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Mongolia Second Assessment Report on Climate Change-2014

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Editors-in-chief:

Damdin Dagvadorj
Zamba Batjargal
Luvsan Natsagdorj

Disclaimers

TABLE OF CONTENTS

List of Figures

List of Tables

Abbreviations

ADB	Asian Development Bank
AF	Adaptation fund
AIACC	Assessment of Impacts of and Adaptation to Climate Change
AOB	Arctic Ocean Basin
AR	Assessment Report
AWS	Automated weather station
BOD	Biological oxygen demand
CBD	Convention on Biological Diversity
CCCO	Climate Change Coordination Office
CCO	Climate change office
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CDR	Carbon Dioxide Removal
CER	Certified emission reduction
CES	Central Energy System
CHPs	Combined heat and power plants
CMDL	Climate Monitoring and Diagnostics Laboratory
CNDS	Comprehensive National Development Strategy
CRU	Climate Research Unit
DEFRA	Department for Environment, Food and Rural Affairs
DEMoS	Department of Emergency and Management of Selenge aimag
DNA	Designated National Authority
DRI	Disaster Research Institute
ELA	Equilibrium Line Altitude
ENSO	El Nico/Southern Oscillation
ESD	Education of sustainable development
EST	Environmentally suitable technology
FBC	Fluidized bed combustion
GAM	Global Atmosphere Watch
GCF	Green climate fund
GCMs	Global Climate Models
GCOS	Global Climate Observing System
GDP	Gross domestic product
GEF	Global Environment Facility
GGGI	Global Green Growth Institute
GHG	Greenhouse gas
GISS	Goddard Institute for Space and Studies
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH

GoM	Government of Mongolia
GRACE	Gravity Recovery and Climate Experiment
HDI	Human development index
HQL	High quality livestock
HVDC	High-voltage direct current
IEA	International Energy Agency
IMHE	Institute of Meteorology, Hydrology and Environment
IPCC	Intergovernmental Panel on Climate Change
JC	Joint Committee
JCM	Joint Crediting Mechanism
KOICA	Korea International Cooperation Agency
LDCs	Least Developed Countries
LUCF	Land use change and forestry
MARCC	Mongolia: Assessment Report on Climate Change
MAS	Mongolian Academy of Sciences
MCDA	Multi Criteria Decisions Analysis
MCUD	Ministry of Construction and Urban Development
MDG	Millennium Development Goals
MED	Ministry of Economic Development
MEGD	Ministry of Environment and Green Development
MIA	Ministry of Industry and Agriculture
MNET	Ministry of Nature, Environment and Tourism
MoE	Ministry of Energy
MoF	Ministry of Finance
MoU	Memorandum of Understanding
MRV	Measurement, Reporting and Verification
MSUE	Mongolian State University of Education
MSW	Municipal solid waste
MUST	Mongolian University of Science and Technology
NAMA	Nationally appropriate mitigation actions
NAMHEM	National Agency for Meteorology, Hydrology, Environment and Monitoring
NAPCC	National Action Program on Climate Change
NASA	National Aeronautics and Space Administration
NCC	National Climate Committee
NCDC	National Climate Data Center
NDDI	Normalized drought difference index
NDVI	Normalized Difference Vegetation Index
NEMA	National Emergency and Management Authority

NGOs	Non-governmental organizations
NMVOC	non-methane volatile organic compounds
NOAA	National Oceanic Atmospheric Administration
NSO	National Statistical Office
NUM	National University of Mongolia
ODI	Official development assistance
PES	Payment of ecosystem services
POB	Pacific Ocean Basin
PoM	Parliament of Mongolia
PSPS	Potato seed production system
RCP	Representative concentration pathway
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RVE	Relative volume error
SAoM	Scout Association of Mongolia
SDC	Swiss Agency for Development and Cooperation
SPLEWS	Seasonal to Inter-annual Prediction and Livestock Early Warning System
SPW	Sustainable Pasture Management
SREX	IPCC Special Report on Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation
SWDS	Solid waste disposal site
SWI	System of wheat intensification
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TPPs	Thermal power plants
TWS	Terrestrial water storage
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Education, Science and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
VETC	Vocational education training center
VPS	Vegetable production system
WB	World Bank
WG	Working group
WHO	World Health Organization
WMO	World Meteorological Organization
WW	Wastewater
WWF	World Wide Fund for Nature

Unit

˚C	degree Celsius
cm	centimeter
cub.km	cubic kilometer
g	gram
g/m^2	gram per square meters
Gcal	gigacalorie
Gg	gigagram
Gt	gigatonnes
GtCO$_2$eq	gigatons of carbon dioxide equivalent
ha	hectares
ka	1000 years ago
kg	kilogram
km	kilometer
km^2	square kilometer
km^3	cubic kilometer
km^3/year	cubic kilometer per year
kW	kilowatt
kWh	kilowatt-hour
m	meter/metre
m/s	meter per second
m^3	cubic meter
mm	millimeter
MNT or tugrug	national currency of Mongolia
Mpa	megapascal
MtCO$_2$	million tons of carbon dioxide
MW	megawatt
Pg	petagram
PM$_{10}$	Particulate matter with Aerodynamic Diameter<10μm
PM$_{2.5}$	Particulate matter with Aerodynamic Diameter<2.5μm
ppb	parts per billion
ppbv	part per billion by volume
ppm	parts per million
ppt	parts per trillion
sq km	square kilometer
tCO$_2$/yr	tons of carbon dioxide per year
tCO$_2$e	ton of carbon dioxide equivalent
W/m^2	watt per square meters
μg	microgram

Foreword

The new Constitution of Mongolia, adopted in 1992, establishes the right of Mongolian citizens to live in a safe and healthy environment and states that all land and natural resources of Mongolia are subject to state protection. The Parliament and Government of Mongolia approved and are implementing over 20 national programmes towards the climate change and environmental priorities specified in the national policy documents. These programmes aim at the comprehensive actions on reduction of adverse impacts of climate change and adaptation approach at the land-based and ecosystem level, environmental conservation, sustainable use and restoration of natural resources, mitigation of greenhouse gas (GHG) and other pollutants' emissions where necessary. The Mongolian Action Programme for the 21st Century (MAP 21), the National Action Plan to Combat Desertification, the National Biodiversity Action Plan, National Water Programme, the Action Programme to Protect Air, and the National Action Programme to Protect the Ozone Layer were developed subsequently. In particular, the MAP 21, developed by the National Council for Sustainable Development (NCSD) includes concrete considerations and recommendations on adaptation to climate change and mitigation of GHG emissions. The revised Law on Air (2012) and the Law on Environmental Protection (2012) are the main legal instruments for the protection of atmosphere and the environment.

The Millennium Development Goals-based Comprehensive National Development Strategy (MDG-based CNDS) of Mongolia approved in 2008 identifies the need "to create a sustainable environment for development by promoting capacities and measures on adaptation to climate change, halting imbalances in the country's ecosystems and protecting them". In addition, the MDG-based CNDS includes a Strategic Objective to promote capacity to adapt to climate change and to reduce their adverse impacts.

Relevant national programmes on forest, water and desertification as well as on natural disasters were updated and approved by the Parliament in 2010 and 2011 respectively. The government has identified a critical need to strengthen the institutional framework, and to build the human capacity for achieving effective action on environmental issues. Several Master and Action Plans have been developed that have implications for the environment, including the National Development Concept, Road Master Plan, Power Sector Master Plan, Tourism Master Plan, and Renewable Energy Master Plan and others.

In order to address challenges relevant to climate change, Mongolia has developed its National Action Programme on Climate Change (NAPCC) and the programme was approved by the State Great Khural (Parliament) in 2000 and updated in 2011. The action programme includes the national policy and strategy to tackle the adverse impacts of climate change and to mitigate GHG emissions. The Mongolian NAPCC is aimed not only at meeting national obligations under the United Nations Framework Convention on Climate Change (UNFCCC), but also at setting priorities for action and to integrate climate change concerns into other national and sectorial development plans and programmes. The NAPCC is based on the pre-feasibility studies on climate change impact, assessment on adaptation, estimation of GHG inventories, and analysis on GHG mitigation options. This Action Programme includes a set of measures, actions and strategies that enable vulnerable sectors to adapt to climate change and to mitigate GHG emissions. The starting point was that these measures should not adversely affect sustainable socio-economic development of the country. The sustainable development of Mongolia is largely dependent on the beneficial relation between the environment and the economy, since the economy is closely related with use of natural resources such as pasture land, minerals and other environmental services that the Earth Mother is providing. Recently approved by the State Great Khural in June 2014, the Policy Concept on Green Development included clear targets on adaptation measures and mitigation actions. Green development policy is a transition to the development model that results in human well-being by safeguarding environmentally friendly, inclusive economic growth, enhancing natural resources utilization and maintaining the ecosystem service sustainability.

At the international level, Mongolia has joined environment-related United Nations Conventions and Treaties, such as the UN Framework Convention on Climate Change (UNFCCC), the UN Convention on Biological Diversity (CBD), the Convention to Combat Desertification (CCD), the Vienna Convention for the Protection of the Ozone, and others. The United Nations Programmes and Agencies like United Nations Development Program (UNDP), World Bank and United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) support capacity building of concerned national and local institutions to fulfil their commitments and provisions received under these conventions, to implement and monitor related policies, and to enhance coordination. The international organizations and partner countries also cooperate with local governments, civil society organizations, research institutions and the media for a wider outreach of environmental awareness campaigns. Public awareness activities on climate change are crucial, and it is necessary to increase government willingness to cooperate with NGOs and the general public in supporting and providing them with adequate information. The best available scientific knowledge informs climate policies and actions for reducing greenhouse gas emissions and adapting to climate risks.

At the Climate Summit hosted by UN Secretary-General Ban Ki - moon on 23 September 2014, the Heads of States and Governments will join leaders from business and civil societies to chart a new course of action on climate change and to announce new commitments and practical actions to address climate change. I will participate in the Summit and co-chair the thematic session on “Climate Science” at this Summit. It is essential that reliable climate science is fundamental milestone of policies and actions in reducing emissions and building climate resilience. I will highlight climate change induced challenges in Mongolia and the role of climate science in supporting climate policies and actions in the country. This updated Second Assessment Report on Climate Change of Mongolia (MARCC 2014) would be important source of information on latest outputs of assessments and research on climate change, including observed and projected changes, impacts on environmental components, economic sectors and social spheres as well as response measures against climate change.

The Government of Mongolia has made significant progress in climate change research, awareness and planning since the first assessment report prepared in 2009 (MARCC 2009). The Climate Change Coordination Office (CCCO), under the supervision of the Minister for Environment and Green Development was established by the Government, in order to carry out day to day activities related to the implementation of commitments and duties under the UNFCCC and Kyoto Protocol, to manage climate change activities nationwide, and to integrate climate change concerns into various national and sectorial development plans and programmes.

In order to integrate climate change concerns and actions into national and sectorial development programmes, measures and actions that have an inter-sectorial and inter-disciplinary nature are included in recently approved sectorial development programmes such as Energy Efficiency Improvement Programme, Renewable Energy Programme, Mongolian Livestock Programme and others. There is strong necessity in close cooperation among all the stakeholders dealing with climate change issues.

The Second Assessment Report on climate change in Mongolia is fully reflecting the observed climate change and its impact on the national economy and livelihood of local communities in the country referring best scientific knowledge around the world including new Fifth Assessment Report on Climate Change developed by the Intergovernmental Panel on Climate Change (IPCC 2013).

This assessment report was made possible thanks to the commitment and dedication of many experts from different government entities, scientific institutions and professional societies representing a wide range of disciplines. I express my deep gratitude to all authors and editors for devoting their knowledge, expertise and time.

The Government and people of Mongolia will do their best to promote successful implementation of those nationwide programmes in order to undertake all necessary adaptation measures to reduce the possible stress on the society from climate change and contribute to mitigation actions for benefit of the international community as a whole. Findings in this assessment report and relevant recommendations would be incorporated in the future national development programmes and action plans.

TSAKHIAGIIN ELBEGDORJ

President of Mongolia

Preface

Mongolia is one of the most vulnerable to climate change countries in the world because of its specific geographical and climate conditions as well as the structure and development level of the economic sectors, and life style of the people. Therefore, regular update of the research and studies in all relevant areas of climate change and a comprehensive assessment of outputs and results of these studies and progress of climate change response measures and actions in the country in a periodic manner is essential to address climate change challenges and risks.

Since MARCC 2009, considerable progress has been made in assessing climate change impacts, vulnerabilities and associated risks as well as in conducting national greenhouse gas monitoring and inventories, and identifying GHG mitigation options. Impacts of climate change on environmental components, biophysical elements, economic sectors and social sphere have been assessed to determine vulnerabilities to, and risks associated with any changes in climate system. Relevant adaptation and mitigation policy and measures have been outlined based on the outputs of these assessments.

Measures to reduce the adverse impacts caused by climate change are based on impact and vulnerability assessment of climate change on the environmental and socio-economic sectors. New developments and amendments of policies and legal documents are required in order to align them with recent climate change issues and the latest socio-economic development trends. The major part of adaptation is targeted on studies and assessments of climate change impact, including its damages and risks and the formulation of methods and measures to mitigate it. Efficient methods and strategies are needed in the first place in order to implement adaptation policy on climate change. Implementation strategies must include factors related to legislation, structure, finance, human resources, science and media, and it must be coherent with other policies and strategies. On the other hand, the effectiveness of adaptation measures is not easily recognized in the short term. Apart from funding, the major factors in the successful implementation of adaptation measures are capability, willingness and the concern of the people involved in the implementation of those measures. Successful implementation is ensured only when there is public participation in the action. The herders, farmers and local communities are the ones to benefit directly from a policy on adaptation. Also, it is crucial to involve and get assistance from experts and specialists in actions like trainings and studies such as dealing with cropland, selection and invention of new breeds and construction and management of irrigation system. Adequate understanding and support of policy makers are vital in order to address the existing and emerging challenges associated with a climate change. Although Mongolia's total GHG emissions are negligible to compare to the World net emissions, there is very high energy and carbon intensity in the country. Therefore, GHG mitigation measures, in particular the actions aimed to reduce per-capita or per-GDP emissions are equally important for Mongolia. The GHG and air pollution mitigation measures should be implemented in close association with the national policies to introduce environmentally sound advanced technologies and to improve effectiveness and efficiencies at all levels of the country.

Currently, Mongolia does not have a specific laws on climate change that concern the coordination of all climate change related activities, but some existing laws and their amendments reflect climate change concerns and challenges and promote climate change related activities. In other words, these issues are not well coordinated in the various related laws and the main national development policy documents which include the basic concepts, principles and legal framework of climate change.

According to the Law on Air, the Climate Change Coordination Office (CCCO), under the supervision of the Minister for Environment and Green Development was established in 2012 with responsibilities to carry out day to day activities related to the implementation of commitments and duties under the UNFCCC and Kyoto Protocol, to manage the nationwide activities, and to bring into action the integration of climate change related problems in various sectors. The CCCO includes Clean Development Mechanism National Bureau, which is responsible for climate change mitigation, reduction of greenhouse gases, implementation of low carbon development, GHG inventory and Bilateral and Multilateral offset crediting activities as stipulated in the Law on Air.

In order to address challenges relevant to climate change, Mongolia has developed its National Action Programme on Climate Change (NAPCC) and the programme was approved by the State Great Khural (Parliament) in 2000 and updated in 2011. The main goal of NAPCC is setting priorities for action and to integrate climate change concerns into other national and sectorial development plans and programs. NAPCC includes a set of measures, actions and strategies that enable vulnerable sectors to adapt to potential climate change and to mitigate greenhouse gas emissions. The implementation of these goals will support Mongolia in achieving sustainable socio-economic development. In NAPCC five strategic objectives and its 96 activities were proposed to be implemented in two phases over the periods from 2011 to 2016 and 2017 to 2021. The implementation plan for the first phase (2011-2016) of NAPCC was approved by the Government in November, 2011. The measures to achieve the five strategic objectives of NAPCC will result in the accomplishment of the first phase of the proposed measures, which is the establishment of the proper legal environment, structure and improvement in the cooperation between related institutions.

The climate change assessment outcomes included in the current report are fully corresponded with objectives and targets of the NAPCC. Structure and content of the report were streamlined with outputs of the assessment reports of the Intergovernmental Panel on Climate Change (IPCC), particularly with the latest Fifth Assessment Report (AR5).

Team of experts contributed to this report were involved in different ways and means in the climate change assessment work in the country, addressing many multi-sectorial and cross-cutting issues.

Overall preparation work of the report was supervised by Dr.D.Dagvadorj, as a

Chair of the Climate Change Coordination Office (CCCO) and Government Special Envoy on Climate Change with strong logistic support of all staff of the Office, particularly, Ms. Ts.Battsetseg. General outline and content design of the report, as well as overall editing were undertaken by Dr.D.Dagvadorj, Dr.Z.Batjargal and Dr.L.Natsagdorj (editors). Herewith, a special note of appreciation and gratitude is extended to the authors: D.Dagvadorj, Z.Batjargal, L.Natsagdorj, G. Sarantuya, P.Gomboluudev, B.Erdenetsetseg, Ch.Dorjsuren, D.Enkhbileg, G. Davaa, B.Bolortsetseg, N.Mandakh, G.Davaadorj, B.Gantsetseg, D.Jugder, G.Radnaa, Ya.Jambaljav, B.Burmaajav, M.Doljinsuren, J.Dorjpurev, B.Namkhainyam, Ts.Battsetseg, Ts.Gerelt-od, B.Tegshjargal, D.Oyunchimeg, E.Sanaa, D.Saruul and Sh.Gerelmaa, who made valuable contribution to the chapters on specific areas and without their generous time and efforts, the report could simply not have been produced. Also expressed is the sincere gratitude to Ms S.Saran, who translated majority of the texts in English from original Mongolian texts, and special appreciation goes to Laura S. Steele who kindly agreed and edited the English version of the texts.

Thanks to the dedication of all experts from different economic and social sectors, from different field of climate associated disciplines were possible to conduct the assessment exercises and compile the assessment report in limited time within limited financial resources. GIZ is deserved the appreciation for its financial support of publication of the report, and Mr. Klaus Schmidt - Corsitto, Coordinator of the GIZ “Biodiversity and adaptation of key forest ecosystems to climate change” programme for his personal contribution to the report.

This report is intended for the use by decision makers, by members of professional societies and scientific communities, by educators and students and by general public as well.

This report would serve as a significant contribution of Mongolia to the Climate Summit hosted by UN Secretary -General Ban Ki - moon in September 2014 and the Thematic session on “Climate Science” at this Summit is to be co-chaired by the President of Mongolia Tsakhiagiin Elbegdorj to highlight the climate science as an essential instrument in tackling with climate change concerns.

1 Introduction

1. Introduction

- Background information about the country — Batjargal Z.
- Introductory information about the second assessment report MARCC 2014

MONGOLIA SECOND ASSESSMENT REPORT ON CLIMATE CHANGE - 2014

1. Introduction

1.1 Background Information About the Country

Geography

Mongolia (41°35'- 52°09'N and 87°44'E-119°56'E) is located in Northeast Asia covering an area of 1,564,000 km^2. It borders with the Russian Federation and the People's Republic of China, and stretches for 2,392 km from west to east and 1,259 km from north to south.

Mongolia's average altitude is 1,580 m above sea level. The highest point is Khuiten Uul (Mongolian Altai Range, 4,374 m) and the lowest point is Khoekh Nuur (Mongolian Eastern Steppe, 560 m). The northwest and central parts are high mountainous regions, while the eastern part is a vast steppe region. The southern part of the country is covered with semi-desert and desert area (the Mongolian Gobi). Forests cover 7.8% of the country and mainly consist of larch and pine. Certain areas in the Gobi are occupied by saxaul forests. There are four natural zones in the country: forest steppe, steppe, semi desert and desert. The territory is surrounded by high mountains that form a barrier from both the northern cold and western dry air masses and as well as from the Pacific and Indian oceans moisture sources.

Climate

The climate is harsh continental with sharply defined seasons, high annual and diurnal temperature fluctuations and low rainfall. Because of the high altitude, Mongolia's climate is generally colder than other countries of the same latitude. Average annual temperatures are around 8.5°C in the Gobi and -7.8°C in the high mountainous areas. The extreme minimum temperature is -31.1°C to -55.3°C in January and the extreme maximum temperature is +28.5°C to +44.0°C in July. The annual precipitation amount is averaging 200-220 mm, ranging from 38.4 mm in the extreme south (Gobi desert region) to 389 mm in limited areas in the north. About 90.1% of precipitation evaporates, only 9.9% forms surface runoff, partially recharging into ground water aquifers. Most precipitation occurs in June, July and August; the driest months are from November to March. Mongolia has an annual average of 3,000 hours of sunshine, which is well above the amount received by other countries of the same latitude.

Population.

The population growth rate in Mongolia was one of the highest in Asia (2.1-2.5% per year) before the 1990s. The population of Mongolia reached 2867.7 thousand at the end of the year 2012, increased by 2.0 % compared with the previous year (NSO 2013). However, the growth rate has been decreasing during the last decades. Birth rate or births per 1000 population increased in 2006-2009 reaching 25.7 in 2009, while it decreased to 23.1 in 2010 then reached to 25.1 in 2011 and 26.0 in 2012. In 2012, life expectancy at birth at the national level was 68.71 years, while a life expectancy of female and male was 74.32 and 64.91 years respectively.

There is a strong trend toward urbanization and the country has undergone rapid economic development and industrialization in the past four decades. The 65.9 % of the population in Mongolia live in urban areas as end of the year 2012. A high migration stream to the Ulaanbaatar city is becoming a cause of rapid growth of population in capital city. In 2012, population density was 280 persons per square kilometer in Ulaanbaatar, increased by 10.1% from 2009.

The accelerating growth in population, therefore, has been matched by an increase in the per-capita rate of natural resource consumption. The sustainable rates of use or loss of renewable natural resources, including surface water, ground water, forest, soil and rangeland resources, have already been exceeded in some areas; this situation is likely to become more widespread if current trends continue, and measures to conserve and manage natural resources need to be strengthened and implemented.

Land use

In general, land cover in Mongolia can be broken down as follows: 73.8% used for agriculture land (of which approximately 0.8% is cultivated, 1.6% is used for hay making, and 97.6% is pasture land); 0.28% is occupied by cities and settlements; 9.1% is forest and shrub land; 0.4% is covered by water, and 1.7% is unused or not suitable, in common sense, for usage (NSO 2013). Significant portion of land calssified as a land of the state special needs (which includes land allocated for the state security and defence purposes, natural reserves and national parks, roads, and communication network of national importance) and from which nature conservation area covers 17.2% of the territory by 2014. Soil erosion, desertification and other forms of land degradation are considered high priority issues, in view of the strong dependence of Mongolia's economy and food supply on agriculture, and the reliance of other sectors, including mining, on land resources. The degraded area is growing year to year. The development of strip mines and the deposition of overburden, spills and tailings all degrade land resources. Domestic and industrial construction and other forms of waste are currently deposited on the soil surface in overly-large, designated dumping sites on the outskirts of cities and towns.

Before 1960s, a very small proportion of the country's land area was under cultivation. However, since that time an aggressive agricultural programme, including a "virgin lands" programme to spread primarily wheat farming to vast areas of steppe land, was undertaken. The area under crops tripled in 30 years, and the total land under cultivation at the present time is around 1.3 million ha. Dry land farming is the prevailing practice. A considerable area is taken up by livestock feeds and fodder crops. However, after 1990 the total cultivated area has decreased significantly because of economic crisis and political reform in the country. Restored recently "virgin lands" programmes lead to recovery the once collapsed crop production. The grain produced during the last years was enough to meet a domestic demand.

