report on State of a Solid Waste Management in Municipalities of Nepal, Final Report. Solid Waste Management and Resource Mobilization Center (SWMRMC), Thornton, P.K., Kruska, R.L., Henninger, N., Kristjanson, P.M., Reid, R.S., Atieno, F., Odero, A. and Ndegwa, T. (2002), Mapping poverty and livestock in the developing world. International Livestock Research Institute, Nairobi, Kenya.

Thornton, P.K., Steeg, J., Notenbaert, A. and Herrero, M. (2009), The impacts of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know. Agricultural Systems 101, 113-127.

Tiwari, K. R., Awasthi, K. D., Balla, M. K., and Sitaula. B. K. (2010), Local people Twinomugisha, Ben. Tiempo: a bulletin on climate and development: Indigenous Adaptation. United Nations, 1992. United Nations Framework Convention on Climate Change. URL: http://unfccc.int/resource/docs/convkp/conveng.pdf

Tsigas, M.E., Frisvold, G.B. and Kuhn, B. (1997), Global climate change and agriculture. In: Hertel, T.W. (ed.), Global Trade Analysis: Modeling and Applications. Cambridge University Press, Cambridge, pp. 280-301.

UNDP (2010), Human Development Report 2010. UNDP, New York.

Velders, G.J.M., Fahey, D.W., Daniel, J.S., McFarland, M.A., Thelarge, S.O. (2010), Contribution of Projected HFC Emissions to Future Climate Forcing, pp. 10949–10954.

Vivekanandan,E. and Jayasankar, J. (2008), Winter School on Impact of Climate Change

on Indian Marine Fisheries, Central Marine Fisheries Research Institute (CMFRI), Indian Council of Agricultural Research.

WECS (2001), Wood Energy Planning. Water and Energy Commission Secretariat, Government of Nepal, Kathmandu.

WECS (2006), National Water Plan. Water and Energy Commission Secretariat, Government of Nepal, Kathmandu.

WECS (2010a): Energy Sector Synopsis Report 2010. Water and Energy Commission Secretariat, Government of Nepal, Kathmandu.

WECS (2010b), National Water Plan. Water and Energy Commission Secretariat, Government of Nepal, Kathmandu.

WECS (2011), National Water Plan. Water and Energy Commission Secretariat, Government of Nepal, Kathmandu.

WHO (2007), Using climate to predict infectious disease epidemics.

WMO (2009), Climate information for securing food. Fact Sheet # 4. World Meteorological Organization, Geneva, Switzerland.

World Bank (2008), Towards a strategic framework on climate change and development for the World Bank group; Concept and issue paper (Consultation draft). The World Bank, Washington DC.

Yamada, Y., Shiraiwa, T., Iida, H., Kadota, T., Watanabe, T., Rana, B., Ageta, Y. and Fushimi, H. (1992), Fluctuations of the glaciers from the 1970s to 1989 in the Khumbu, Shorong and Langtang regions, Nepal Himalayas, Bulletin of Glacier Research 10, 11-19.

Yudog, K.C. (2002), Consumption of Krishi Chun in Nepal. Quoted in: MOPE. (2004). Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change.