Water resources

The total surface water resource of Mongolia is estimated as 608,3 km^3/year (Dorjsuren 2011) and is composed mainly from water stored in lakes (500 km^3/year) and glaciers (62.9 km^3/year). The long-term average annual renewable water resources include 32.7 km^3 of surface water and 6.1 km^3 of groundwater.

Salinization and poor water quality is a major problem in arid and semi-arid regions. Salinization is caused by a combination of poor drainage and high evaporation rates that concentrate salts in the surface layers of soil, lakes and groundwater aquifers. Natural water quality problems related to saline waters and seasonal freezing and droughts limit the use of water resources in Mongolia.

Mining, agriculture and deforestation have resulted in substantial lowering of river flows and water tables with the result that aggravated desertification, salinization and poor water quality are major problems in the arid and semi-arid regions. Water shortage is one of Mongolia's major socio-economic and ecological problems, but large quantities of water are wasted via leaks in supply pipes and by improper use of water.

Energy

Mongolia's power supply is separated into two parts. First, the major part of the country, in terms of population, is supplied by the interconnected grid operated by the Central Energy System (CES). Second, in the more remote areas of the country, non-interconnected power stations - mainly diesel powered, are installed. There are five coal-fired Combined Heat and Power (CHP) Plants and 18 provincial enterprises that operate isolated energy systems.

Coal, mainly lignite, made up to 80% of primary energy supply. It was mined in the country and delivered by rail to the electricity generating and heating plants that consume 65% of the coal mined. Some 49% of total energy supplied to the heat and power plants was lost in conversion processes and 11% was lost in transmission, distribution and the operation of power stations. Thus, only 40% of the heat is lost in distribution via above ground, leaking and poorly maintained pipes. The net result is that only about 25% of the energy as coal was finally consumed as heat and electricity.

Apart from the inefficient use of coal resources, the main issues with respect to coal are damage to the environment at and around mine sites, and pollution from the electricity/heating plants. For example, air pollution from the three coal-fired thermal power plants in Ulaanbaatar have been an issue of great public concern, especially during winter when temperature inversion that restricts the air dispersion from the Ulaanbaatar city basin is frequent and pronounced. Some WHO estimation has included the Ulaanbaatar city to the list of cities where air pollution is high by dust and other suspended particular matter (Batjargal 2012).

Rising demand for energy reflects rapid economic growth, the development of the mining industry, and the doubling of Ulaanbaatar's population since 1995. This tendency would cause the significant increase of greenhouse gas emissions from energy sector which is responsible for almost 52% of net GHG emissions of the country as of 2012.

Mongolia does not produce natural gas and oil, and therefore, all requirements for petroleum products are met entirely by imports, primarily from Russia. Petroleum products, which are consumed mostly in the transport sector, represent an important source of vulnerability for Mongolia. The non-commercial primary energy sources include fuel wood and animal dung, which are used in households for heating and cooking.

Coal fuels 70% of electricity generation and 90% of heating but with poor energy efficiency. Facilities are old, and electricity tariffs below market rates put proper maintenance and investment in new plants beyond the reach of undercapitalized plant operators. Over the longer term, the government is considering using public–private partnership to expand electricity generating capacity.

Mongolia has huge potential for renewable energy resources. The rich renewable energy resources have not been exploited significantly. At present, there are only five small scale hydropower plant in the northwest, four of which can only be operated in summer because the river freezes in winter. Mongolia's hydropower potential needs to be considered carefully in the light of climate change, declining river flows, environmental impacts and total life-cycle costs. There is considerable potential to supply many nomadic families, particularly, in the Gobi desert with small portable PV or wind generation systems. There are 43 geothermal sites in the Altai, Khangai and Khentii mountains where infrastructure is not yet developed. The country's first wind farm, at Salkhit hill, is expected to add 5% of national electricity supply while reducing carbon dioxide emissions. Tapping these resources requires sound public planning and resource management and effective cooperation with private investors.

With poor incentives for efficient consumption of energy, its use per unit of production is 1.5 times that of developed economies. Heat loss in buildings reaches 30%. Mongolia consumes more commercial energy per capita than any other developing country in the region. This is partly due to the severe climate but more to sheer wastage.

Economy, including agriculture

Economic development faces serious challenges as Mongolia is navigating the difficult transition from a centrally planned to a market oriented economy, and overcoming considerable geographical obstacles to development, including being super-landlocked with an extreme continental climate. Under these tough circumstances, the Government has committed itself to market reform through an active privatisation programme, trade and investment liberalization and the unification of exchange rates. These policies have born fruit to a certain extent: declining growth rate of 1990 to 1993 has been reversed since 1994. Mongolia's economy, fuelled by a mining boom, grew at a record 17.5% pace in 2011 and slowed to 12.4 % in 2012,. That pace slowed after the country implemented measures to increase government oversight of the mining industry, which spurred disputes with some investing companies and discouraged foreign investments. Exports are concentrated in mineral-based commodities, accounting for more than 80 % of total exports in 2012.

While economic growth in 2012 originated in the mining sector, it was quite broadly based. Construction continued to boom, raising concerns about another bubble as in 2004–2008. Mining grew by 8.9% to generate 89.2% of exports, 17% of government revenue, and 18.6% of GDP, while employing less than 2% of the workforce.

The pasture based livestock husbandry still plays an important role in the national economy, employment and export revenues of Mongolia. The estimation for 2012 have shown that 17.6% of GDP was produced by the agriculture sector, of which 77.5 %

accounts for livestock husbandry. Around 35.0% of total labour force of the country is engaged in the agricultural sector and 7.0 of export income is contributed by the agriculture sector. Agricultur finally emerged from the devastating winter of 2009/10 that had decimated the country's livestock by nearly a fifth.

According to results of the livestock census for 2012 in total 40.9 million head of livestock were counted and 27.1 % of total household was registered as possessing private livestock. In 2012 the total loss of adult animals reached 0.4 million heads which equals to 1.2 % of total livestock at beginning of the year. It can be considered as normal year without extreme damage for livestock sector due to weather condition and other factors. The total number of livestock is increasing further and reached around 50 million in 2014 which was never happened in modern Mongolian history. It means more pressure on pasture due to overgrazing in combination with increased aridity in some areas of the country. Most of this growth has been the increase in goats, as the demand for cashmere wool has increased significantly. However, most Mongolian livestock is an indigenous breed of animals, grazing around of year on natural pastures, with very low productivity and their body sizes are small compared to other breeds of animals in the world. Intensive livestock activities, such as pig production, poultry, and dairy do not play so far an important role in the livestock sector.

Traditionally, crop production has not been a major agricultural activity in Mongolia. Intensive land cultivation only began in 1958 with livestock collectivization and "ATARI" (virgin land) campaign in Mongolia. The area of arable lands was increasing up to the 1990s when about 1.3 million ha was under cultivation every year. However, since 1991 the area has been decreasing due to the economic crisis, as marginal croplands that had been growing wheat have been taken out of production. The main crops are cereals, potatoes, vegetables and fodder crops. Government initiated "ATAR III" campaign promoted an increase of crop yield. An average harvest has been recovered and for instance, by 2012 it was increased by 3.8 times, including potatoes by 2.6 times, and vegetables by 54.5 %. In 2012, there were 379.8 thousand hectares of sown area, of which 306.2 thousand hectares were for cereals,16.8 thousand. hectares for potatoes, 7.9 thousand hectares for vegetables. In 2012, the production was 479.3 thousand ton of cereals, 245.9 thousand ton of potatoes, 98.9 thousand ton of vegetables, 46.2 thousand ton of machine-harvested fodder. In 2012, Mongolia consumed 99.3 % of cereals, 98.7 % of potatoes and 54.9 % of vegetables from domestic harvest. But rain fed crop production in Mongolia is risky business due to high magnitude variability of weather attributed to the deep continental dry climate condition.

GDP grew by 11.7% in 2013, easing from 12.4% in 2012. Growth was boosted by highly expansionary fiscal and monetary policies to compensate for the marked slowdown in coal exports and mine development financed through foreign direct investment (FDI), which have been the drivers of growth in recent years. Strong economic growth has helped reduce the poverty rate by more than 11 percentage points in the past 2 years, to 27% in 2012.

Industrial production increased by 20.1% in 2013, contributing 5.1 percentage points to economic growth. It was driven by construction, which expanded by 66%, boosted by monetary and fiscal stimulus. Mining output expanded by 20.7%, thanks to the ramp-up of copper production at the vast Oyu Tolgoi mine, which started in June 2013.

Services expanded by 10.0%, contributing 4.3 percentage points to economic growth. Favorable weather allowed agriculture to expand by 13.5%, contributing 2.0 percentage points. Domestic consumption was the main driver of economic growth from the expenditure side, increasing by 16.3% in constant prices and contributing 13.7 percentage points to growth.

The total 53.3 million tonne of freight and 318.7 million passengers with double counting were carried by various modes of transport in 2012. According to results of the Motor Vehicle Inspection, the total number of vehicles reached 345.5 thousand, of which 228.7 thousand . were passenger automobiles, 83.7 thousand trucks, 21.6 thousand. buses and 11.5 thousand special equipped vehicles. Of the total vehicles in Mongolia 66.3% vehicles are in Ulaanbaatar. Moreover, 5.9 % of the total vehicles in the country were up to 3 years old, 22.9 % were used for 4 years up to 9 years, and the rest 71.2% were used for more than 10 years. The total length of improved road network was 7918.9 km, which of 4348.9 km were paved as of the end of 2012. Most of industrial enterprises and transportation means in Mongolia have certain impact on climate change being source of GHG emissions, aerosols and dust.

Medium-term prospects remain promising, with growth expected in the double digits after a dip in 2014, given Mongolia's potential to develop its natural resources. Economic growth is forecast at 9.5% in 2014,but in fact, the GDP growth in the first half of 2014 was not more than 5 percent. Three years of growth-oriented economic policies have led to large economic imbalances. In 2014, the economy is undergoing an adjustment in response to the large external and internal imbalances. Key concern is that, unfortunately, Mongolia has not accumulated savings from its resource revenues during the past high-growth period.

Economic growth is expected to pick up slightly to 10% in 2015, spurred by further development in mining, including the possible development of the Oyu Tolgoi underground mine and an expansion of coal production from the Tavan Tolgoi mine (ADB 2014)

Mongolia is at the threshold of a major transformation driven by the exploitation of its vast mineral resources and the share of mining in GDP today stands at 20 percent, twice the ratio of a decade ago. The economic growth rate in 2012- 2013 was almost twice more than 6.4 percent GDP growth in 2010. GDP is expected to grow at a double digit rate over the period from 2013 to 2017.

1.2 Introductory Information on the Second Assessment Report - MARCC 2014

Because of its specific geographical and climatic conditions, Mongolia is likely to be more heavily affected by global climate change. The impact of climate change on the ecological systems and natural resources would have a direct and serious effect on almost all sectors of the national economy and all spheres of social life, i.e. it touches all aspects of the life support system. Climate change response measures will help to address the inevitable need to adapt to climate change and to mitigate greenhouse gas emissions, in order to meet the requirements of Mongolia's sustainable development strategies, including "Green Development Concept". As a result of climate change countermeasures, climate resilient and low carbon society expected to be established in the country.

Climate change studies, conducted in Mongolia so far, were mostly based on the available instrumental observation data and outputs of global climate models (GCM) resulting in a very important message that the present global warming will in the long run lead to a shift of climate zones with dominance of arid and desert areas in this country (Dagvadorj et al.1994; Batima, Dagvadorj 2000; Mijiddorj 2000; Batima et al. 2005, Gomboluudev 2006). The National Action Programme on Climate Change (NAPCC) of Mongolia (GoM 2000), approved by the Government of Mongolia in 2000 and upgraded in 2011 incorporated this message in the outline of possible actions as the response measures to climate change. The Government of Mongolia has established an interagency and inter-sectorial National Climate Committee (NCC), led by the Minister in charge of the Environment, to coordinate and guide national activities and measures aimed to adapt to climate change and to mitigate GHG emissions. Series of impact and risk analyses studies have been undertaken in relation with different ecosystems and economy sectors (MNE 2006, MNET 2009, MNET 2010).

There is a need to further update results of existing studies by involving additional analysis of driving factors taking into account newly emerging challenges in socio-economic development in the country. The issues of continued and increased aridity in some parts of Mongolia and possible alteration in moisture supply regime for this area due to global warming need to be proved with sufficient scientific confidence for guaranteed adaptation options of local communities and for better strategy of economic development. More detailed analysis needed to be undertaken on the regional and local scale land use changes which contribute to variability of precipitation, soil moisture and river runoff through certain, underestimated so far, factors like aerosols in atmosphere and land surface albedo.

The water resource issues, particularly in respect of climate variability and land use change have not been addressed in comprehensive manner, despite their importance in term of food security and sustainable livelihood in Mongolia. Some assessments were made on surface water resources, snow cover, and permafrost. The conclusion was made that the climate warming would have a significant effect, including an earlier start of spring snowmelt, an increase in high runoff as a fraction of total runoff, and an increase in flood frequency (Batima et al., 2005). There are some obstacles still existing to get high confident and integrated data on the water resources which can be used for sensitive national level decision making exercises.

In this report, in relation with a climate system, a more detailed evaluation was provided on the response of local climate parameters to the global warming with particular focus on glacier melting, water resource declining and land degradation in Mongolia and on the role of principal factors as regional climate forcing. Detailed analyses have been conducted using the standard observation records from the national meteorological network, in order to indicate the peculiarities of local response to global climate change, revealed in the trend of temperature , precipitation and other parameters. The overall discussions are addressed the water resource issues in Mongolia in respect of the ongoing and future climate changes. An attempt is made to the indicate the emerging challenges for this country, particularly in respect of extended mining activities in most water scarce areas and traditional livestock and agriculture development in the future.

In respect of the global climate change the IPCC AR4 (2007) concluded that "warming of the climate system is unequivocal." The recent new assessment report AR5 goes further, concluding that many observed changes are "unprecedented over decades to millennia. The globally averaged combined land and ocean surface temperature has been increased by 0.85°C over the period 1880 to 2012, while the AR4 estimated average warming across the globe over the past century (1906-2005) was 0.74°C. New analyses continue to support the AR4 and SREX conclusions that the heat wave frequency has increased since the middle of the 20th century in large parts of Asia (WGI AR5 2013). Precipitation trends, including extremes, are characterized by strong variability, with both increasing and decreasing trends observed in different parts of Asia and different seasons.

A new set of scenarios, the Representative Concentration Pathways (RCPs), was used for the new climate model simulations carried out under the framework of the Coupled Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Programme. In all RCPs, atmospheric CO_2 concentrations are higher in 2100 relative to present day as a result of a further increase of cumulative emissions of CO2 to the atmosphere during the 21st Century.

Since the first assessment report MARCC 2009, a current climate change risk assessment for Mongolia was conducted, in addition to water resources, on biodiversity, ecosystem services, forest, agriculture/animal husbandry, arable farming, social health and infrastructure.

The results demonstrated that pasture based animal husbandry and rainfed arable farming sectors, biodiversity and certain component of infrastructure are the most vulnerable to climate change (UNDP, 2012). Also, permafrost and glacier melting, surface water shortage, soil and pasture degradation were identified as a country specific concerns caused by climate change adverse impacts. Relevant policy framework was outlined for adaptation actions and mitigation measures as respond to estimated climate change, including soft approaches as a legal regulation and institutional arrangements. Another approaches also were considered, particularly, application of advanced technology and innovation issues in adaptation and mitigation measures. The areas and fields assessed were covered environmental components, biophysical elements, economic sectors and social sphere, including human health, poverty etc.

The first part (chapters 1-3) provides basic information about Mongolia and its climate change associated problems in line of the global warming and attributed regional and local impacts. The second part (chapters 4-7) reviews adaptation options and possible mitigation measures, including GHG inventory and related technology issues. The chapter 8 covers policy framework, legal instruments and institutional arrangements, and public awareness as response measures to climate change. These chapters were written by different authors and contributors and hence certain inconsistent might be indicated in use of terminology and references.

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2 Climate change: observed changes and future projections

2. Climate change: observed changes and future projections

- Global climate change and its regional and local implications	Batjargal Z.
- Climate research and observed climate change in Mongolia	Natsagdorj L., Sarantuya G.
- Future climate change projection in Mongolia	Gomboluudev P.

CLIMATE CHANGE: OBSERVED CHANGES AND FUTURE PROJECTIONS

2.1 Global climate change and its regional and local implications

The countries like Mongolia cannot avoid elevated impact of the climate change in global scale due to their more exposed to external condition, traditional lifestyle and more dependent on the fragile natural resources as life supporting system. In this chapter certain analysis are made covering the issues of the global climate change and its regional and local consequences based on Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC) and climate change studies at the national level.

The IPCC Fifth Assessment Report (AR5) brings policymakers and the public up to date on the state of climate science. The AR5 is being released in four parts between September 2013 and November 2014 is the most comprehensive assessment of scientific knowledge on climate change and existing climate change research since 2007 when Fourth Assessment Report (AR4) was released. It provides a baseline for understanding and response action as for individual nation and global community as a whole. Analyses of global surface temperature changes are routinely carried out by several scientific institutions in different advanced countries. Among them are the NASA Goddard Institute for Space Studies (GISS), the NOAA National Climatic Data Center (NCDC) in USA, and a joint group of the Hadley Research Centre and the University of East Anglia Climate Research Unit (HadCRUT) in UK. Scholars, researchers and other related professionals from these and other leading institutions around the world are contributing to the climate change assessment reports, producing by the IPCC. AR5 is made up of the full reports prepared by the three Working Groups (WGI, WGII and WGIII) and has made greater emphasis on assessing the socio-economic aspects of climate change and its implications for sustainable development. Some new features of AR5 include, among others, a new set of scenarios for analysis, much greater regional detail on climate change impacts, adaptation and mitigation interactions, chapters on carbon cycle and climate phenomena such as monsoon and El Nico and risk management and the framing of a response as well.

The IPCC Synthesis Reports are written in a non-technical style suitable for policymakers and addresses a broad range of policy-relevant but policy-neutral questions. Assessment report at the national level like current one for Mongolia would pursue this principal but some critical topics could be highlighted in less policy-neutral manner or in more prescriptive ways to promote proactive decision making exercises (GOM 2001, GOM 2010) in this country.

2.1.1 Observed global climate change as estimated within IPCC AR5

The IPCC Working Group I on the physical science basis of climate change in its report (WGI AR5 2013) states with greater certainty than ever that climate change is happening and that human activity is the principal cause. The report said it is now *extremely likely* that much of the warming over the past 50 years is due to human activities. It is a greater than 95 percent chance upgraded from *very likely* or greater than 90 percent chance in the last Fourth Assessment Report (AR4) published in 2007 (IPCC 2007). If go back it can be recalled that The Third Assessment Report (AR3) in 2001 made a similar statement with approximately 66 percent certainty (IPCC 2001). The Arctic Ocean is now projected to be ice-free during the summer by mid-century under a high emissions scenario, instead of the end of century as in previous reports. The future sea level rise has been estimated to be significantly increased due to a better understanding of the movement of ice sheets in a warming climate.

The AR4 concluded that "warming of the climate system is unequivocal." The AR5 goes further, concluding that many observed changes (warming of the atmosphere and ocean, sea level rise and melting ice) are "unprecedented over decades to millennia .The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85°C, over the period 1880 to 2012, while the AR4 estimated average warming across the globe over the past century (1906-2005) was 0.74°C. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 °C, based on the single longest dataset available .Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 (Figure 2.1). For the longest period when calculation of regional trends is sufficiently complete (1901 - 2012), almost the entire globe has experienced surface warming (Figure 2.2). In the Northern Hemisphere, 1983–2012 was *likely* the warmest 30-year period of the last 1400 years.

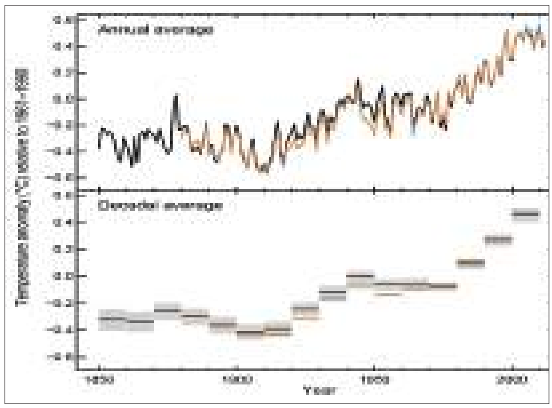


Figure 2.1 Observed global mean combined land and ocean surface temperature anomalies, from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961-1990. *Source: WGI AR5 2013, Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis*

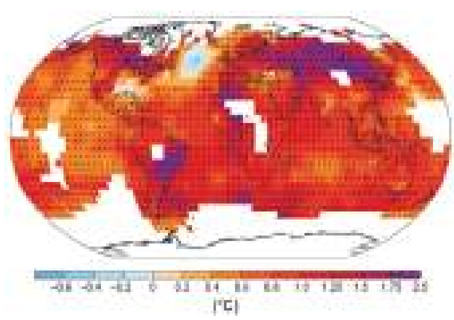


Figure 2.2 Map of the observed surface temperature change from 1901 to 2012 derived from temperature trends determined by linear regression from one dataset (Figure 2.1 orange line in top panel). Trends have been calculated where data availability permits a robust estimate and other areas are white. Grid boxes where the trend is significant at the 10% level are indicated by a + sign. *Source: WGI AR5 2013 , Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis*

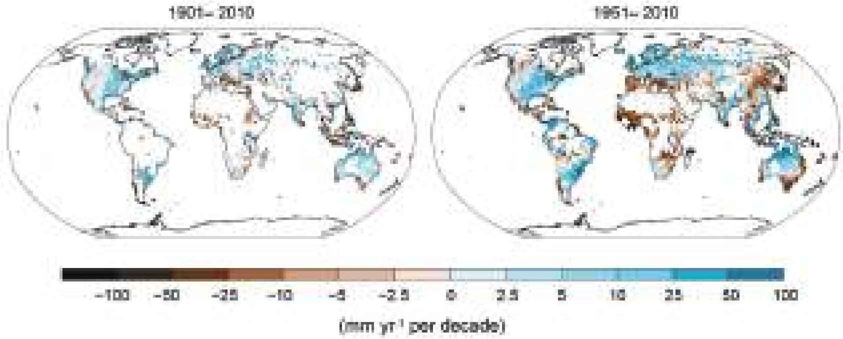


Figure 2.3 Maps of observed precipitation change from 1901 to 2010 and from 1951 to 2010 (trends in annual accumulation calculated using the same criteria as in Figure 2.1) from one data set. *Source: WGI AR5 2013,Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis*

Continental-scale surface temperature reconstructions show, with high confidence, multi-decadal periods during the Medieval Climate Anomaly (year 950 to 1250) that were in some regions as warm as in the late 20th century. This period associated with turbulence time in Eurasia, when Mongols being a tiny nomadic tribe were able to establish biggest by that time empire covering many settled and civilized nations throughout the continent, changing world order to some extent. Scholars in modern days have different approaches in respect of climate factor to this unprecedented historical phenomenon (Fagan 2008, Weatherford 2004), sometimes controversial ones, particularly, with regard nomadic civilization itself (Batjargal 2010). These regional warm periods did not occur as coherently across regions as the warming in the late 20th century. It is virtually certain that globally the troposphere has warmed since the mid-20th century (WGI AR5 2013).

Confidence in precipitation change averaged over global land areas since 1901 is low prior to 1951 and medium afterwards. Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901 (medium confidence before and high confidence after 1951). For other latitudes area-averaged long-term positive or negative trends have low confidence (Figure 2.3)

Changes in many extreme weather and climate events have been observed since about 1950. It is very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale. It is likely that the frequency of heat waves has increased in large parts of Europe, Asia and Australia. Two exceptional heat waves hit Europe and Russia during summer 2003 and 2010 respectively with disastrous impacts and thousands of deaths and outbreaks of prolonged bush fires. Flooding was the most reported extreme event during the decade with many parts of the world affected. Historical widespread and prolonged flooding affected Eastern Europe in 2001 and 2005, Africa in 2008, Asia (in particular Pakistan) in 2010 and India in 2005, and Australia in 2010. A large number of countries reported extreme drought conditions, including Australia, eastern Africa, the Amazonia region and the western United States. Northern East Asia had a cold period during its 2012/13 winter season, associated with negative Arctic Oscillation conditions and blocking patterns around eastern Siberia. During this period, most of Siberia was 2-3°C below average, making this one of the coldest winters for the region in the 21st

Century (WMO 2014). In Mongolia it is not uncommon for zuds (severe weather event mostly in winter season) to kill over 1 million head of livestock in a winter. The so called “Monkey year zud” of 1944-45 with record of almost 7million head of livestock lost and recent similar 2010 zud (Batjargal and Enkhjargal 2013a), both were probably associated with the Arctic oscillation (AO). There are likely more land regions where the number of heavy precipitation events has increased than where it has decreased. The frequency or intensity of heavy precipitation events has likely increased in North America and Europe. In other continents, confidence in changes in heavy precipitation events is at most medium (WGIAR5 2013).

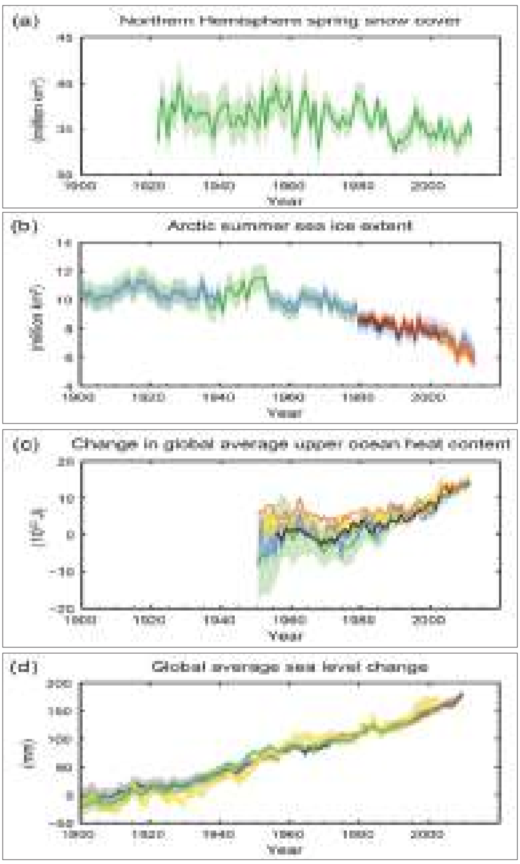


Figure 2.4 Multiple observed indicators of a changing global climate: (a) Extent of Northern Hemisphere March-April (spring) average snow cover; (b) extent of Arctic July-August-September (summer) average sea ice; (c) change in global mean upper ocean (0–700 m) heat content aligned to 2006-2010, and relative to the mean of all datasets for 1970; (d) global mean sea level relative to the 1900–1905 mean of the longest running dataset, and with all datasets aligned to have the same value in 1993, the first year of satellite altimetry data. All time-series (coloured lines indicating different data sets) show annual values, and where assessed, uncertainties are indicated by coloured shading. *Source: WGI AR5 2013, Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis.*

The AR5 also states that scientists have “high confidence” (80 percent chance) that glaciers have shrunk worldwide, and that the Greenland and Antarctic Ice Sheets have lost mass over the past two decades. The report notes with “very high confidence” (90 percent chance) that ice loss from Greenland has accelerated during the past two decades. Greenland is now losing about 215 gigatonnes (Gt) of ice per year, while the rest of the world’s glaciers lose about 226 Gt per year. Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent. As we can see that the atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen (see Figures 2.1, 2.2 and 2.4).

Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010. More than 60% of the net energy increase in the climate system is stored in the upper ocean (0–700 m) during the relatively well-sampled 40-year period from 1971 to 2010, and about 30% is stored in the ocean below 700 m. It is *virtually certain* that the upper ocean (0–700 m) warmed from 1971 to 2010, and it *likely* warmed between the 1870s and 1971. On a global scale, the ocean warming is largest near the surface, and the upper 75 m warmed by 0.11°C per decade over the period 1971 to 2010. Since AR4, instrumental biases in upper-ocean temperature records have been identified and reduced, enhancing confidence in the assessment of change.

There is very high confidence that the extent of Northern Hemisphere snow cover has decreased since the mid-20th century (see Figure 2.4a). Northern Hemisphere snow cover extent decreased in average 1.6 % per decade for March and April, and 11.7 % per decade for June, over the period 1967 – 2012. There is also high confidence that permafrost temperatures have increased in most regions since the early 1980s. In some regions, soil temperature have been warmed up to 2- 3˚C and a considerable reduction in permafrost thickness and areal extent over the period 1975 – 2005. Multiple lines of evidence support very substantial Arctic warming since the mid-20th century.

The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia. The mean rate of global averaged sea level rise was 1.7mm per year between 1901 and 2010, while it was 2.0 mm per year between 1971 and 2010, and 3.2 mm per year between 1993 and 2010. It is likely that similarly high rates occurred between 1920 and 1950 (See Figure 2.4d).

2.1.2 Temporary slowing down of the warming

After a period of rapid warming during the 1990s, global mean surface temperatures have not warmed as rapidly over the past decade. In addition to robust multi-decadal warming, global mean surface temperature exhibits substantial decadal and inter annual variability. Due to natural variability, trends based on short records are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends. The rate of warming, for instance, over the past 15 years (1998–2012) was 0.05 ˚C per decade, which begins with a strong El Nico. It was smaller than the rate 0.12 ˚C per decade calculated since 1951 for the period 1951–2012. Strong negative temperature anomalies observed, for instance, in December 2009 at middle latitudes in the Northern Hemisphere, as great as - 8˚C in Siberia, averaged over the month. There was a large region in the United States and Canada in June, July, August 2009 with a negative temperature anomaly greater than 1˚C, the largest negative anomaly on the planet (Hansen et al. 2010). In Mongolia, air temperature in November and December 2009 were 1.3- 6.3˚C below the norm and by the end of December 2009 the recorded temperatures were as low as minus 40-47˚C in the areas like Great lakes and Darkhad depressions, areas close to the center of Siberia-Mongolian High (SMH) and minus 25- 30˚C in southern part of Gobi (NAMHEM 2010). The absolute minimum temperature record have been breached at certain meteorological stations in Eastern Mongolia, like Dashbalbar (-42.0˚C) and Matad (-37.0˚C). Researchers explained that in December 2009 there was an unusual exchange of polar and middle latitude air in the Northern Hemisphere due to the negative Arctic Oscillation (AO) index (weaker middle latitude jet stream and zonal winds), which was most extreme negative since the 1970th (Hansen et al. 2010). The temperature record shows that similar situations with extreme cold spells were occurring in Mongolia in the past. In December 1966 air temperature dropped to minus 40.0-52.5^{0}C covering most part of the territory. Lowest temperatures were recorded as minus 55.3^{0}C in Zuungobi soum district of Uvs aimag (province) and minus 34.7^{0}C in Ekhiingol (Bayankhongor aimag), which is the most warm oasis in the country. The lowest temperature records were breached in Ulaanbaatar area (-49.0^{0}C at the Buyant-ukhaa station in December 1954), in Zavkhan aimag (-52.9⁰C at the Tosontsengel station in January 1969 and -51.9˚C at the Bayantes station in January 1977), in Khuvsgul aimag (-50.4⁰C at the Renchinlhuimbe station in January 2000) and other central and northern aimags like Bulgan, Selenge and Tuv (NAMHEM 2012). It is interesting to note that these sites are revealed to be more responsive to the global warming having average temperature increase in winter season.

The AR5 concludes that the recent reduction in surface warming is probably due to a redistribution of heat in the ocean, volcanic eruptions, and the recent minimum in the 11-year solar cycle. Some researchers note that the warming “pause” is actually explained by the unusual number of La Nina in the Pacific Ocean (La-Nina-like decadal cooling.), while other papers suggest that some of this “lost” heat is actually in the deep ocean. The report concluded that although similar decadal hiatus events may occur in the future, “the multi-decadal warming trend is very likely to continue.”

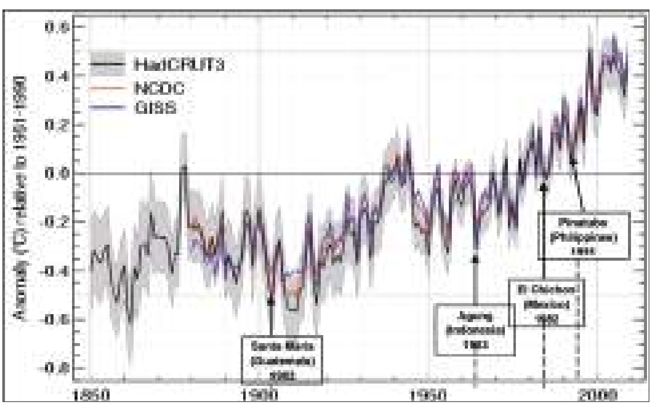


Figure 2.5 The effects of large scale volcanic eruptions on the global temperature trend. (Graph developed using the temperature trend from: WMO 2010)

2.1.3 Driving factors of the global climate change

Recent update made by the World Meteorological Organization (WMO) based on the latest analysis of observations from the WMO Global Atmosphere Watch (GAW) Programme has demonstrated (WMO2013) that the globally averaged mixing ratios of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) reached new highs in 2012, with CO_2 at 393.1 ppm, CH_4 at 1819 ppb and N_2O at 325.1 ppb. These values constitute, respectively, 141%, 260% and 120% of pre-industrial (before 1750) levels. The concentrations of these GHGs have increased to levels unprecedented in at least the last 800,000 years. Carbon dioxide concentrations have increased by 43% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification.

Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750.The National Oceanic and Atmospheric Administration (NOAA) Annual Greenhouse Gas Index shows that from 1990 to 2012 radiative forcing by long-lived greenhouse gases increased by 32%, with CO_2 accounting for about 80% of this increase (WMO 2013). Climate models have improved since the AR4. Models reproduce observed continental-scale surface temperature patterns and trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions (See Figure 2.5).

Observational and model studies of temperature change, climate feedbacks and changes in the Earth's energy budget together provide confidence in the magnitude of global warming in response to past and future forcing. Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. This evidence for human influence has grown since AR4. It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century.

2.1.4 Future Projection of Global Climate Change as outlined within AR5.

Projections of changes in the climate system are made using a hierarchy of climate models ranging from simple climate models, to models of intermediate complexity, to comprehensive climate models, and Earth System Models. These models simulate changes based on a set of scenarios of anthropogenic forcings. A new set of scenarios, the Representative Concentration Pathways (RCPs), was used for the new climate model simulations carried out under the framework of the Coupled Model Inter comparison Project Phase 5 (CMIP5) of the World Climate Research Programme. In all RCPs, atmospheric CO_2 concentrations are higher in 2100 relative to present day as a result of a further increase of cumulative emissions of CO_2 to the atmosphere during the 21st century.

Global surface temperature change for the end of the 21st century is likely to exceed 1.5°C relative to 1850 to 1900 for all RCP scenarios except RCP2.6. It is likely to exceed 2°C for RCP6.0 and RCP8.5, and more likely than not to exceed 2°C for RCP4.5 (See Figures 2.7a). Warming will continue beyond 2100 under all RCP scenarios except RCP2.6. Warming will continue to exhibit inter-annual-to-decadal variability and will not be regionally uniform.

It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase. It is very likely that heat waves will occur with a higher frequency and duration. Occasional cold winter extremes will continue to occur. In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease, while in many mid-latitude wet regions, mean precipitation will likely increase by the end of this century under the RCP8.5 scenario (see Figure 2.6b)

Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this century, as global mean surface temperature increases. Globally, it is likely that the area encompassed by monsoon systems will increase over the 21st century. This statement would have certain interest for researchers in countries like Mongolia, where debate about "how far away monsoon line from the country" is still active. While monsoon winds are likely to weaken, monsoon precipitation is likely to intensify due to the increase in atmospheric moisture. Since the monsoon retreat dates will likely be delayed, resulting in lengthening of the monsoon season in many regions, as noted in the report, this issue needs to be in focus of climate study, particularly, in eastern and south-eastern regions of Mongolia.

There is high confidence that the El Nino-Southern Oscillation (ENSO) will remain the dominant mode of inter-annual variability in the tropical Pacific, with global effects in the 21st century. Due to the increase in moisture availability, ENSO-related precipitation variability on regional scales will likely intensify. Natural variations of the amplitude and spatial pattern of ENSO are large and thus confidence in any specific projected change in ENSO and related regional phenomena for the 21st Century remains low. Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

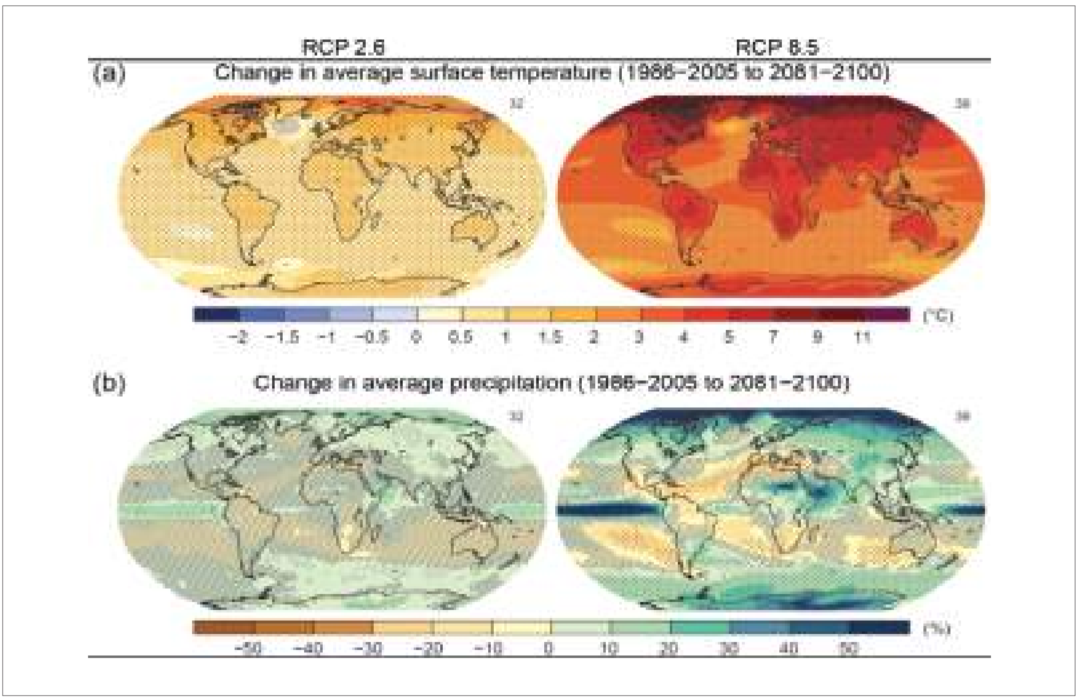


Figure 2.6 Maps of CMIP5 multi-model mean results for the scenarios RCP2.6 and RCP8.5 in 2081–2100 of (a) annual mean surface temperature change, (b) average percent change in annual mean precipitation,

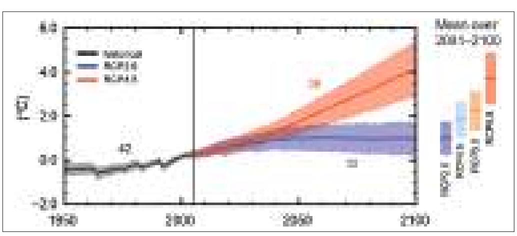


Figure 2.7a Global average surface temperature change relative to 1986–2005

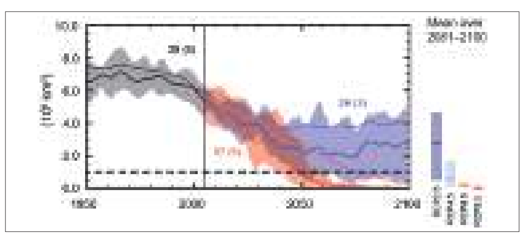


Figure 2.7b Northern Hemisphere September sea ice extent

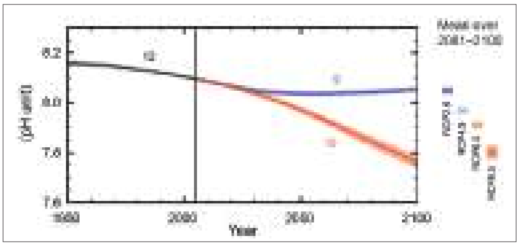


Figure 2.7c Global ocean surface pH

The Figure 2.7 (Source: WGI AR5 2013) demonstrated CMIP5 (Coupled Model Intercomparison Project Phase 5) multi-model simulated time series from 1950 to 2100 for the change in global annual mean surface temperature relative to 1986–2005 (Figure. 2.7a), Northern Hemisphere September sea ice extent (Figure. 2.7b), and the global mean ocean surface pH (Figure. 2.7c). Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). Black (grey shading) is the modelled historical evolution using historical reconstructed forcing. The mean and associated uncertainties averaged over 2081-2100 are given for all RCP scenarios as coloured vertical bars. The numbers of CMIP5 models used to calculate the multi-model mean is indicated. For sea ice extent (Figure. 2.7b), the projected mean and uncertainty (minimum-maximum range) of the subset of models that most closely reproduce the climatological mean state and 1979 to 2012 trend of the Arctic sea ice is given (number of models given in brackets). For completeness, the CMIP5 multi-model mean is also indicated with dotted lines. The dashed line represents nearly ice-free conditions (i.e., when sea ice extent is less than 106 km^2 for at least five consecutive years).

Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions. The global ocean will continue to warm during the 21st century. Heat will penetrate from the surface to the deep ocean and affect ocean circulation. It is *very likely* that the Arctic sea ice cover will continue to shrink and thin and that Northern Hemisphere spring snow cover will decrease during the 21st century as global mean surface temperature rises. Global glacier volume will further decrease.

The AR5 projects it is likely (greater than 66 percent chance) that the Arctic Ocean will be ice-free during part of the summer before 2050 under a high emissions scenario. This represents a large shift from the AR4, which estimated that the Arctic Ocean would not be ice-free during the summer until late in the 21st century (IPCC 2007). The AR5 finds that Arctic sea ice surface extent has decreased by 3.5-4.1 percent per decade (9.4-13.6 percent during summer), which is higher than the AR4 estimate of 2.1-3.3 percent per decade (5-9.8 percent during summer). That amounts to between 0.45 and 0.51 million square kilometers per decade. The AR5 finds these changes unprecedented in at least the last 1450 years.

Global mean sea level will continue to rise during the 21st century. Under all RCP scenarios, the rate of sea level rise will *very likely* exceed that observed during 1971 to 2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets. The AR5 report has significantly increased projected sea level rise over the next century and the new projections show an increase of 0.26-0.55 meters by 2100 under a low emissions scenario and 0.52-0.98 meters under the high emissions scenario. The AR4 did not include some of the effects of ice sheet movement due to warming, and therefore published much lower estimates in the range of 0.18-0.38 meters under a low emissions scenario and 0.26-0.59 meters under a high emissions scenario for sea level rise by 2100 (Figure 2.8).

Total anthropogenic GHG emissions have continued to increase over 1970 to 2010 with larger absolute decadal increases toward the end of this period. Despite a growing number of climate change mitigation policies, annual GHG emissions grew on average by 1.0 gigatonne carbon dioxide equivalent ($GtCO_2eq$) per year (2.2%) from 2000 to 2010 compared to 0.4 $GtCO_2eq$ per year(1.3%) from 1970 to 2000. Total anthropogenic GHG emissions were the highest in human history from 2000 to 2010 and reached in average 49 $GtCO_2$ eq/yr in 2010. The global economic crisis 2007/2008 only temporarily reduced emissions. CO_2 emissions from fossil fuel combustion and industrial processes contributed about 78% of the total GHG emission increase from 1970 to 2010, with a similar percentage contribution for the period 2000–2010 (WGIII AR5 2014).

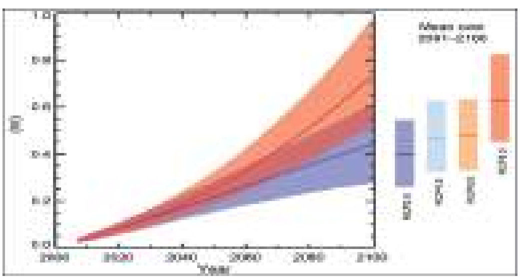


Figure 2.8 Global mean sea level rise

Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond (See Figure 2.9). Most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2. Multi-model results from a hierarchy of climate-carbon cycle models for each RCP until 2100 are shown in Fig.2.9 with coloured lines and decadal means (dots). Some decadal means are labelled for clarity (e.g., 2050 indicating the decade 2040-2049). Model results over the historical period (1860 to 2010) are indicated in black. The coloured plume illustrates the multi-model spread over the four RCP scenarios and fades with the decreasing number of available models in RCP8.5. The multi-model mean and range simulated by CMIP5 models, forced by a CO_2 increase of 1% per year, is given by the thin black line and grey area. For a specific amount of cumulative CO_2 emissions, the 1% per year CO_2 simulations exhibit lower warming than those driven by RCPs, which include additional non-CO_2 forcings. Temperature values are given relative to the 1861-1880 base period, emissions relative to 1870. Decadal averages are connected by straight lines. As it can be seen from the presented Figure 2.9, cumulative emissions of CO_2 will continue increase further during the current century and beyond it “controlling” global climate behaviour if adequate radical counter measure will not be taken in time.

The AR5 noted with *high confidence* that climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere. Higher CO_2 concentrations enhance photosynthesis and growth (up to a point), and reduce the water used by the plant. However, high CO_2 levels cause the nitrogen content of forest vegetation to decline thus reducing their quality as a source of food for plant-eating animals. Furthermore, rising CO_2 causes ocean waters to become acidic (See Figure 2.7c) affecting fish stocks and other aquatic species and can stimulate more intense algal blooms in lakes and reservoirs.

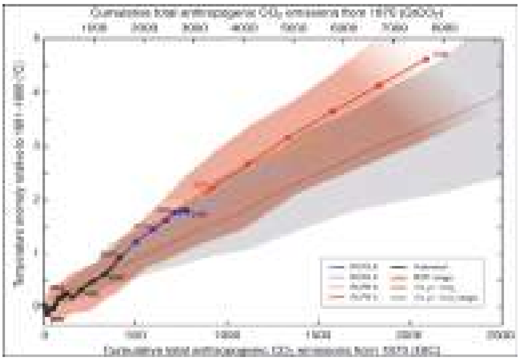


Figure 2.9 Temperature increase and cumulative carbon emissions

2.1.5 The regional and local consequences of the global scale climate change.

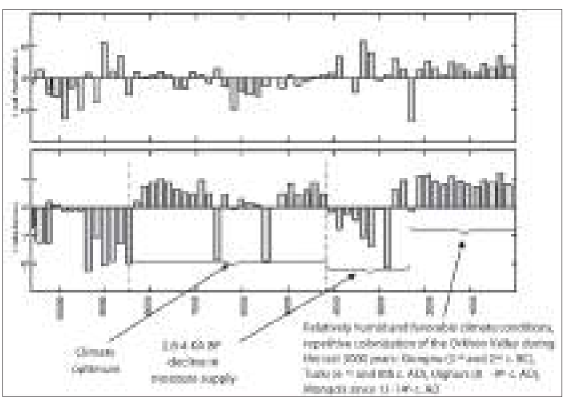
Interaction of climate system with other human and non-human systems is a very complex process involving events of different scales in a wide range of timeframe. This process, in case of Mongolia, has certain specifics due to the country's deep inland location with less direct influence from the world oceans and due to the fact the livelihood approach of people was adaptive to their living environment rather than conquering.

During the long history of the humankind, collapse of empires, raise of nations, mass movement of people, Great Famine, regional conflicts, all were linked to climate fluctuations (Fagan 1999 and 2008). Scientists in China, using multiple paleo climate proxy records obtained from ice cores, tree rings, lake sediments and historical documents, identified five periods of temperature variation during the last 2000 years period; namely, a warm stage in 0-240, a cold interval between 240 and 800, a return to warm conditions from 800-1400, including the Medieval Warm Period between 800-1100, the cool Little Ice Age period between 1400-1920, and the present warm stage since 1920 (Yang et al.2001). The results of a study related to the unsaturated zone moisture profiles in Badain Jaran desert of Inner Mongolia, lead to assumption that before 1300, it was relatively dry, but distinct wet periods may be recognized during 1340-1450, 1500-1610 and 1710-1820. Since the mid 1800s, the climate shows a trend towards greater aridity (Ma and Edmunds 2006).

The researchers suggested that the climate changes during historical periods had significant effects on changes in the position of agriculture–grazing transitional zones and the fate of Chinese dynasties. However, the overall influences of climate remain poorly understood (Wang et al. 2010) while there is some evidence of the collapse of dynasties during periods with a weak summer Asian Monsoons or periods with unusually low temperatures . Over the last 2000 years, for instance, around 38 ancient cities were abandoned through desertification in Hexi Corridor in Northwest China. While macro-process of desertification was mainly controlled by the climate changes, there was another factor also contributing to these incidents. The population density in the middle of Qing Dynasty had exceeded its critical index of population pressure and usage of water resources had exceeded 40% in Hexi Corridor (Wang et al. 2005).

There still are not many studies available on the historical aspect of a relationship between climate and social systems for the current territory of Mongolia. The studies undertaken in the basins of the lakes Khuvsgul in the north, Uvs in the west and Ugii in the central part of Mongolia and other regions with "old age" lakes have shed some light on climate history during the Holocene and other periods. Researchers inferred that between 4 and

2.8 ka BP, a decline in moisture supply occurred, followed by relatively humid conditions until today. Late Holocene was characterized by favorable climatic conditions that probably were an important prerequisite for the repetitive colonization of the Orkhon Valley throughout the last 3000 years (Schwanghart et al. 2008). The petroglyphs, khirigsuurs, wall remnants, numerous burials and memorial stones in Orkhon valley and adjusted areas testify to anthropogenic influence since the Palaeolithic and document the presence of different tribes, including Xiongnu (BC 3rd-2nd century), Turks (AD 6 - 8th century) and the Uighurs (AD 8 - 9th century). Remnants of Karakorum, the capital of the Mongolian empire in the Orkhon Valley is the best evidence of the raise of Mongols as a nation. The climate was obviously favorable (Figure 2.10) since the area had been able to support extended agricultural activities to meet the supply and demand of the internationalized capital city of the empire.



Figire 2.10 Holocene climate and landscape evolution of Ugii Nuur basin, Orkhon Valley, Central Mongolia. (The graph was modified by author using original graph from: Schwanghart et al. 2008)

Nomadic lifestyle was created as a way of life for human beings in unstable harsh climate conditions with added stresses due to prolonged cooling and dry periods. When severity of climate condition was exceeding their survival threshold, it could lead to diminishing capacity of communities to sustain life, resulting in shrinking of their population. It can be assumed that expansion and migration were possible only when the climate conditions shift to its positive phase (more warm periods with increased or regular rainfalls) supporting the capacity building to expand their domain of inhabitation and to maintain other capabilities. Conflicts or clashes with neighbors, in most cases, probably were occurring for life style, but not for life space (Batjargal and Enkhjargal 2013b). In this respect, one can say that the Chinese Great White Wall served much less purpose in preventing sporadic attacks from nomadic tribes of north, but more in preventing them from moving to the south due to worsening weather and climate conditions in their lands. In fact, it stands almost as a border line between nomadic and settled life styles preventing mass migration from both sides. Apparently, this unprecedented endeavor of human beings had benefited those whom the Wall was intended stop more. Nomadic tribes, obviously, due to their tiny size of population in comparison with those who were settled inside the Walls might not have been able to avoid or withstand the possible radical assimilation during the long period of history, unless the Wall shielded them from this ill fate (Batjargal and Enkhjargal 2013b). Some authors believe that Mongols transformed to pastoralism from nomadism thanks to efforts made by Hublai Khan while he was establishing the Yuan empire with its capital city in the heart of the sedentary Chinese civilization (Bergreen 2007). No doubt that a comprehensive studies are needed for more deep understand the

Mongolian specifics in linkage between climate conditions and transformation in society, in its historical perspective

2.1.6 Climate of Mongolia in the last centuries

The reconstructed surface temperature at hemispheric and global scale for much of the last 2000 years, using an expanded set of proxy data, updated instrumental data, and additional complementary methods that tested and validated with model simulation experiments, has led to the conclusion that the recent Northern Hemisphere surface temperature increases are likely anomalous in a long-term context, for at least the past 1300 years (Mann et al. 2008). The results of analyses of the surface air temperature variations during the last 100 years (1901–2003) in mid-latitude Central Asia suggest that temperature variations in four major sub-regions, i.e. the eastern monsoonal area, Central Asia, the Mongolian Plateau and the Tarim Basin, respectively, are coherent and characterized by a striking warming trend during this period. The average annual mean temperature increasing rate for the Mongolian Plateau was 0.23°C per decade while it was 0.18°C for the whole four sub-regions. In Asian mid-latitude areas, surface air temperature increased relatively slowly from the 1900s to 1970s, and it has increased rapidly since 1970s (Chen et al. 2009).

The Mongolian proxy record for temperature extended back over 450 years, based on the sampling from the Tarvagatain mountains located in western Mongolia matches up well with large-scale reconstructed and recorded temperatures for the Northern Hemisphere and the Arctic (Batima et al. 2005), clearly indicating the increase of temperature over the past hundred years. The longest reconstruction for the past 1700 years made on the sample taken from the site Solongotiin Davaa (Solongot pass), located in north-central Mongolia (D'Arrigo et al. 2001), also has shown that the twentieth century is the warmest period in Mongolian history during the last millennium. The most severe cold occurred in the 19th century and recent decades have been some of the warmest in the past 500 years for this region. According to the instrumental record the annual mean temperature in Mongolia increased by 2.14°C during the last 70 years with certain fluctuations, including decrease of the mean temperature in winter season for the period of 1990-2006 (MNET 2009). The warming trend indicated in all ecological zones during the last 4 decades and the trends were more or less synchronous (Batjargal and Enkhjargal 2013a) despite the big enough distance between them (Figure 2.11).

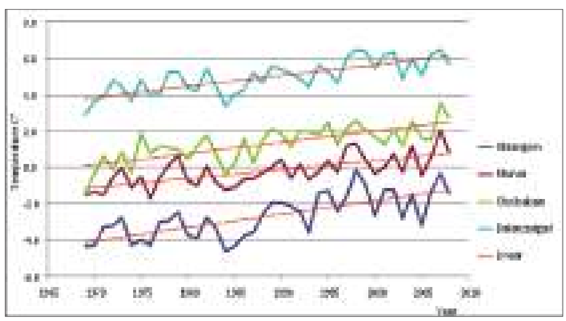


Figure 2.11 Mean temperature trend in different distinct ecological zones (West, North, East and South) in Mongolia

In respect of precipitation the trend was a little bit different. Almost no change was indicated during this period except slight decrease in "open" areas like steppe in the east and Gobi in the south (Figure 2.12).

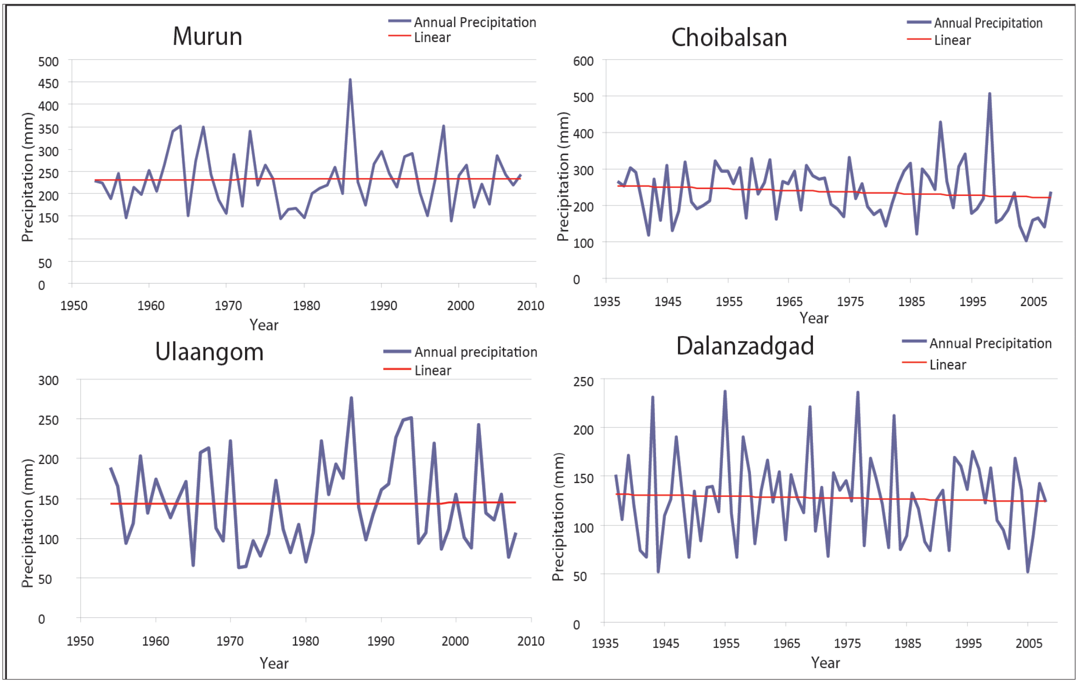


Figure 2.12. Annual precipitation trend in different distinct ecological zones (West, North, East and South) in Mongolia

2.1.7 Climate impact mechanism for the territory of Mongolia

Central Asia, including Mongolia, is located in the triangle of the Westerlies, the East Asian Monsoon and Indian Monsoon (Figure 2.13).This circulation pattern governing moisture supply in Mongolia raises the question, in how far the paleoclimatic evolution in this area differs from or resembles to developments recorded in the summer monsoon dominated regions to the south or the Westerlies dominated border regions to the North. The ecosystem patterns and environmental condition in this area as a whole are strongly influenced by moisture supply from outside, the temporal and spatial variability of the wind systems are crucial for landscape evolution in this area (Chen et al. 2008;Herzschuh 2006; Li et al. 2008; Qian et al. 2009b). There is evidence that the region was sensitive to changes of the westerlies during the early Holocene period (Schwanghart and Schütt 2008).

Figure 2.13. Moisture supply scheme for the territory of Mongolia through atmospheric circulation. *Source for monsoon impact line: the present-day monsoon limit after (Herzschuh 2006)*

Extremely dry air causes a strong radiative cooling of the surface and temperature regime in winter in most part of Mongolia controlled by high pressure, including the stable so called

Siberia-Mongolian High (SMH) with short period interruption due to infrequent cyclonic activities. Any slight alteration in intensity of cyclonic activities' trajectories would have direct impact on precipitation patterns in most parts of the territory of Mongolia. The dominant Interannual and Decadal variability of surface air temperature (SAT) all over Asia in winter seasons are connected with the influence of surrounding oceans (Miyazaki and Yasunari 2008). These and other relevant circumstances can serve an explanation for the inconsistency in localized response to global warming in the region. Territory of Mongolia is a tiny latitude oriented land strip, which is located at the end of Westerlies' pathway over the middle latitude inland areas of Eurasian super continent (Figure 2.13). The Westerlies are bringing most of air moisture from distant Atlantic Ocean with partial contribution from North Seas (Natsagdorj 1980, Tuvdendorj, Myagmarjav 1986, Dagvadorj et al. 1994, Mijiddorj 2000).

Contribution in supply of air moisture for Mongolia from seas in Pacific and Indian ocean areas has not yet been reported and its direct impact is questionable as discussed above. The moisture transport along the southwesterly wind of the Asian summer monsoon has difficulty reaching Mongolia as a monthly/seasonal mean perspective. However, eastern Mongolia and northeast China are situated on the border area between westerly wind moisture transport by mid latitude synoptic cyclones and southerly wind moisture transport by Asian summer monsoon (Sato et al. 2004). It should not be neglected, partly because of the change in glacier situation in the Tibetan Plateau and land cover change in East Asia, and as well as, in light of remarks, made in the new AR5 in relation with monsoon circulation.

Studies have shown that large and abrupt fluctuations in the Asian monsoon have occurred numerous times and with great regularity throughout the Holocene, and that the sun played an important role in orchestrating them (Li et al. 2008). A number of factors influence the performance of the South Asian summer monsoon. In addition to sea-surface temperature conditions over the equatorial Pacific and the Indian Oceans, these include winter and spring snow cover and land-surface temperatures over Northern Hemisphere. The strong El Nino event of 1997-1998 was followed by a prolonged La Nina phase that extended from mid-1998 to early 2001, which was consistent with consecutive 3 years zud condition in Mongolia, caused serious economic damage and negative social consequences (Batjargal et al. 2000).

The weak to moderate strength La Nina of 2011-2012 ended in early April 2012, as tropical Pacific sea surface temperatures, sea level pressure and trade winds returned to neutral levels of El Nino/Southern Oscillation (ENSO), with neither El Nino nor La Nna prevailing. As of mid 2014 the tropical Pacific Ocean surface temperatures have reached El nino thresholds, and exceeded them in the far eastern portion of the basin. However the atmospheric indicators remain neutral, and hence an El Nino is not considered to have started for a while (WMO 2014a). A potential reason for this lack of atmospheric response could be explained by the fact that the sea surface temperatures are above average across virtually the entire tropical Pacific, not just in the eastern and central portions (WMO 2014b). All these circumstances need to be carefully considered and analyzed in downscaling exercises from global model results to regional and localized ones.

2.1.8 Recently observed and projected climate change in Asia, referring to the IPCC reports

New analyses continue to support the AR4 and SREX conclusions that it is *likely* that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased across most of Asia since about 1950, and heat wave frequency has increased since the middle of the 20th century in large parts of Asia (WGI AR5 2013). Over the period 1901-2009, the warming trend was particularly strong in the cold season between November and March, with an increase of 2.4°C in the midlatitude semi-arid area of Asia and large warming trends (>2°C per 50 years) in the second half of the 20th century were observed in the northern Asian sector (Figure 2.14)

Precipitation trends, including extremes, are characterized by strong variability, with both increasing and decreasing trends observed in different parts and seasons of Asia. In northern Asia, the observations indicate some increasing trends of heavy precipitation events, but in central Asia, no spatially coherent trends were found. Both the East Asian summer and winter monsoon circulations have experienced an interdecadal scale weakening after the 1970s, due to natural variability of the coupled climate system, leading to enhanced mean and extreme precipitation along the Yangtze River valley (30°N), but deficient mean precipitation in North China in summer (WGI AR5 2013). A weakening of the East Asian summer monsoon since the 1920s was also found in sea level pressure gradients. A decrease in extratropical cyclone activity and intensity over the last 50 years has been reported for northern Eurasia (60°N-40°N), including lower latitudes in East Asia.

2.1.9 Potential impacts of the global climate change within the Asian region, including Mongolia.

The water resources

The water scarcity is expected to be a big challenge in many Asian regions because of increasing water demand from population growth and consumption per capita with higher standards of living. Shrinkage of glaciers in central Asia is expected to increase due to climate warming, which will influence downstream river runoff in these regions (WGII AR5 2014). It is suggested that freshwater resource will be influenced by changes in rainfall variability, snowmelt or glacier retreat in the river catchment, and evapotranspiration, which are associated with climate change. Glaciers are important stores of water and any changes have the potential to influence downstream water supply in the long term like for instance, in western part of Mongolia (Davaa 2011). The water scarcity in northern China, for instance, has been exacerbated by decreasing precipitation, doubling population, and expanding water withdrawal from 1951 to 2000 (Xu*et al.*, 2010), while there is no evidence that suggests significant changes of groundwater in the Kherlen River Basin in Mongolia over the past half century (Brutsaert and Sugita, 2008). Apart from water availability, there is *medium confidence* that climate change also leads to degradation of water quality in most regions of Asia, although this is also heavily influenced by human activities (Winkel*et al.*, 2011).

Projections suggest there will be insufficient water in China for agriculture in the 2020s and 2040s due to the increases in water demand for non-agricultural uses, although precipitation may increase in some areas (Xiong*et* *al.*, 2010). Mismanagement of water resources has increased tension due to water scarcity in arid areas. Adaptation of freshwater resources to climate change can be identified as developing adaptive/ integrated water resource management of the trade-offs balancing water availability against increasing demand, in order to cope with uncertainty and change (Molle and Hoanh, 2009). Better water management strategies (Dorjsuren 2011) could help ease water scarcity. Examples include developing water saving technologies in irrigation, building reservoirs, increasing water productivity, changing cropping systems and water reuse.

Inland water related issues

Climate change impacts on inland waters will interact with dam construction, pollution, and land use changes. Increases in water temperature will impact species, like cold water fish and temperature-dependent processes. Climate change is also expected to change flow regimes in running waters and consequently impact habitats and species that are sensitive to droughts and floods. Habitats that depend on seasonal inundation, including floodplain grasslands and freshwater swamp forests, will be particularly vulnerable. For most Asian lakes, it is difficult to disentangle the impacts of water pollution, hydro-engineering, and climate change. In Mongolia the existing irrigation systems, newly constructed hydropower stations on small rivers without outlet from the country and proposed projects for electricity production using water of bigger rivers with trans boundary issues are topics for polemic and discussions involving public, media and policy makers. But possible impact from climate change in relation with those issues so far ignored, probably, because of evidence based mentality.

The food security

Climate change impacts on temperature and precipitation will affect food production and food security in various ways in specific areas throughout this diverse region. Climate change will have a generally negative impact on crop production in Asia, but with diverse possible outcomes. For example most simulation models show that higher temperatures will lead to lower rice yields as a result of a shorter growing period. But some studies indicate that increased atmospheric CO_2 that leads to those higher temperatures could enhance photosynthesis and increase rice yields. This uncertainty on the overall effects of climate change and CO_2 fertilization is generally true for other important food crops such as wheat, sorghum, barley, and maize among others. Yields of some crops will increase in some areas (e.g. cereal production in north and east Kazakhstan) and decrease in others (e.g. wheat in the Indo-Gangetic Plain of South Asia). In Russia, climate change may lead to a food production shortfall, defined as an event in which the annual potential production of the most important crops falls 50% or more below its normal average (WGII AR5). Sea-level rise is projected to decrease total arable areas and thus food supply in many parts of Asia. A diverse mix of potential adaptation strategies, such as crop breeding, changing crop varieties, adjusting planting time, water management, diversification of crops and a host of indigenous practices will all be applicable within local contexts.

Human health

Climate change will have widespread and diverse health impacts. More frequent and intense heat waves will increase mortality and morbidity in vulnerable groups in urban areas. Changes in the geographical distribution of vector-borne diseases, as vector species that carry and transmit diseases migrate to more hospitable environments, will occur. Extreme climate events will have an increasing impact on human health, security, livelihoods, and poverty, with the type and magnitude of impact varying across Asia. More frequent and intense heat-waves in Asia will increase mortality and morbidity in vulnerable groups. Increases in heavy rain and temperature will increase the risk of diarrheal diseases, dengue fever and malaria.

Biological resources

Biological changes consistent with climate trends have been reported in the north and at high altitudes, where rising temperatures have relaxed constraints on plant growth and the distributions of organisms. Impacts on inland water systems have been difficult to disentangle from natural variability and other human impacts For example, the shrinking of the Aral Sea over the last 50 years has resulted largely from excessive water extraction from rivers, but was probably exacerbated by decreasing precipitation and increasing temperature.

Satellite NDVI (Normalized Difference Vegetation Index) for Asia for 1988-2010 shows a general greening trend, except where water is limiting. Changes at high latitudes show considerable spatial and temporal variability, despite a consistent warming trend, reflecting water availability and non-climatic factors. In Central Asia, where NDVI is most sensitive to precipitation there was a heterogeneous pattern for 1982-2009, with an initial greening trend stalled or reversed in some areas.

Forest

Changes in the distributions of major vegetation types (biomes) have been reported from the north and high altitudes, where trees are invading treeless vegetation, and forest under stories are being invaded from adjacent biomes. In central Siberia, dark needle conifers (DNC) and birch have invaded larch-dominated forest over the last three decades. Soil moisture and light are the main factors governing the forest-steppe eco tone and Mongolian taiga forests have responded heterogeneously to recent climate changes, but declines in larch growth and regeneration are more widespread than increases (Dulamsuren *et al.*, 2010a, 2010b).

Permafrost

In the Northern Hemisphere, a 20-90% decrease in permafrost area and a 50-300 cm increase in active layer thickness driven by surface warming is projected for 2100 by different models and scenarios. It is *likely* that permafrost degradation in North Asia will spread from the southern and low-altitude margins, advancing northwards and upwards, but rates of change vary greatly between model projections. Permafrost formed during the Little Ice Age is thawing at many locations and Late Holocene permafrost has begun to thaw at some undisturbed locations in northwest Siberia. Permafrost thawing is most noticeable within the discontinuous permafrost zone and the boundary between continuous and discontinuous permafrost is moving northwards. In Mongolia, mean annual permafrost temperature at 10-15 m depth increased over the past 10-40 years in the Hovsgol, Hangai and Hentei Mountain regions. Permafrost warming during the past 15–20 years was greater than during the previous 15-20 years (Sharkhuu *et al.*, 2008; Zhao *et al.*, 2010).

Drought stress

For much of interior Asia, increases in drought stress, as a result of declining rainfall and/or rising temperatures, are the key concern. Because aridity is projected to increase, for instance, in the northern Mongolian forest belt during the 21st century (Sato *et al.*, 2007), larch cover will *likely* be reduced (Dulamsuren *et al.*, 2010a). In the boreal forest region, a longer, warmer growing season will increase vulnerability to fires, although other human influences may over shadow climate impacts in accessible areas.

Negative and non-negative impact of the carbon dioxide.

Changes in precipitation will be important for semi-arid and arid ecosystems, as may the direct impacts of atmospheric CO_2 concentrations, making responses harder to predict. Rising CO_2 concentrations are expected to favor increased woody vegetation in semi-arid areas. The future direction and rate of change of steppe vegetation are unclear because of uncertain precipitation trends. The role of CO_2-fertilization is also potentially important here (WGII AR5).

Climate change attributed extreme events

Increases in floods and droughts (IPCC 2012) will exacerbate rural poverty in parts of Asia due to negative impacts on crops, particularly, on the rice and wheat and resulting increases in food prices and the cost of living. Decreased summer precipitation in Mongolia with non frequent heavy rainfalls would increase risks of desertification (IG/EIC 2014) and local flooding with damages. Increase of heavy snowfall events in winter season would cause added stresses on traditional livestock husbandry and other economic sectors like transport, mining etc. Climate change attributed extreme events will have greater impacts on sectors with closer links to climate, such as water, agriculture and food security, forestry, health, and tourism and all of them relevant to the current and future development of the Mongolian society.

Sustainable development issues

Climate change is expected to adversely affect the sustainable development capabilities of most Asian developing countries by aggravating pressures on natural resources and the environment. Asia is predominantly agrarian, with 58% of its population living in rural areas, of which 81% are dependent on agriculture for their livelihoods. Rural poverty in parts of Asia could be exacerbated due to negative impacts from climate change on crop production, and a general increase in food prices and the cost of living. In AR4 the climate change was projected to lead mainly to reductions in crop yield. New research shows there will also be gains for specific regions and crops in given areas. In Mongolia the precipitation trend in principal cropland areas is not favorable for plant growth for certain period in coming decades (Gomboluudev 2006). A diverse mix of potential adaptation strategies, such as crop breeding, changing crop varieties, adjusting planting time, water management, diversification of crops and a host of indigenous practices will be needed to use in complimentary manners , while combining in optimal way the best traditional practices and modern technologies (MEGD 2013) within local contexts.

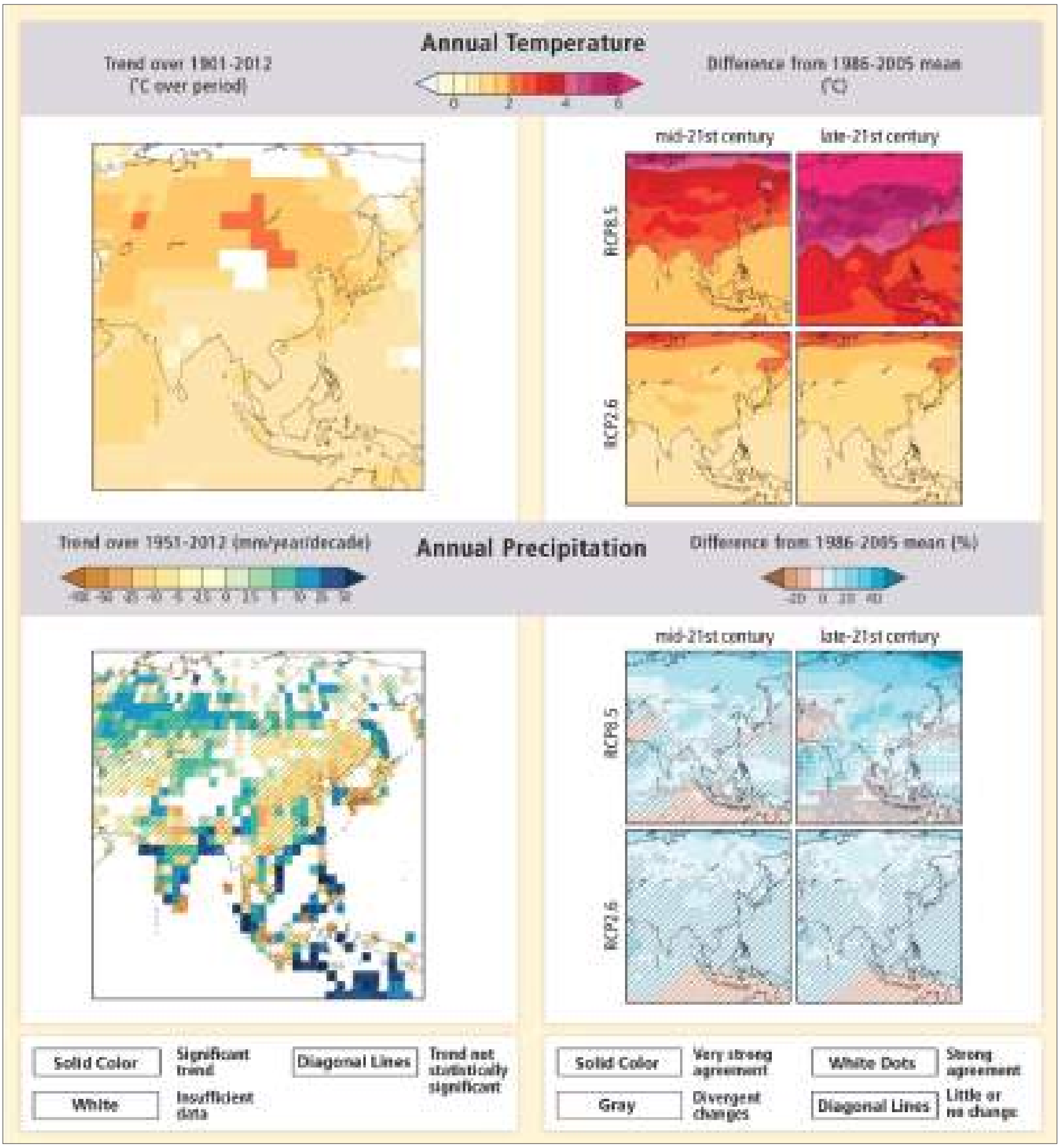


Figure 2.14 Observed and projected changes in annual average temperature and precipitation in Asia. Observed temperature trends from 1901-2012 determined by linear regression (Top panel, left). Observed precipitation change from 1951-2010 determined by linear regression. [WGI AR5 Figure SPM.2] For observed temperature and precipitation, trends have been calculated where sufficient data permits a robust estimate (Bottom panel, left). Other areas are white. Solid colors indicate areas where change is significant at the 10% level. Diagonal lines indicate areas where change is not significant. CMIP5 multi-model mean projections of annual average temperature changes and average percent change in annual mean precipitation for 2046-2065 and 2081-2100 under RCP2.6 and 8.5 (Top and bottom panel, right). Solid colors indicate areas with very strong agreement and>90% of models agree on sign of change. Colors with white dots indicate areas with strong agreement, where>66% of models show change greater than the baseline variability and >66% of models agree on sign of change. Gray indicates areas with divergent changes, where >66% of models show change greater than the baseline variability, but <66% agree on sign of change. Colors with diagonal lines indicate areas with little or no change, less than the baseline variability in >66% of models. *Source: WGI AR5 2013*

2.2 Climate Research and Observed Climate Change in Mongolia

2.2.1 Monitoring of the Climate System

Climate observation network. There are 135 meteorological stations in Mongolia which conduct regular observation of the air pressure, air and soil surface temperature, air humidity, precipitation, wind, distribution of snow cover, thickness of snow (when there is snow) and air phenomena 8 times daily in line with the World Meteorological Organization (WMO) program (Figure 2.15). In soums or in the primary administrative units of Mongolia (around 330 in total), there are 181 meteorological observation posts where 1 observer can work during day light. At the meteorological posts, observations of soil surface temperature, relative humidity, wind and air phenomena are conducted at 00, 06 and 12 o'clock GMT. The 40 stations of Mongolia's meteorological observation network belong to the WMO basic synoptic station network, 10 of which are included in the Global Climate Observing System(GCOS) list. Since 1993, automatic devices are installed at the meteorological stations with the result that human and automatic are combined in currently 90-95 posts. However, the fact that automatic devices installed in Mongolia are of 6 different brands (CAMS62020 pieces from China, MAWS3018 pieces, AWS330, 40 pieces from Vaisala, Finland, SK4100 7 pieces from Japan etc.), poses challenge for consistency in measurement.

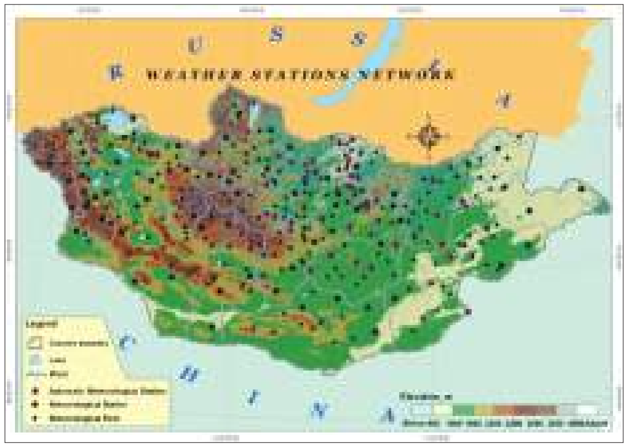


Figure 2.15: Meteorological basic observation network of Mongolia

Around 40 meteorological stations measure soil temperature in depths of 20 to 320 cm and 24 stations can measure in depths up to 1 m. About 25 stations used to record the intensity of rain precipitation with rain recorder (recording on a paper ribbon) whereas now at 20 points, old rain recording gauge is used and at 50 stations automatic devices are used.

Actinometric network. Around 1961, solar radiation observation network was first established in Mongolia. Since 1970's to 2004-2005, direct and scattered sunlight, long and short-wave radiation balance, surface albedo were measured in 19 points. Due to automation of stations, this number has decreased and today, in addition to the 5 stations belonging to the WMO actinometric stations network, 6 stations with Russian old instruments are measuring the accumulated ray and radiation balance. Solar radiation was measured in 32 stations and since 2008, due to the expansion of automatic devices.

Aerological network. In Mongolia, since 1939,observation with balloon ascent and since 1941, aerological observation has started. 8 aerological stations were functional until 1990's but today 7 of them can hardly function due to shortage of funds so that irregular observation is conducted including twice daily in Ulaanbaatar, once daily in Murun and Ulaangom stations. 2 stations worked for a certain period of time with the Chinese and Korean support, however, 2 in Altai and Arvaikheer are stopped to work temporary. In aerological network, also devices of different systems are used including ABK 2 from Russia, M2K2 - DC MODEM from France and DigiCORA of Vaisala, Finland.

Greenhouse gas monitoring site. The National Oceanic and Atmospheric Administration (NOAA) of the USA established a greenhouse gas observation point in a location called "Ulaan uul" in Erdene soum, Dornogobi province in 1991 which was first of its kind in central Asia that belonged to the global greenhouse gas monitoring network. Since 1992 until today, the Climate Monitoring and Diagnostics Laboratory (CMDL) of the NOAA is measuringthe greenhouse gases, publishing the results and archiving it in the World Data Centre for Greenhouse Gases in Tokyo, Japan.

Dust storm monitoring in Mongolia. Since the early days around 1936 when first meteorological stations were established at the organization for hydrology and meteorology, visual observation of dust storms started and as the meteorological observation network expanded, so did the dust storm observation. As of 2014, in 135 meteorological stations and 181 posts, visual synoptic observation of dust storm is conducted. Other countries are using satellite data for detecting and analyzing dust storm, volcanic ash etc. extensively for research which began in Mongolia around the 2000.

Since 2000, globally, dust storm has been observed and measured intensively. These observations include dust size distribution, mass content, chemical structure and optic qualities of dusts. In addition, the vertical distribution of dusts is measured by ground based Lidar (Light Identification, Detecting and Ranging) device.

In order to conduct detailed research on the content of the dust from the soil of countries where dust storm originate and vertical distribution, the long range distribution, to develop the dust storm prevention system and to improve the results from models, a regional master plan "Monitoring and prevention of dust storm in North east Asia" was developed in 2003 with the support from the Asian Development Bank, Global Environment Facility and the UNEP. According to the master plan, dust storm monitoring network is supposed to be established in Mongolia. Following this plan, since 2006, a new network including dust storm, dust measurement, monitoring and early warning system has been established in the national hydrology, meteorology and environment network. As of 2013, the number of dust measuring stations reached 11, creating a dust monitoring network. Figure 2.16 shows the location of these stations.

Figure 2.16 Location of dust monitoring stations in Mongolia.

Agrometeorological observation network. In 44 meteorological stations and posts of agriculture regions, observation of wheat, potato, phenological phase of vegetables, height, density, damage conditions, cause, yield, precipitation in certain fields and indicator for productivity of certain plants (e.g. weight of 1000 wheat seed etc.) is conducted.

Land cover monitoring. In 329 soums, a land monitoring and measurement of pasture condition is conducted since the 1960's. The pasture condition observation network is divided into 3 types a) phenology of pasture plants, b) common pasture pests and rodents and c) pasture degradation or desertification (since 2001).

a) Observation of plant growth stages is conducted on the dominant 2-4 species of a specific pasture group from the re-growth of spring or since the protrusion till the drying and withering in autumn; in the unfenced plot on the 9th, 19th and 25th of each month and in the fenced plot, on every even days (if the plot is farther than 5 km away from the station, then twice every 10 days, such as on the 4, 10, 14, 20, 24 etc.).

b) The regular observation of pasture pests and rodents conducted on unfenced plots on the 9th, 19th and 25th of each month and if there are too many pest or rodents, then a certain area is chosen on a specific pasture for monitoring. Such observation includes pasture pests, locust larvae and adult locust development stages, spring and fall "container" density, pasture rodents, epicenter of Brandt's vole area, distribution, density and damage caused to the pasture. Based on these observations, a map is produced which shows where plant diseases, pest and rodents are spread as well as their epicenter and distribution in the soum area.

c) Assessment of pasture condition and desertification is conducted by mobile research stations at the smallest administrative unit (bagh) level at about 1550 points. The mobile research has two categories - regular and seasonal- and it has the objective to provide important information for pasture management including evaluation of winter-spring, summer-fall general conditions, pasture carrying capacity, volume, pasture degradation and/or desertification.

The pasture volume for winter-spring is evaluated based on pasture yield condition and type and number of livestock in that bagh or soum during the second ten days of August. Winter pasture condition is determined for the given winter and spring site using:

- Snow cover, density, depth, ice layers;
- Condition of plants above snow;
- Pasture edibility.

In addition, soum and bagh's pasture, water, fodder availability, livestock weight and strength are evaluated.

Meteorological observation of animal husbandry. Environmental factors on livestock were observed in over 10 soums representing different ecological zones from 1976 till the 1990's. Today, this observation is conducted on cattle, sheep and goat herd in 7 points of 3 soums representing desert, steppe and forest regions. This includes,

- Mobility
- Strength and fatness or weight (young male or adult female livestock)
- Micro-climate in the fenced area
- Disease, mortality, causes etc.

Soil moisture monitoring. In Mongolia, soil moisture of pasture and cultivated areas in depths up to 1m is measured in 54 points with weight methods every 10 days. Soil moisture of fallow land is also measured. Before measuring soil moisture, the agro hydrographic parameters of the given area is determined with laboratory and field methods and it is updated every 10 years. During the soil thawing and freezing period, mobile stations measure the soil moisture in 135 points using weight method. Since 2014, soil moisture of 26 points on pasture and cultivated areas are measured with automatic devices.

Surface water monitoring. National agency for meteorology, hydrology and environmental monitoring of Mongolia conducts surface water monitoring. Runoff observations of rivers have started in 1942 and today in 132 stations, water level, discharge, ice phenomena, ice thickness and water temperature are measured daily. In addition to this, several stations collect and measure sediment samples. Also, 18 large and small lake water levels are monitored (Figure 2.17).

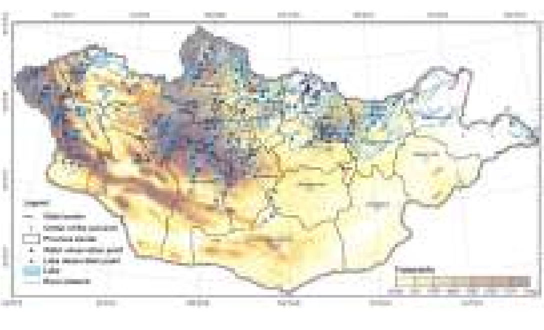


Figure 2.17 Location of hydrological monitoring stations

In addition, at the 106 fixed points collect samples of water plankton and other related items and analyze them. 177 water quality and chemistry fixed points take samples and analyze the chemical composition, biological pollution and hard metals. 25 subsurface water observation points, 11 stream source observation points and 10 water surface and soil moisture evaporation measurement points are operational.

Cryosphere monitoring. Cryosphere monitoring in Mongolia begun around the 1950's. Even though the first boreholes for cryosphere monitoring were made already at the end of 1950's, the measurements lacked continuity and common methodology. Related to climate warming, a national permafrost monitoring network has been established with around 120 boreholes within the framework of following international and national programs and projects: the Global Terrestrial Network for Permafrost (GTN-P), circumpolar active layer monitoring, thermal state of permafrost, Mongolian National Water program, Japan-Mongolia joint project implemented at the Institute of Geography and Mongolian government's "Long term monitoring and research of permafrost" research program. These boreholes belong to the Institute of Geography of the Mongolian Academy of Sciences and the Institute of Meteorology, Hydrology and Environment (Figure 4).

Glaciology and permafrost monitoring. The glacier and ice stream mass - balance observation is conducted in Tavanbogd, Tsambagarav, Munkhkhairkhan and Turgen mountains since 2003. It includes melting, accumulation, area of ice, thickness, water regime and regular meteorological observation. There are several permafrost monitoring sites in Mongolia (Figure 2.18).

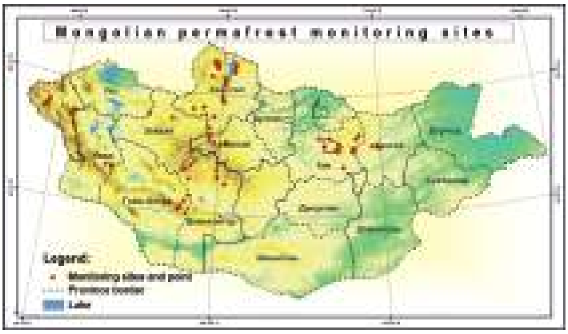


Figure 2.18 Permafrost monitoring sites /Newly established since 2005-2006/

Aerospace surveillance system. Since 1970, Mongolia received analog data from polar meteorological satellite and used it for developing weather forecasts. However, the quality of this data was not sufficient, therefore, since 1986-1988, satellite digital data has been used, which created the possibility to conduct research not only of clouds but also on other rapidly changing natural resources. In 1994 ARC/INFO geographic information system was installed that combines satellite data with terrain data, thus creating a large information database that fulfills modern technological requirements. Within the framework of the cooperation agreement of 1993 with the National Aeronautics and Space Administration of the USA, a new system for receiving and processing digital data from satellites became operational in 1995 and started receiving and processing SeaWIFS digital data from SEAstar satellite. From 2001 to 2003, the number and type of satellite sources increased thus including NOAA16 and FY2C of People's Republic of China. In May 2008, within the "National geo-information center for natural resource management" project funded by the Government of the Netherlands, a terrestrial station for receiving data from the FY2C satellite was established. The advantage of this type of data from the satellite is that it has a good temporal density or it can send data every 30 minutes. At our station it has been configured to receive every hour. With the possibility to receive this type of data, opportunity was created to conduct monitoring of rapidly changing phenomena. In August 2013, with the upgrading of the land station that receives data from MODIS/Terra, Aqua satellites, it became possible to receive data from its next generation model NPP (Suomi) and also the next generation model of NOAA, the Meteo satellite of the European Union.

2.2.2 Climate research

In recent years, climate research in Mongolia has gained momentum and progress has been made in the following areas: downscaling global climate model results using regional dynamic models, atmosphere and land cover interaction assessment, risk assessment of climate change in relation to natural and socio-economic factors, climate adaptation technology needs assessment, development of climate adaptation policy and strategy, historic climate change research with the analysis of annual tree ring growth and geological sediments.

Regional dynamic downscaling is conducted using a regional climate model RegCM3 on the results of global climate models in order to identify specific region's history and to conduct detailed assessment of the future climate trends (Gomboluudev P. 2010). Based on these results, assessment of water resources in selected river basins (Buyant, Khovd, Kharkhiraa-Turgen, Ulz) and recommendations for measures that need to be taken were developed (Davaa G. et al. 2012).

The question of how land cover change or desertification that has intensified in the last 30 years in Mongolia affects the constitution of climate regime deserves special attention.

Some research results were published on how climate regime changes with the altering of land cover types in East Asia and in Mongolia (Natsagdorj L. and Gomboluudev P. 2009, P.Gomboluudev 2011). Results of model based experiments show, if Mongolia's desert-steppe region turns into desert, and steppe region into desert-steppe, it would increase summer air temperature by 1.0^{0}C, land surface temperature by 1.5^{0}C and decrease total precipitation by 14%. In terms of atmospheric circulation, following changes may be observed: weakening of west and north-western circulation, weakening of the moisture convergence due to decrease of latent heat determined by total evaporation and enhancement of atmospheric down current due to land surface radiation heat loss. Chinese scientists have also conducted research on how future potential change of pasture could affect Mongolian climate (Fan Zhang, Xing Li et.al. 2013). According to this research, by the mid-century (at 10 year level of 2040-2050), total annual precipitation in Mongolia could decrease by 20-50mm. This is not an insignificant number and especially the fact that it predicts highest precipitation decline in the Great Lakes depression area which already gets little precipitation deserves special attention.

The main cause for pasture degradation is the doubling of livestock number since the 1990's, change of traditional herd composition where goats used to compose 20% of the total herd and now this number has doubled in combination with the drying of the climate. Asian Development Bank and the Swiss Development Cooperation conducted a joint field research using Century 4.0 model to evaluate the change in soil biology in order to find out the change in mechanic structure of soil and soil fertility in relation to pasture degradation degree on the example of Tariat soum of Arkhangai aimag located in a forest-steppe region (Wang S. et. al., 2014). This research showed for the first time, when evaluating pasture degradation, it is not sufficient to consider only the vegetation cover, instead soil fertility, for instance detection of organic carbon change is of high importance.

Considerable progress has been made in assessing climate change impacts. Mongolian scientist Davaa G. has been conducting regular monitoring of glaciers in the Altai high mountains since 2003 and found out that glaciers have decreased by 30% since 1940's (Davaa G. et. al. 2010). Number of research has been conducted on assessing climate extremes such as drought and zud impacts on animal husbandry (L.Natsagdorj, G. Sarantuya 2011, Altanbagana, 2013). Altanbagana proposed assessing pasture carrying capacity for evaluating zud risks whereas Natsagdorj proposed calculating climate elements trend for drought and zud assessment. He also stated, winter cold intensity is the main climatic indicator for the livestock mortality. In terms of climate change impacts on forest ecosystems, certain study has been done by Dulamsuren Ch. and others from the University of Goettingen, Germany and scientists from the Columbia University, USA and the National University of Mongolia. It was (Natsagdorj L. Khaulenbek A. 2013: Material on the establishment of forest seed laboratory) identified a correlation between forest seed quality, forest area affected by pests and drought intensity and made attempts to assess future trends. In addition, when annual growth of tree rings from the Kharkhiraa-Turgen mountain region and other regions from the rest of the country are analyzed and compared, it seems that the conditions for forest growth in the Mongolian Altai forest might be improving since the 1940's.

Mongolia is extremely vulnerable to the impacts of climate change, therefore it is of utmost importance to formulate climate change adaptation policy and to integrate it in the national mid to long- term development planning and implement it. This issue is gaining momentum since the time around 2011 when Climate change office was established at the MEGD and the Special Envoy for climate change started to be nominated by the Prime minister. First of all, an adaptation technology needs assessment was conducted according to the UNEP methodology including possible costs and benefits for introducing the technology with some vulnerable sectors. The technology needs assessment also included recommendations to reducing greenhouse gas emissions (Technology needs assessment: vol. 2, 2013). A publication was recently made available about the research in this field (Namkhainyam B., Tsolmon N. 2014).

Until now, Mongolia has conducted its greenhouse gas inventory using the IPCC methodology. In 2012-2013 within the framework of a government funded project, for the first time, some country specific emission factors were estimated for animal husbandry sector (Namkhainyam et.al, 2013). The measurements at Ulaan-Uul station show an increase in summer minimum concentration of carbon dioxide in the atmosphere due to the degradation of plant cover and desertification in Mongolia. This increase is occurring more rapidly than the increase of spring maximal value which is related to the global anthropogenic carbon dioxide (Natsagdorj L. 2011). Because of this, the annual amplitude of atmospheric carbon dioxide concentration is decreasing in Mongolia. In terms of historic climate change, scientists Baatarbileg N. Jakobi G. and others updated the Palmer's drought indicator with the help of annual growth of tree rings and made attempts to relate the annual growth of tree rings and southern oscillation. Mijiddorj R. attempted to find the correlation between annual growth index of tree rings sampled from all over Mongolia with river discharge (Mijiddorj 2012).

Climate change risk assessment was conducted on water resource, biodiversity, ecosystem services, forest, agriculture/ animal husbandry, arable farming, social health and infrastructure and an integrated assessment of all sectors were done using multi-criteria analysis. The risk assessment was conducted using "Climate change risk assessment" methodology of the Department for Environment, Food and Rural Affairs (DEFRA), United Kingdom. The results showed pasture animal husbandry and biodiversity, especially pasture, infrastructure and arable farming sectors are the most vulnerable (UNDP, 2012).

Climate change adaptation strategy was elaborated in 2010 in a general form including strategic goals, objectives and measures for biodiversity, forest, animal husbandry, arable farming and water sectors. In 2013, detailed cost and benefit analysis was conducted on each of the measures of the vulnerable sectors such as forest, water, agriculture (animal husbandry, arable farming) for the timeframe between 2014 and 2021.

2.2.3. Climate regime

Mongolia has a harsh continental climate due to its geographic location in the central Eurasian continent, landlocked; surrounded by high mountains with an average altitude of 1.5km. The unique characteristics of Mongolian climate is the clearly distinctive four seasons which leads to high fluctuation of air temperature, low precipitation and the fact that latitude and altitude distinctions are clearly visible. Mongolia has short, dry summer (June to mid-August), long, cold winter (November to April) and the length of spring and autumn fluctuates every year within a broad range.

Atmospheric heat and cold. Winter mean temperature is -15^0 to -30^{0}C and summer mean temperature is 10^0 to 26.7^{0}C. Annual mean air temperature in mountainous region of Altai, Khangai, Khentii, Khuvsgul is –4^{0}C, in lowlands between mountains and large river valleys it is –6 to –8^{0}C, in desert-steppe region 2^{0}C and in southern Gobi region 6^{0}C (Figure 2.19). The annual mean temperature of 0^{0}C line is roughly located at the northern boundary of desert-steppe, Gobi region of Mongolia along the northern latitude of 46^0. In addition, permafrost is distributed in areas where the annual mean air temperature is lower than –2^{0}C.

The mean air temperature of the coldest month January is -30…-34^{0}C in the valleys between Altai, Khangai, Khuvsgul, Khentii mountains, -25…-30^{0}C in high mountains and valleys between them, -20…-25^{0}C in steppe regions, -15…-20^{0}C in desert-steppe regions and –15^{0}C…12^{0}C in the southern Gobi region (Figure 2.20).

According to the meteorological monitoring since the 1940's, the lowest absolute air temperature was -55.3^{0}C (December 1976 in Zuungobi soum, Uvs aimag) whereas in Ulaanbaatar it was -49.0^{0}C (December 1954). Temperature inverse plays a significant role in the temperature regime of cold seasons. An inverse phenomenon is when the air temperature increases as elevation increases whereas normally, in flat steppe areas, the air temperature drops the higher one gets from the land surface. According to the aerological stations located in large river valleys, during the cold season, almost every day a temperature inverse can be observed with 600-1000 m thickness from ground with 6-17^{0}C intensity. As a result, in river valleys and lowlands, the air temperature increases by 0.8-0.9^{0}C and in steppe areas by 0.6^{0}C with every 100m increase.

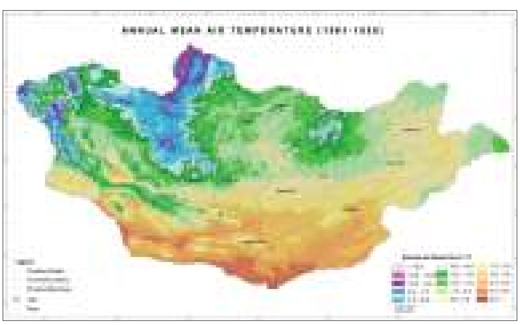


Figure 2.19 Geographic distribution of annual mean air temperature (Munkhbat, Natsagdorj 2013)

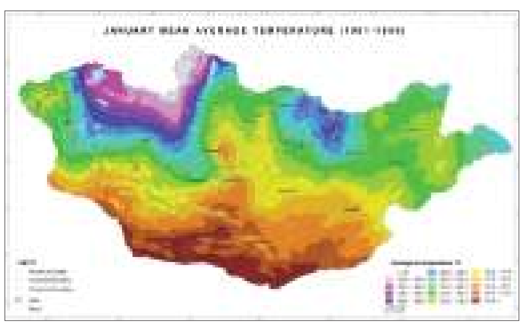


Figure 2.20. Geographic distribution of mean air temperature in January (Munkhbat, Natsagdorj2013)

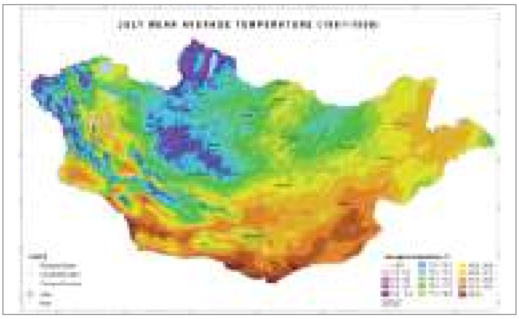


Figure 2.21 Geographic distribution of July mean average temperature (Munkhbat, Natsagdorj 2013)

The mean air temperature in the warmest month of July is 15⁰C in Altai, Khangai, Khuvsgul, Khenti mountains, 10⁰C at the top of mountains, 15...20⁰C in Great Lakes depression, areas between Altai, Khangai, Khuvsgul, Khenti mountains and in Orkhon, Selenge, Khalkh river basins, 20...25⁰C in southern part of the Dornod steppe and in desert regions, 25⁰C in southern part of the Gobi and in Dornogobi lowlands (Figure 2.21). The highest absolute temperature can reach 28.5⁰C ...44.0⁰C (44.0⁰C was measured in Khongor soum, Darkhan-Uul aimag on 24th of July, 1999).

During the warm seasons, the normal vertical temperature gradient occurs so that temperature decreases with height. In other words, temperature decreases with an increase in elevation at a rate of 0.5-0.6⁰C per 100 m. In the high mountain regions, spring frost ends late (mid-June) and the autumn frost starts early (late August), thus, the duration of the season without frost is short, with less than 70 days and in other regions, it is 90-130 days long. In terms of plant heat supply, the duration when daily mean air temperature is above 10⁰C and the heat accumulation of this period is important. The period when daily mean air temperature is above 10⁰C is 90 days and less in high mountain region or in areas with an altitude of 2000m and above, in forest-steppe region 90-110 days, in steppe region 110-130 days, in desert steppe region 130-150 and more than 150 days in the desert region. An indicator of heat supply for pasture plants is the ratio of temperature and days or Growing Degree Days-GDD. The sum of T_0 =5⁰C in Orkhon-Selenge basins is 2000-2500⁰C, in medium high mountains of 1500-2000 m height, it is 1500-2100⁰C, in mountains with an elevation of 2500-3000m it is 900-1300⁰C, and at 3500m, it is around 400-500⁰C (Natsagdorj L, Khaulenbek A.) (Figure 2.22).

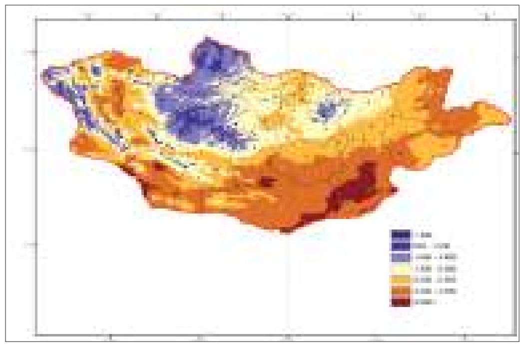


Figure 2.22 Growing Degree Days-GDD. T_0 =5⁰C

Precipitation. Mongolia has relatively low precipitation with 300-400 mm in Khangai range, Khuvsgul, Khenti mountains, 250-300 mm in Mongol Altai and forest-steppe region, 150-250 mm in steppe region and 150-50 mm in Gobi desert region. The precipitation generally decreases from the north to the south and from the east to the west, however, land contours play significant role for its distribution (Figure 2.23). There is overall low moisture in Mongolia as the soil rate of evaporation or the evaporability (potential evapotranspiration) far exceeds the amount of precipitation. The amount of evaporability is less than 500 mm in high-mountain, 550-700 mm in forest-steppe, 650-750 mm in steppe and 800-1000 mm in desert-steppe, steppe regions respectively (Figure 2.24).

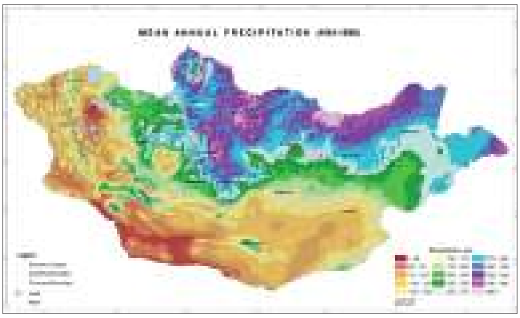


Figure 2.23 Geographic distribution of annual mean precipitation (Munkhbat, Natsagdorj 2013)

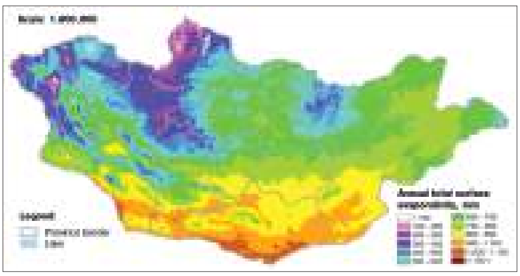


Figure 2.24 Annual total surface evaporativity

85% of the total precipitation comes in the warm season (April to September)and 50-60% of this amount happens in July and August alone. Even though the precipitation amount is little, its intensity per unit of time is high. According to the meteorological measurements since the 1940's, the largest daily precipitation was 138 mm in Dalanzadgad (5th of August, 1956) and 121 mm in Sainshand (11th of July, 1976) and everywhere it is possible for a 40-65 mm rain to fall in less than one hour. The number of rainy days can range from 60-70 in the northern mountainous part, 40-60 in the lower mountains of Khangai and Khenti range, valleys between mountains and Dornod steppe and about 30 days in the Gobi. However, most of the annual precipitation consists of few rains. In other words, Mongolia has low precipitation with high intensity and it is possible for any region to see a rain over 50 mm in one day. In the cold season (November to March), Gobi region sees about 10 mm snow, the mountainous region and in the Uvs lake basin 20-30 mm and the rest of the country gets 10-20 mm snow respectively. The number of days with snow cover range from over 150 days in the Altai, Khangai, Khentii, Khuvsgul mountains, 100-150 days in the forest-steppe region, 50-100 days in the Great Lakes depression and Dornod steppe, steppe regions and less than 50 days in the Gobi-desert region. The depth of the snow cover is low, with 5 cm average in mountainous regions, the average of the thickest snow is over 30 cm, in steppe region it's about 2-5 cm on average and the average depth of the largest amount of snow is 15-20 cm. Gobi region sees many years without snow cover.

Sunshine. Mongolia has relatively little clouds, so the number of sunny days is high with 230 to 260 days or 2600-3300 sunshine hours

Wind and storm. Mongolian steppe and Gobi-desert steppe region are relatively windy. Annual mean wind speed is 4-6 m/s in this region, 1-2 m/s in the valleys between the Altai, Khangai, Khuvsgul, Khentii mountains and 2-3 m/s in the rest of the country. According to the meteorological measurements in the 250 settlements in Mongolia,annual mean wind speed is higher than 4.0 m/s in quarter of the country. Normally, west, north-west and northerly wind dominate, however, due to land surface contour, local especially mountain-valley wind occurs often.

The number of days with dust storm is less than 10 days in the Altai, Khangai, Khuvsgul, Khentii mountainous region, more than 50 days in the Gobi-desert region and in the Great Lakes depression and over 90 days in the southern part of Altai Gobi and Mongol els area (Chung Y.S, Kim.H.S, Natsagdorj L. et.al. 2004, Mongolian national atlas 2009) (Figure 2.25).

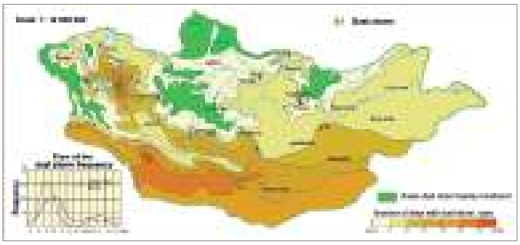


Figure 2.25 Distribution of dust storm (1960-2008)

61% of days with dust storm occur in the three spring months, 7% in the summer, the secondary highest value in autumn and secondary lowest value occur in winter. This however is different in different regions. For instance, there is no dust storm in Uvs lake basin in the winter whereas in southern part of Arts, third of all dust storms occur in winter. 80% of all dust storms happen during day light. Multi-year observation shows 300-600 hours of dust storm annually in the Mongolian Gobi desert region. Mongolian dust storm is one of the main sources of East Asian so-called "yellow dust".

2.2.4. Observed Climate Variability and Change

Mongolia is extremely vulnerable to climate change due to its geographic location, vulnerable ecosystem, people's lifestyle and economic system. This is comparable to low lying coastal regions. Mongolian people have practiced pasture animal husbandry for thousands of years, however, the animal husbandry risks associated with environment and climate is almost the same. According to the results from climate modeling and the annual growth of tree rings from around the last 2000 years, the observed climate change of Mongolia in the last 40 years and the change that is likely to occur in the coming decades, surpasses every change that happened in the last few thousand years when animal husbandry was practiced. This will have serious impacts on the ecology and economy.

Atmospheric heat and cold. According to the data between 1940 and 2013 from 48 meteorological stations that are almost evenly distributed across the entire country, the air temperature by the land surface (2m high) has increased by 2.07^{0}C (Figure 2.26). This increase has occurred more intensively in the mountainous regions and less so in the Gobi and steppe regions. The warmest 10 years of the last 74 years have all occurred since 1997.

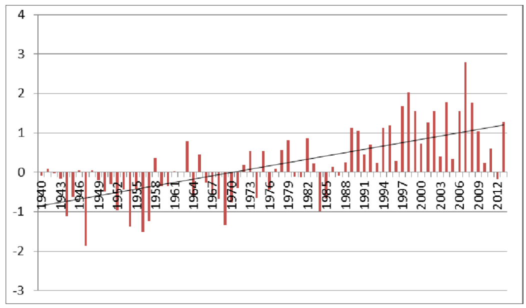


Figure 2.26 Deviation from the multi- year average (1961-1990) of annul mean temperature average of the entire territory of Mongolia

When the multi-year progress of the air temperature is considered by season, at the end of the analyzed period (1990-2013), the warming intensity is weakening in all seasons except in summer and also the annual average. Even a mild cooling is observed in the winter (Figure 2.27). As of summer, it is clear that the warming intensity is increasing with time (Figure 2.28).

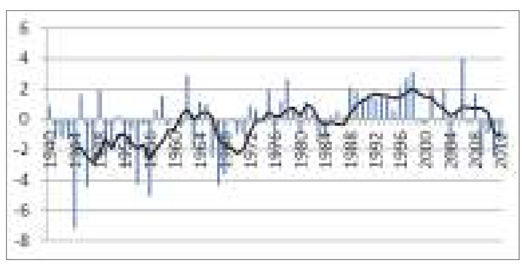


Figure 2.27 Deviation from the multi-year average (1961-1990) of winter (December to February of the next year) mean temperature average of the entire territory of Mongolia

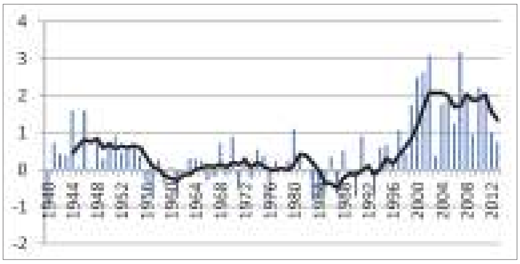


Figure 2.28 Multi-year trend of summer air temperature deviation (deviation from the norm of 1961 to 1990)

One obvious change of the air temperature change is the sudden rise in number of extreme hot days and decline of extreme cold days. When the value of the angular coefficient from the equation of multi-year linear trend of number of hot days is considered with the data between 1975 and 2007 when 64 meteorological stations worked in parallel, the results show 5-8 days increase in 10 years in the eastern part of Mongolia as well as in the Great Lakes depression area and less rate of increase in the Altai, Khangai mountainous regions. The increase in number of hot days has over 95% statistical significance in all meteorological stations except those in high-mountain regions and 99% in most steppe gobi-desert regions (Figure 2.29).

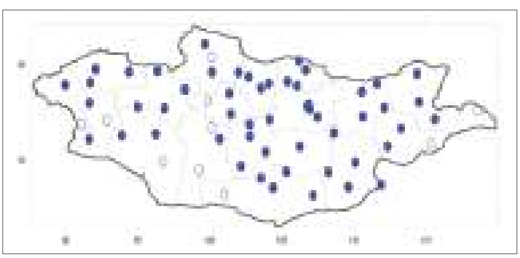


Figure 2.29 Statistical significance (marked with bright colors when above 95%) of angular coefficient from the equation of multi-year (1975-2007) linear trend of number of hot days above 30^{0}C

In recent years, related to climate warming, it has been observed that the record of the highest absolute air temperature measured at meteorological stations between 1940's and 1990's is broken. Research shows since 1991, the highest absolute temperature was measured in 58 out of 64 meteorological stations. Figure 2.30 shows multi-year trend of number of cold days below -25^{0}C in Ulaangom station.

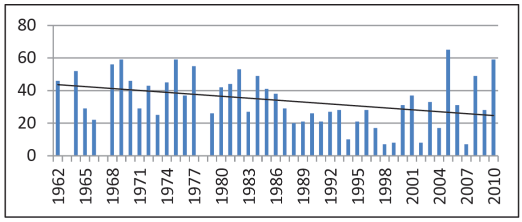


Figure 2.30 Multi-year trend of number of cold days below -25^{0}C (Ulaangom station)

Precipitation. 92% of Mongolia's precipitation falls in warm seasons and the winter receives less than 3%. Therefore, the annual precipitation trend is determined by the precipitation in the warm seasons, especially by summer precipitation trend which constitutes 70% of the annual total precipitation. Figure 2.31 shows multi-year trend of annual total precipitation. The winter precipitation on the other hand could increase gradually /Figure 2.32/.

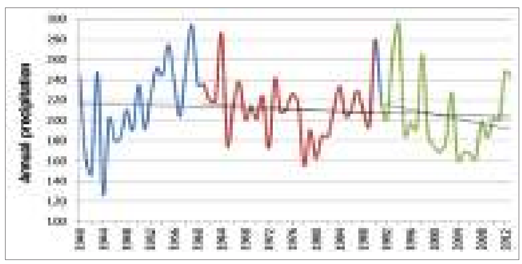


Figure 2.31 Multi-year trend of annual total precipitation (average of 48 meteorological stations)

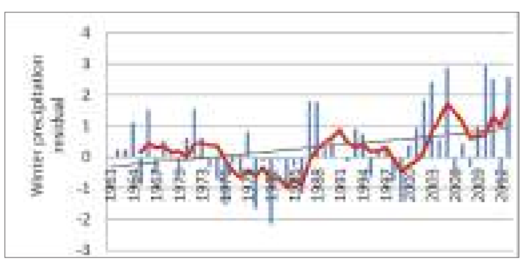


Figure 2.32 Multi-year trend of total winter precipitation (average of 48 meteorological stations)

If the precipitation change is considered according to meteorological stations, warm season and summer precipitation increased slightly in Altai mountain region, Altai Gobi region and far south-eastern part of the country since 1961. In the rest of the country, precipitation is decreasing at a rate of 0.1-2.0 mm per year (Figure 2.33).

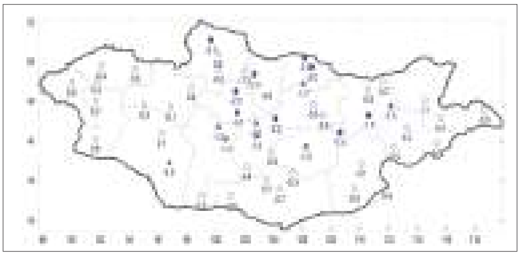


Figure 2.33 Angular coefficient of linear trend equation of annual precipitation change in warm season in Mongolia. *Note: Dark blue circle indicates significance higher than 95%, half dark circle for 90% significance, circles without filling indicate precipitation decrease and triangle indicate precipitation increase respectively.*

The largest precipitation decrease occurred in the central regions of Mongolia, in some places with 95% significance. In areas where precipitation is increasing, there is 95% significance only by Altai Gobi region. Another change of precipitation that is occurring during the growing season is the increase in stormy rain in the overall rain amount. In addition to the increase in the volume of stormy rain in the overall rain during the growing season, there is also a trend that the maximum amount of daily precipitation is increasing (Figure 2.34).

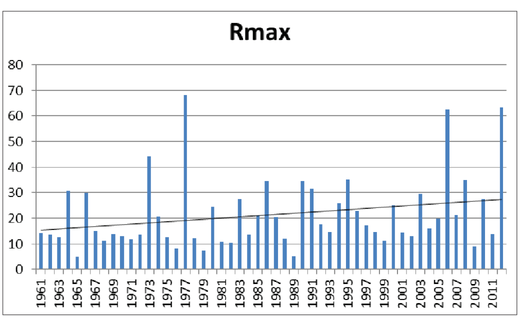


Figure 2.34 Multi-year trend of maximum daily precipitation per year (as in Bulgan soum, Umnugobi aimag)

This increase is mostly observed in Gobi, steppe and forest-steppe regions which are affected by desertification to a certain degree. However, there is basically no statistically significant trend in the multi-year trend of daily maximum precipitation.

Change in climate extremes. For climate change research, it is significant to take peripheral value change of climate elements into consideration. Change in climate extremes in Mongolia was analyzed using data from meteorological stations between 1961-2001 and 1961-2007 (MARCC 2009, Gwangyong Choi, Purevjav Gomboluudev, et al. 2008). Within the framework of a research project implemented at the Institute of Meteorology, Hydrology and Environment, the above mentioned research was continued using data from 1961 to 2010. The results of this research confirm the results from previous researches (Davaanyam E., Gomboluudev P., et.al. 2013).

The data from meteorological stations with over 30 years of continuous monitoring data showed the following results: number of cold days decreased by 8-27 days, growing season has extended by 5-24 days and number of hot days (days with a maximum temperature of 26^{0}C and above) extended by 5-28 days
(Figure 2.35).

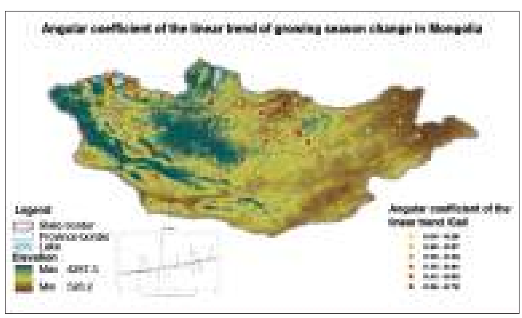


Figure 2.35 Angular coefficient of the linear trend of growing season change in Mongolia

The angular coefficient value for the linear trend of the extremes index of the total precipitation of a day with precipitation (prcptot) is fluctuating between -3.04… 1.19, with decrease in most observation points and increase in some regions. When the results are averaged according to the observation points in the western, central, eastern and southern regions, the western region shows slight increase whereas the central and eastern region show rapid decline (Figure 2.36). This is similar to the precipitation change in a warm season of the year calculated with data from 1961 to 2007 (see Figure 2.31).

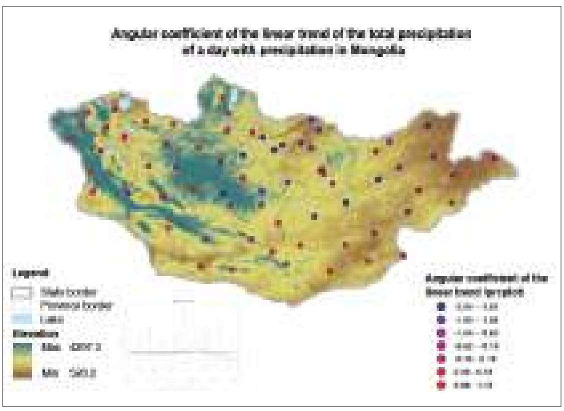


Figure 2.36 The angular coefficient for the linear trend of the total precipitation of a day with precipitation in Mongolia

2.3 Future Climate change projection over Mongolia

The driven force of global warming is important in the assessment of future climate change projection, as well as climate system response due to increasing greenhouse gas (GHG) concentration, especially under future change of emission scenarios. The Representative Concentration Pathway (RCP), dependent on the future world socio-economic trends, has been defined in Assessment Report 5, AR5 of IPCC Working Group I. Once the emission scenario and pathway are adequately assessed, then these are applied in the radiation budget scheme of Global Climate Models (GCMs).

Finally, the global climate change is projected and its impact, vulnerability, and risk assessment is needed to be done based on those projections. Adaptation measures should be defined in order to reduce vulnerability of socio-economic sectors.

Within the framework of IPCC AR5, more than 40 global climate models of 28 international centers and institutions around the world have simulated historical climate from 1860 to 2005 and predicted a future climate change projection under different RCP scenarios from 2006 to 2100 (Taylor, K.E et al, 2012). Models use four main RCP scenarios in which they would change the world radiation balance by 2.6, 4.5, 6.0 and 8.5 W/m^2 during the end of this century, 2100 (Climate Change 2013: The Physical Science Basis, IPCC Working Group I Contribution to AR5, 2014). Among those GCMs, we have selected ten models based on assessing model skills against observation on how they simulated past climate from 1986 to 2005 as a reference period. Their skill measures are ranked by using the multi-criteria analysis technique based on spatial correlation and normalized standard deviation. Here, the focused domain was selected as covering 41.5-52.0^0 latitude, 87.5-120.0^0 longitude area and the model simulation result is compared against CRU (Climate Research Unit) grid data, University of East Anglia (http://www.cru.uea.ac.uk/cru/data/hrg/),UK.

The climate change future projection over Mongolia in different time slices such as near-future 2016-2035 and far-future 2081-2100 are selected depending on end-user utilization needs (policy makers, researchers, etc.), who are going to use climate change projection results over Mongolia under different RCP scenarios.

2.3.1 Review on previous study

The first coupled atmosphere and ocean global climate model was developed in Geophysical Fluid Dynamic Laboratory, National Atmospheric and Oceanic Administration, USA in 1960. Since that time, many countries developed different GCMs and improved them over the years. Currently, nearly 40 familiar GCMs are operating in the world, mostly in developed countries (http://cmip-pcmdi.llnl.gov/cmip5/availability.html). In the beginning stage, GCMs only had atmospheric components, but nowadays it has comprehensively developed an earth system model including atmosphere, land, ocean, aerosol, carbon cycle, dynamic vegetation, atmospheric chemistry components, and their interaction. Global climate change projection is completed and assessed by accounting the future change of GHG concentration in the radiation model scheme, and compiled results have been published in IPCC assessment report 1-5 (IPCC, WG I, 1990, 1996, 2001, 2007, 2013).

In Mongolia, country climate change projection is completed by using the GCMs output focusing on its own region, and quantitative results were used in the climate change impact assessment of the different socio-economic sectors. The latest projection considering the collective data of the multi-model output based AR4 has been published in the first Mongolian Assessment Report on Climate Change (MARCC, 2009). Comparatively good GCMs, which have less error when estimating past climate of the country, is downscaled from global to regional, meso, and river basin scales. This high resolution climate change projection is completed by using dynamic downscaling and could better represent the local climate feature, depending on topography and land cover (Sato et all, 2006 and P. Gomboluudev, 2011)

2.3.2 Climate change projections

Model evaluation. Statistical measures such as spatial correlation and normalized standard deviation of the 40 GCMs models output (http://cmip-pcmdi.llnl.gov/cmip5/availability.html) have been estimated against observed winter and summer temperature and precipitation from 1986 to 2005. These measures are selected as criteria in multi-criteria analysis and converted to a 100-score system, and are ranked by weighting scores (Multi-criteria analysis, 2009). Among them, the first ten GCMs are selected to use further estimation of the future climate change projection. Table 2.1 shows the selected global climate model names and abbreviations, and their belonging institutions.

Table 2.1. Selected global climate model and centers around world

Modeling Center	Model	Institution
CNRM-CERFACS	CNRM-CM5	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique
EC-EARTH	EC-EARTH	EC-EARTH consortium
MIROC	MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
MOHC	HadGEM2-ES	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
MPI-M	MPI-ESM-LR MPI-ESM-MR	Max Planck Institute for Meteorology (MPI-M)
MRI	MRI-CGCM3	Meteorological Research Institute
NOAA GFDL	GFDL-CM3 GFDL-ESM2G	Geophysical Fluid Dynamics Laboratory
NSF-DOE-NCAR	CESM1(CAM5)	National Science Foundation, Department of Energy, National Center for Atmospheric Research

Output of the above models have different format and spatial resolution from 120 to 300km. Therefore, when we do comparison and projection estimation, model output is converted to the Gaussian grid format T62, approximately 200km (1.8^0) resolution, using the bilinear interpolation method. Tailor diagrams in Figures 2.37-2.38 show statistical measures for winter and summer temperature and precipitation of the models, compared with observation. In the case of ten selected models, the spatial correlation of the winter temperature varies 0.84-0.96,with a normalized standard deviation that corresponds as 1.9-3.5, and for precipitation 0.71-0.93 and 2.2-8.1, respectively. In the summer season model, the temperature spatial correlation is 0.84-0.96, and the normalized standard deviation is 0.02-0.2; precipitation is 0.84-0.96 and 0.1-0.3, respectively. Here, normalized standard deviation reaches to 1(REF), less error, because it is the observed standard deviation.

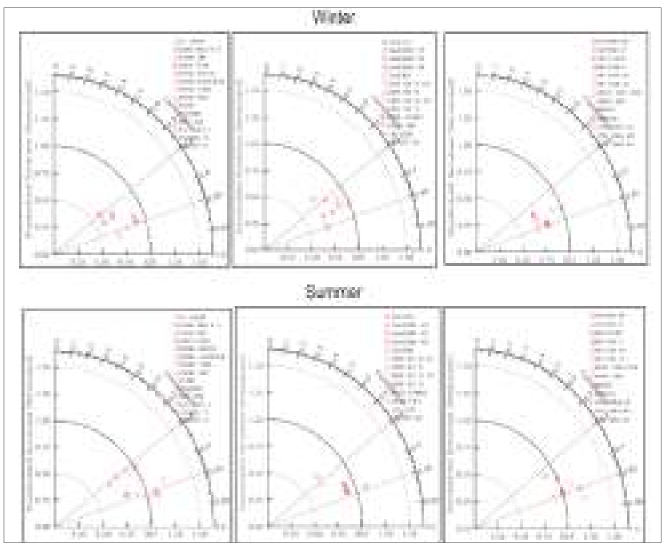


Figure 2.37 Statistical measure of winter and summer temperature

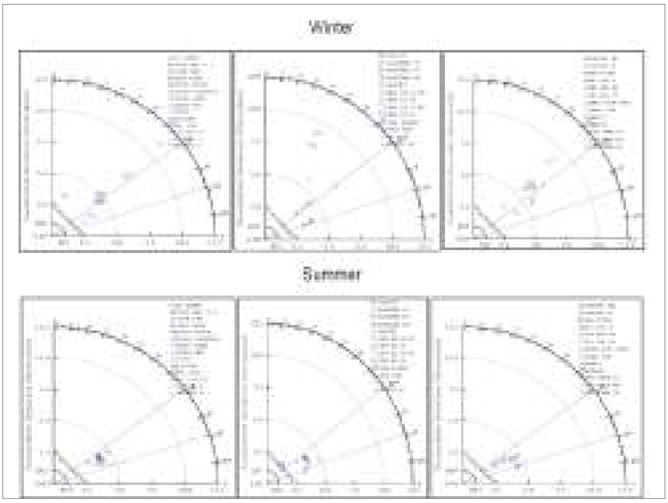


Figure 2.38 Statistical measure of winter and summer precipitation

Generally, the selected models simulated winter and summer climate reasonably well based on statistical measures as shown in the Tailor diagram. However, winter precipitation has lower spatial correlation and 5-10 times overestimation compare to summer precipitation (Figure 2.37). Comparatively good models such as HadGEM2-ES in Hadley Center, UK, and MPI-ESM-MR in Max Plank Institute, Germany, and their spatial pattern of seasonal temperature and precipitation are shown in Figure 2.39-2.44 with the corresponding observation.

Finally, the future climate change projection of Mongolia is estimated using collective data of 10 selected GCMs output with respect to 1986-2005 reference climate periods under different RCP scenarios.

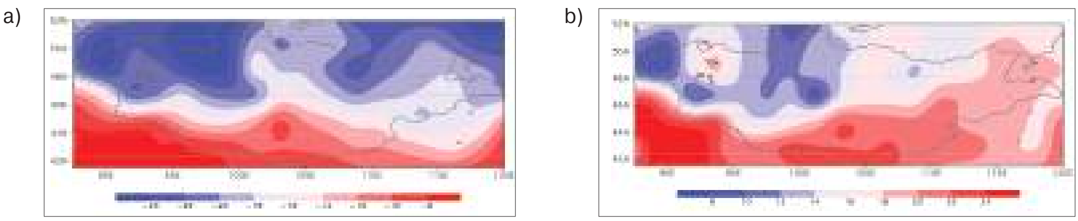


Figure 2.39 Observed a) winter and b) summer temperature, ^{0}C

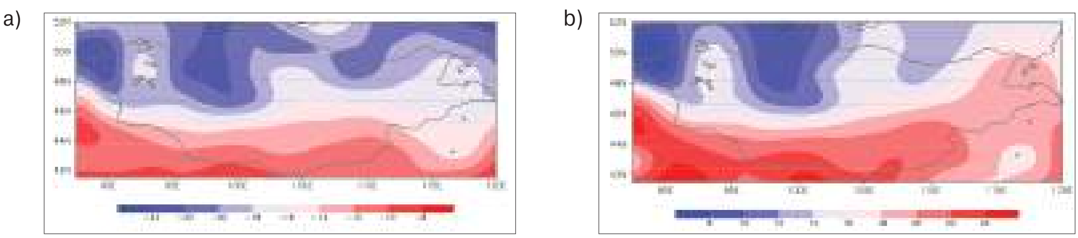


Figure 2.40 Simulated spatial pattern of a) winter and b) summer temperature by HadGEM2-ES, ^{0}C

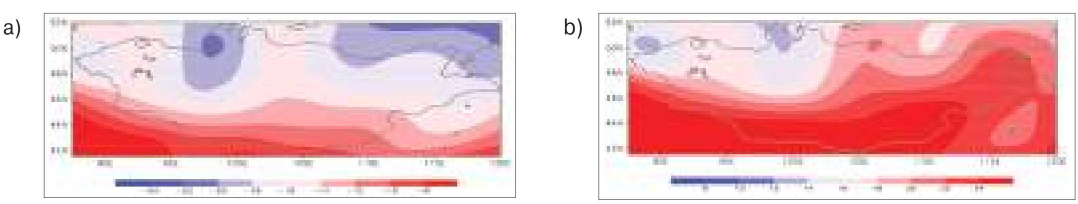


Figure 2.41 Simulated spatial pattern of a) winter and b) summer temperature by MPI-ESM-MR, ^{0}C

a)
b)

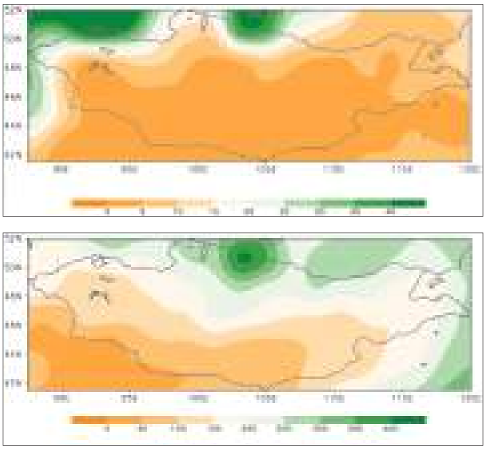


Figure 2.42 Observed a) winter and b) summer precipitation, mm

a)
b)

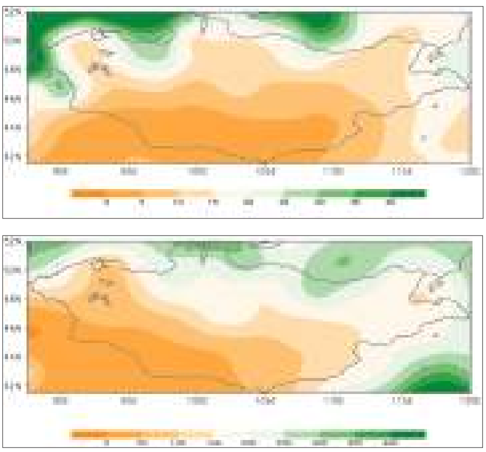


Figure 2.43 Simulated spatial pattern of a) winter and b) summer precipitation by HadGEM2-ES, mm

a)
b)

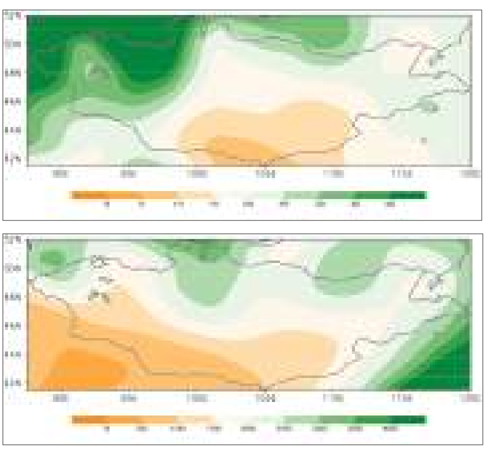


Figure 2.44 Simulated spatial pattern of a) winter and b) summer precipitation by MPI-ESM-MR, ^{0}C

Climate change projection over Mongolia. Among the RCP scenarios, we selected RCP 2.6, RCP 4.5 and RCP 8.5, and estimated the intra-annual change of winter and summer temperature and precipitation over the country from 2016 to 2100 with respect to the 1986-2005 reference periods (Figure 2.45-2.46). Here, the ensemble mean is shown with the light bold curve line in each of the RCP scenarios. Generally, the intensity of temperature change directly depends on the increasing intensity of GHG concentration. However, winter intensity and intra-annual change are little bit higher than summer season (Figure 2.45-2.46). At the beginning of this century, temperature change is almost equal in every RCP scenario and tends to differ with each other since that time. For example, the winter temperature change is projected to increase by nearly 2.1-2.3^{0}C for RCP scenarios in 2016-2035, but to increase by 2.5^{0}C in RCP2.6, to increase by 3.7^{0}C in RCP4.5, and to increase by 6.7^{0}C in RCP8.5 scenarios (Table 2.2).

According to precipitation the projection, winter precipitation will be increased and there is almost no change in summer precipitation (Figure 2.46). At the end of this century, winter precipitation is projected to increase by 15.5% in RCP2.6, 28.7% in RCP4.5, and 50.5% in RCP8.5 scenarios (Table 2.2).

The climate change projection assessment of the country is similar as the previous projection assessment based on IPCC AR4 in terms of general trends, especially A1B (MARCC 2009) is close to RCP8.5 based on IPCC AR5. All seasonal change values of the climate change projection over Mongolia are shown in every RCP scenarios in Table 2.2.

a) b)

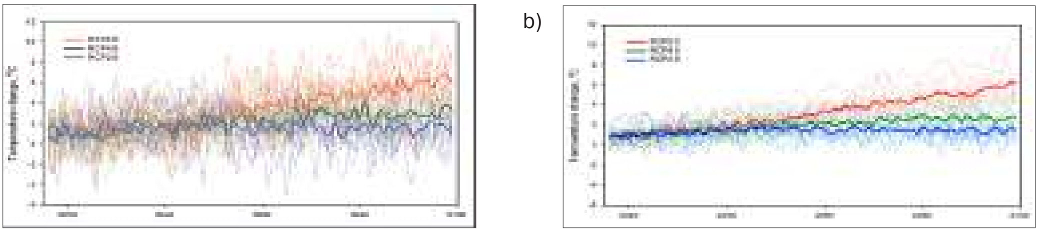


Figure 2.45 a) Winter and b) summer temperature change

a) b)

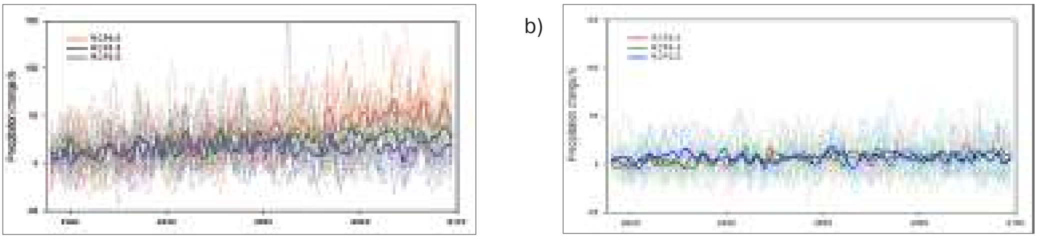


Figure 2.46 a) Winter and b) summer precipitation change

Table 2.2 Seasonal climate change over Mongolia under different scenarios (ensemble mean of 10 GCMs)

GHG scenarios	Seasons	Near future, 2016-2035		Far future, 2081-2100	
		Temperature,^{0}C	Precipitation, %	Temperature,^{0}C	Precipitation,%
RCP2.6	Winter	2.3	10.1	2.5	15.5
	Spring	2.3	9.2	2.4	11.7
	Summer	2.2	6.2	2.5	5.1
	Fall	2.1	7.6	2.4	7.6
RCP4.5	Winter	2.1	12.3	3.7	28.7
	Spring	2.0	7.8	3.4	17.4
	Summer	2.1	1.1	3.5	7.8
	Fall	2.0	8.1	3.4	11.7
RCP8.5	Winter	2.2	14.0	6.3	50.2
	Spring	2.2	9.8	5.6	28.6
	Summer	2.2	2.4	6.0	8.7
	Fall	2.2	6.4	6.1	24.1

In terms of the change of the spatial pattern, the climate change projection over Mongolia in the near future (2016-2035) and far future (2081-2100) is shown in Figure 11-14 for winter and summer temperature and precipitation. Here only RCP8.5 scenarios are shown because generally all spatial patterns are similar and the only difference is their intensity. A high intensity pattern of temperature is projected - by 5.5-7.5^{0}C - in eastern and western parts of the country in winter (Figure 2.47a), and by 5.0-5.5^{0}C in the western part in summer (Figure 2.47b). Winter precipitation will be increased by 55-75% in the central, western and eastern parts (Figure 2.48a) and summer precipitation will be decreased by 5-10% in the western part of Mongolia (Figure 2.48b). The spatial pattern change in the near future has been shown in Figure 2.49-2.50.

a) b)

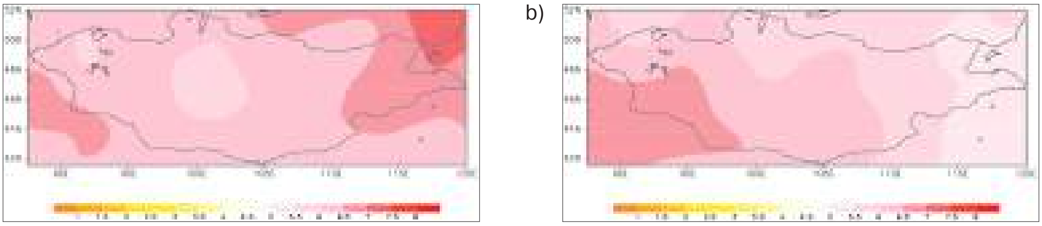


Figure 2.47.Spatial pattern of a) winter and b) summer temperature change in 2081-2100, ^{0}C

a) b)

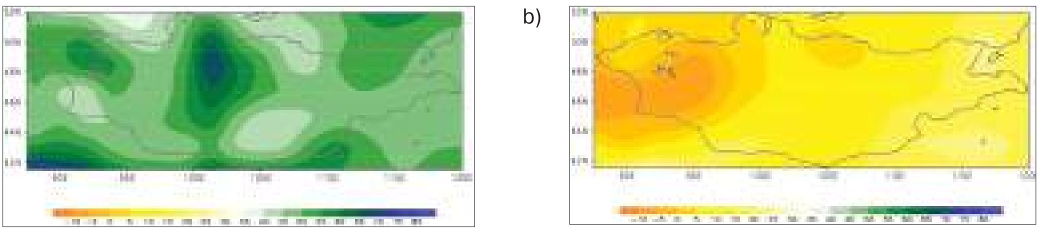


Figure 2.48 Spatial pattern of a) winter and b) summer precipitation change in 2081-2100,%

a) b)

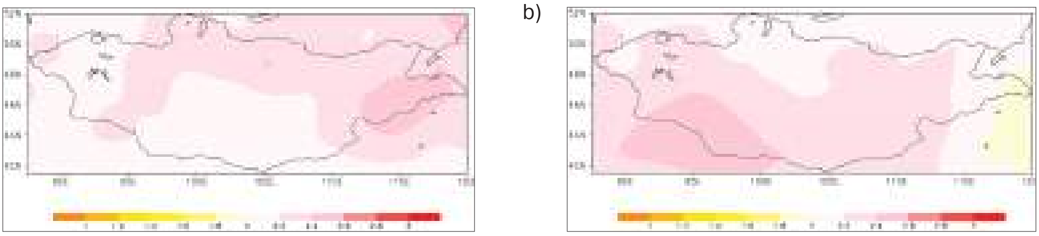


Figure 2.49 Spatial pattern of a) winter and b) summer temperature change in 2016-2035, ^{0}C

a) b)

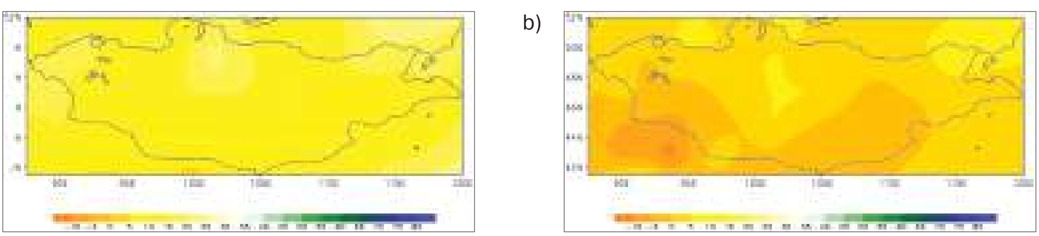


Figure 2.50 Spatial pattern of a) winter and b) summer precipitation change in 2016-2035,%

2.4 Concluding remarks

- It is essential to understand that the outcome of studies focused on Mongolia, where social structure, life style and land use are unique and cannot fit the generalized picture common for the most of countries in Asia and in the world. Another key issue is that the highlighted outcomes of studies, particularly those related to the future scenarios, can be considered in optional terms but not in categorical ones.
- Bearing in mind the findings of researches so far there is a need to further update the results of those already undertaken studies involving

new data and upgrading them in terms of spatial scale. In downscaling exercise, there is a need to shift the focus from macro-scale frontal type alteration to meso-scale pattern change and evaluate the after-effect of interaction of the climate and human systems at the local level, particularly in relation with water resource issues as vital for both of local communities livelihood and ecosystem functions as a whole.

- Suggested strategies for maximizing the adaptive capacity of ecosystems include reducing non-climate impacts, increasing landscape connectivity, and protecting 'refugee' where climate change is expected to be less than the regional mean (WGII AR5 2013). Additional options for inland waters include operating dams to maintain environmental flows for biodiversity, protecting catchments, preserving river floodplains and ground water sources , what about the countries like Mongolia have much less experience and would be benefitted greatly from technology transfer activities.
- Habitat restoration may facilitate species movements across climatic gradients, particularly, in those countries like Mongolia, where free access to land is common even in nature conservation sites, including specially protected areas and national parks. There are certain success stories in respect of *Ex situ* conservation activities in Mongolia, covering some species like wild horses (takhi), gazelle etc. (Amarkhuu et al. 2004). Similar conservation exercises can provide back-up for populations and species most at risk from climate change.
- Development of sustainable cities in Asia with fewer fossil fuel driven vehicles and with more trees and greenery would have a number of co-benefits, including improved public health. The issue is essential for the countries like Mongolia, where cities are growing faster occupying more and more green areas for construction and number of the vehicles, including poor standard second hand cars is increasing. The initiatives to minimize the direct use of coal in heating and producing electricity, involving new technologies for use of the unconventional energy sources (Badarch 2013) like coal mine methane (CMM) and coal bed methane (CBM) are needed to be stimulated and promoted .
- The climate change projection over Mongolia under different greenhouse gas emissions scenarios is done by an ensemble mean of 10 global climate model outputs, which have less error when estimating the past climate from 1986-2005. It has a reduced uncertainty related to the global climate model and GHG emissions as well.
- The general climate change trends, according to the projection assessment, are similar to the previous projection assessment based on IPCC AR4. The temperature will continuously increase in all seasons; precipitation will be increased by a much higher percent in winter, and there will be almost no change in the summer season. The high intensity of the above mentioned temperature change is projected in the western and eastern parts of the country in winter and in the western part in the summer season. There will be a high intensity increase in winter precipitation in the central, western and

eastern parts, and in the western part in the summer season.

- There is a need to downscale the spatial resolution of the projection from the global scale to 10-20km using the regional climate model, which obtains initial and boundary data from Hadley Center model HadGEM2-ES and Max Plank Institutions model MPI-ESM-MR, because they have comparatively good skill for simulating the past climate of the country. Once global output is downscaled, weather and climate extreme events and their trends in frequency and intensity are needed to be analysed and estimated in order to use them in impact, vulnerability and risk studies.
- The future change of land cover and use change should be considered in future climate change projections over Mongolia. To improve the accuracy of the assessments.

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3 Climate change impacts and exposure

3 Climate change impacts and exposure

- Soil and pasture	Erdenetsetseg B.
- Forest ecosystem	Dorjsuren Ch.
- Fauna	Enkhbileg D.
- Water resources, glacier	Davaa G.
- Permafrost	Jambaljav Ya.
- Natural disaster	Doljinsuren M.
- Land degradation and desertification	Mandakh N.
- Dust and sand storm	Jugder D.
- Animal husbandry	Bolortsetseg B., Radnaa G.
- Arable farming production	Davaadorj G., Gantsetseg B.
- Poverty and human development	Battsetseg Ts.
- Infrastructure	Battsetseg Ts.
- Human health	Burmaajav B.

CLIMATE CHANGE IMPACTS AND EXPOSURE

3.1 Climate Change Impacts on the environmental components

3.1.1 Soil and Pasture

Change in pasture vegetation. As of 2012, pasture monitoring data from the national network of meteorology, hydrology, and environment monitoring sites suggested that 90% of total pasture had changes to some extent (Erdenetsetseg B., 2014). This percentage was produced by the state transition model based on the ecological potential of pasture in accordance with the "Principle of categorizing plant population by their recovery rate," which was developed with support from the Green Gold project (SDC) and the Rangeland Research Center of the United States Department of Agriculture. The development of reference data of the plant population in pastureland of Mongolia and the relative greenness (no change) of plant species allowed to estimate the change in pasture. When assessing the state of pastures using the 2012 pasture monitoring data and following the principle of categorizing plant population by their recovery rate, the pasture are divided into four categories:

- Category 1: No change to pasture (5% of total pasture)
- Category 2: Pasture that can be recovered within 3-5 years if good pasture use management is implemented (57% of total pasture)
- Category 3: Pasture that can be recovered within 5-10 years if good pasture use management is implemented (36% of total pasture)
- Category 4: Pasture that exceeded the threshold value and is losing its quality (2% of total pasture)

It shows that there has been a transition in plant population and some changes to the plant species in pastures. Pastures containing grass and forb shrank while pastures containing Artemisia and annual plants grew in size. However, almost 60% of total pasture is recoverable within 3-5 years using the right pasture management. About 40% of total pasture had bigger changes, which means the pasture can be recovered within 5-10 years. When calculating these time periods, pasture use was taken into account. However, this calculation did not take climate change impacts into account.

Soil organic matter. The Century model that calculates plant-soil organic dynamics has been used to assess climate change impacts on pasture. In the process, climate, soil, and pasture use data from about 40 meteorological stations were used. Calculations show that the current topsoil (0-20cm) organic carbon and nitrogen contents differ by natural zones (Table 3.1).

Table 3.1 Current content of soil organic matters, g/m^2; Future change, %

Natural zones	Soil organic carbon			Soil organic nitrogen		
	1961-2010	Change, %		1961-2010	Change, %	
		2020	2050		2020	2050
High mountains	2921.9	-1.02	-1.78	165.8	0.62	0.76
Forest steppe	5445.1	-6.30	-9.47	448.7	-0.73	-1.77
Steppe	3328.6	-5.76	-8.40	249.4	-1.06	-1.84
Desert, desert/ steppe	1857.5	-0.32	-1.06	90.7	0.24	0.31

The high content of soil organic carbon and nitrogen in the forest steppe indicates that the region is more fertile than others. The results produced by the Century model suggest that, compared to the current levels, soil organic carbon will dramatically decrease in forest steppe and steppe regions in the future (6.4-5.8% by 2020, and 9.5-8.4% by 2050). It shows that fertile soil in Mongolia's territory is likely to lose its quality, be affected by external impacts, and become more vulnerable by 2050 and thereafter. In desert and desert steppe regions, it is calculated that there will be a relatively small reduction, 0.32-1.06%, in soil organic carbon while the content of soil organic nitrogen will increase marginally by 0.2-0.3%. Therefore, it looks like soil and plants in the desert and desert steppe regions are likely to be more stable under the climate change expected in the future. In high mountains, there is less reduction in soil organic carbon and a slight increase in soil organic nitrogen. It can be said that heat accumulation will increase, as a result of which, plants will have more favorable conditions in the high mountain region in the future.

Soil organic matter in river basins. The examples of Kharkhiraa/Turgen and Ulz river basins were used to explain how the current levels of soil organic matter in pasture soil will change due to climate change in the future. These two river basins represent vastly different ecosystems that are vulnerable to climate change, but with different soil-plant conditions. The Kharkhiraa/Turgen river, which flows from the Altai mountains, and the Ulz river, which is in the steppe region of Dornod Mongol steppe, are in completely different natural zones with different ecosystems and water reserves. The Kharkhiraa/ Turgen river basin is located in the dry-desert/dry-steppe region while the Ulz river basin is in the dry-steppe/cold-dry steppe region. These two river basins differ greatly in landscape (mountains). Small hills and flat steppes dominate the Ulz river basin. The Century model was run using climate, soil, and pasture using data from soums that represented the two river basins and their surrounding areas. When calculating the current condition of indicators such as pasture soil organic carbon, nitrogen, aboveground biomass, underground biomass, NPP, evaporation, evapo-transpiration and transpiration, pasture grazing levels were set differently - high, medium, low. When calculating the current conditions of main indicators of soil organic matters in the two river basins, the aboveground biomass in the Altai Mountains and the Kharkhiraa/Turgen river basin is 0.4-6.2 grams per square meter while it is 14.8 grams per square meter in Baruunturuun. The soums in the Ulz river basin have an aboveground biomass of 5.5-16.5 grams per square meter. Content of soil organic matter in the Kharikhiraa/ Turgen river basin is 2-3 times less than that in the Ulz river basin (Table 3.2).

Table 3.2 Current content of soil organic matter, g/m^2; river basins

River basins	Soil organic carbon	Soil organic nitrogen	Aboveground biomass	Underground biomass	NPP
Ulz	3729.2	326.5	9.5	353.2	41.7
Kharkhiraa	1992.4	115.9	3.8	201.2	16.0

Increased pasture use will reduce biomass, which decreases the amount of organic carbon absorbed by soil. Therefore, carbon content in degraded pastures is always lower than that of normal pastures. It makes the soil less fertile and more vulnerable to degradation. Soil organic matter stabilizes soil content, supports grass root growth, improves water retaining and enhances microorganism activities. Organic carbon is most vulnerable to degradation and is accumulated in the surface of the soil (Humberto B., 2011). Table 3.3 shows the results produced by the Century model when pasture grazing (pasture use) levels were set differently as high, medium, and low.

Table 3.3 Change in soil organic matter in relation to pasture use, Kharkhiraa/Turgen river basin

Soums	**Indicators**	**Pasture using and relative changes, %**				
		Low	Medium	difference between low and med, %	High	difference between low and high, %
Ulaangom	Aboveground biomass	3.56	3.51	-1.52	3.62	1.44
	Underground biomass	154.80	151.57	-2.09	150.88	-2.53
	NPP	14.79	14.53	-1.76	14.93	0.91
Turgen	Aboveground biomass	0.71	0.54	-23.31	0.21	-70.48
	Underground biomass	110.63	104.77	-5.30	65.77	-40.55
	NPP	3.38	3.00	-11.42	1.49	-56.11
Sagil	Aboveground biomass	3.64	3.06	-15.92	1.60	-56.06
	Underground biomass	161.39	162.26	0.54	139.60	-13.50
	NPP	15.10	14.74	-2.33	9.49	-37.15
Naranbulag	Aboveground biomass	0.79	0.65	-17.60	0.31	-61.02
	Underground biomass	104.58	104.98	0.39	76.98	-26.39
	NPP	3.74	3.57	-4.44	2.01	-46.14
Khovd	Aboveground biomass	1.50	1.20	-20.41	0.49	-67.35
	Underground biomass	121.47	113.64	-6.45	86.70	-28.62
	NPP	6.58	5.98	-9.15	3.07	-53.34
Umnugobi	Aboveground biomass	2.57	2.29	-10.68	1.50	-41.61
	Underground biomass	143.81	147.40	2.49	142.64	-0.82
	NPP	11.18	11.34	1.40	8.99	-19.58
Zavkhan	Aboveground biomass	0.54	0.43	-20.48	0.22	-58.65
	Underground biomass	108.87	109.16	0.27	96.93	-10.97
	NPP	2.62	2.40	-8.54	1.51	-42.35

The calculations clearly show that pasture use greatly affects the soil organic matter, its accumulation and its changes. Soil organic carbon and nitrogen contents in the Kharkhiraa/Turgen river basin are to be 1130-1260 g/m^2 and 56-62 g/m^2 respectively when there is low grazing. When there is medium grazing, the carbon content is decreased by 1-3% while nitrogen content is reduced by 0.1-0.3%. However, when there was high grazing, the soil organic carbon and nitrogen contents are decreased by 10-16% and 1-3%, respectively (Table 3.3).

The results produced by the Century model also suggest that, when there are medium grazing and high grazing, the aboveground biomass decreases by 10-23% and 50-70%, respectively. Total NPP, 5-15 g/m^2, decreased by 10-20% when there is medium grazing, and 60-65% when there is high grazing. It shows that pasture plant cover and topsoil conditions play an important role in the soil organic matter reserve, its accumulation, and its losses. Calculations of soil indicators in the Ulz river basin show that the current organic carbon content is 3800-4200 g/m^2 whereas the nitrogen content is 315-365 g/m^2 (Table 3.2). The soil organic matter contents are greater than those in the Kharkhiraa river basin. It shows that the Ulz river basin has relatively better fertility. Dark chesnut is found in the upper stream of the Ulz river while dark chesnut, chesnut and light chesnut soil is found downstream. However, soil in the Ulz river basin has large content of clay and sand, which makes it more vulnerable to degradation due to wind, water, and pasture use. The results show that aboveground biomass, underground biomass, and NPP are 10-16 g/m^2, 360-470 g/m^2, and 40-80 g/m^2 respectively. When there is medium and high grazing, aboveground biomass goes down by 25-30% and 50-70%, respectively, while NPP decreases by 10-20% and 60-65% (Table 3.4). The high rate of reduction in these indicators suggests that the Ulz river basin has soil that is very vulnerable to climate change.

Table 3.4 Change in soil organic matter in relation to pasture use, Ulz river basin

Soums	Indicators	Pasture using and relative changes, %				
		Low	Medium	%	High	%
Dashbalbar	Aboveground biomass	16.02	12.11	-24.40	4.14	-74.15
	Underground biomass	475.62	421.96	-11.28	273.32	-42.53
	NPP	62.26	52.66	-15.42	21.37	-65.68
Bayan-Uul	Aboveground biomass	22.10	16.55	-25.13	5.18	-76.54
	Underground biomass	627.94	588.01	-6.36	345.51	-44.98
	NPP	82.04	73.53	-10.37	27.12	-66.94
Chuluunkhoroot	Aboveground biomass	8.97	6.60	-26.49	2.78	-69.00
	Underground biomass	360.33	341.72	-5.16	309.05	-14.23
	NPP	39.66	32.40	-18.32	15.27	-61.51
Gurvanzagal	Aboveground biomass	11.66	7.87	-32.53	3.24	-72.24
	Underground biomass	410.92	300.01	-26.99	218.76	-46.76
	NPP	45.70	34.81	-23.83	16.59	-63.69
Sergelen	Aboveground biomass	10.46	7.32	-30.01	2.97	-71.60
	Underground biomass	372.35	321.98	-13.53	233.96	-37.17
	NPP	41.49	33.45	-19.38	15.31	-63.11

It was also calculated by the Century model how the soil-plant productivity in the Kharkhiraa/Turgen and Ulz river basins would change under the effects of climate change. When doing the calculation, the assumptions were that the livestock density (number of livestock per one hectare land) is normal in the western and eastern regions and the pasture grazing level is medium. Table 3.5 shows the future trend of soil organic matter in the Altai Mountains and Kharkhiraa/Turgen river basin. 2050, soil organic carbon content will decrease greatly in Jargalant, Sagil, and Khovdsoums (Table 3.5). In the future, aboveground biomass is likely to decrease in all soums except Bulgan (Bayan-Ulgiiaimag) and Turgen (Uvs aimag). The significant reductions are likely to be in Jargalant, Uvs aimag's Khovd, Ulaangom, and Naranbulag (Table 3.5). These changes differ from each other because of the vast differences in geographical characteristics and soil conditions of these places.

Table 3.5 Future change of soil organic matter in the Altai Mountains and Kharkhiraa /Turgen river basin, %

Soums	Change in soil organic carbon			Change in aboveground biomass			**Change in NPP**		
	2020	2050	2080	2020	2050	2080	2020	2050	2080
Altai	1.43	1.49	-2.37	-20.78	-10.51	-44.29	1.19	7.42	-32.72
Baruunturuun	-4.84	-8.34	-14.21	-23.46	-31.13	-56.18	-9.77	-16.40	-47.11
Ulaangom	-13.85	-8.05	0.67	-67.94	-55.99	-81.02	-66.81	-45.66	-78.06
Jargalant, Khovd	-13.58	-20.98	-19.49	-65.19	-78.36	-92.42	-59.75	-73.83	-81.69
Tonkhil	-0.43	-1.44	-9.82	-6.26	-4.89	-71.37	9.77	14.81	-68.59
Ulgii	1.23	-1.91	-8.09	-6.33	-19.76	-49.92	12.30	-10.88	-45.63
Bulgan, BU	-0.43	-9.39	-17.21	52.74	8.52	-61.49	56.28	7.94	-57.81
Umnugobi	4.33	0.90	-0.68	-10.99	4.06	-30.06	-9.85	10.54	-6.87
Altai, BU	-0.23	-0.77	-11.09	-40.61	5.13	-59.79	-41.30	15.61	-60.29
Zavkhan	19.01	2.87	6.13	-49.90	4.28	-92.65	-56.97	-9.71	-98.81
Sagil	-15.13	-19.64	-10.93	-39.25	-58.56	-52.29	-53.91	-64.25	-53.49
Naranbulag	4.26	20.86	4.21	-96.04	-85.37	-96.03	-74.94	-87.27	-74.70
Khovd, Uvs	-15.12	-18.76	-16.93	-61.31	-62.38	-60.47	-62.11	-61.08	-63.09

Future change in soil organic carbon is relatively low in soums that are in the high mountain region of the Altai Mountains, but it is likely to decrease intensively in the Kharkhiraa/Turgen river basin (Table 3.5). Content of soil organic carbon is likely to significantly decrease (13-15%) in Sagil, Khovd, Ulaangom, and Jargalant (Khovd) soums by 2020 whereas carbon content in Altai, Ulgii, Umnugobi, and Naranbulag is to have a relatively low reduction. By

Change in evaporation was also calculated by the Century model. The results suggest that there will be less evaporation in the high mountain soums such as Altai, Jargalant, Ulgii, and Turgen while there is likely to be increased evaporation in other soums (Table 3.6). Transpiration, on the other hand, is to increase in all soums (Table 3.7). Due to these conditions, native plant populations might be pushed out by plants that are more resistant to dry conditions and drought.

Table 3.6 Evaporation in the Kharkhiraa/Turgen river basin and its future change, %

№	Soum	Evaporation, cm				Change, %		
		1980-2010	2020	2050	2080	2020	2050	2080
1	Altai	4.30	4.27	5.59	6.69	-0.74	29.92	55.51
2	Baruunturuun	6.20	6.54	7.58	8.82	5.41	22.26	42.27
3	Ulaangom	6.62	6.89	8.00	9.47	4.06	20.80	42.99
4	Jargalant, Khovd	6.93	6.84	7.93	8.63	-1.35	14.30	24.42
5	Tonkhil	4.21	4.52	5.53	6.81	7.33	31.46	61.74
6	Ulgii	5.76	5.61	7.31	8.63	-2.63	26.80	49.84
7	Bulgan, Bayan-Ulgii	4.79	5.19	6.12	6.90	8.30	27.81	43.98
8	Umnugobi	5.60	5.90	6.94	7.69	5.35	23.99	37.33
9	Altai, Bayan-Ulgii	3.62	3.72	4.44	5.87	2.64	22.70	62.19
10	Zavkhan	8.00	8.31	9.42	16.81	3.79	17.75	110.04
11	Turgen	7.84	6.62	7.25	9.16	-15.57	-7.53	16.79
12	Sagil	6.30	6.93	8.02	9.53	9.97	27.39	51.36
13	Naranbulag	7.78	8.38	9.66	11.15	7.73	24.22	43.29
14	Khovd, Uvs	7.22	7.50	8.72	10.29	3.91	20.69	42.44

Table 3.7 Transpirationin the Kharkhiraa/Turgen river basin and its future change, %

№	Soums	Transpiration, cm				Change, %		
		1980-2010	2020	2050	2080	2020	2050	2080
1	**2**	3	4	5	6	7	8	9
1	**Altai**	1.02	0.91	1.07	0.86	-11.34	4.16	-16.19
2	**Baruunturuun**	1.46	1.52	1.66	1.54	4.47	13.63	5.83
3	**Ulaangom**	0.83	0.57	0.63	0.40	-30.75	-23.83	-51.53
4	**Jargalant, Khovd**	0.76	0.70	0.70	0.32	-8.80	-7.70	-57.57
5	**Tonkhil**	0.62	0.62	0.67	0.53	0.12	6.94	-14.26
6	**Ulgii**	0.70	0.64	0.72	0.69	-7.79	3.34	-0.98
7	**Bulgan, Bayan-Ulgii**	0.72	0.86	0.82	0.62	18.66	13.16	-13.94
8	**Umnugobi**	0.74	0.70	0.82	0.66	-4.99	10.60	-10.44
9	**Altai, Bayan-Ulgii**	0.72	0.48	0.77	0.65	-34.25	6.39	-10.34
10	**Zavkhan**	0.30	0.28	0.38	0.11	-6.66	25.99	-62.03
11	**Turgen**	0.27	0.63	0.01	0.66	134.21	-97.54	145.59
12	**Sagil**	0.86	0.65	0.70	0.67	-23.96	-18.92	-21.76
13	**Naranbulag**	0.31	0.01	0.27	0.01	-95.70	-12.53	-95.80
14	**Khovd, Uvs**	0.44	0.37	0.40	0.47	-15.74	-8.45	7.52

The below Tables show the future changes in soil organic matter of the Ulz river basin (Table 3.8 and 3.9).

Table 3.8 Soil organic carbon in the Ulz river basin and its future change, %

Soums	1981-2010	Soilcarbon content, g/m^2			Change in soilcarbon content, %		
		2020	2050	2080	2020	2050	2080
Choibalsan	3042.5	2727.3	2592.7	2339.9	-10.4	-14.8	-23.1
Dashbalbar	4032.3	3342.5	3076.3	2826.6	-17.1	-23.7	-29.9
Bayan-Uul	3765.6	3213.2	3009.4	2674.3	-14.7	-20.1	-29.0
Chuluunkhoroot	3834.3	2700.8	2321.5	2521.4	-29.6	-39.5	-34.2
Gurvanzagal	3808.2	3394.2	3152.3	3068.1	-10.9	-17.2	-19.4
Sergelen	3858.1	3275.3	3166.0	3128.4	-15.1	-17.9	-18.9
Bayandun	3857.6	3552.7	3391.5	3317.1	-7.9	-12.1	-14.0
Norovlin	3679.9	3571.9	3464.9	3208.5	-2.9	-5.8	-12.8
Bayan-Adarga	3738.3	3604.4	3492.9	3097.4	-3.6	-6.6	-17.1
Batnorov	3675.27	3520.9	3292.0	3165.8	-4.2	-10.4	-13.9

Table 3.9. Future change in aboveground biomass and NPP in the Ulz river basin, %

Soums	**Change in aboveground biomass, %**			**Change in NPP, %**		
	2020	2050	2080	2020	2050	2080
Choibalsan	-76.11	-69.84	-87.06	-69.81	-64.73	-85.53
Dashbalbar	-54.75	-43.10	-60.25	-43.89	-34.43	-67.02
Bayan-Uul	-30.46	-37.59	-69.90	-27.45	-36.08	-73.86
Chuluunkhoroot	-60.52	-43.24	9.85	-56.80	-35.97	-40.09
Gurvanzagal	23.68	17.94	-17.68	27.46	19.97	-16.19
Sergelen	23.61	28.23	4.88	24.41	25.19	3.61

Future changes in soil organic matter content in the Altai Mountains, Kharkhiraa/Turgen river basin, and Ulz river basin are shown in Table 3.10.

Table 3.10 Future changes in soil organic matter content in river basins

River basins	Year	Soil carbon, %	Aboveground biomass, %	NPP, %
Ulz	2020	-11.6	-29.1	-24.4
	2050	-16.8	-24.6	-21.0
	2080	-21.2	-36.7	-46.5
Kharkhiraa/Turgen	2020	-4.1	-63.9	-62.9
	2050	-4.5	-51.6	-53.6
	2080	-3.4	-76.5	-73.6
Altai Mountains, Great Lakes Depression	2020	-2.6	-33.5	-27.4
	2050	-4.9	-29.6	-24.1
	2080	-7.7	-65.2	-59.1

Although the current levels of soil fertility in the Altai Mountains and Kharkhiraa/Turgen river basin are weaker than that of the Ulz river basin, the future reduction of organic carbon is relatively lower (3-8%). It indicates that the current levels of soil fertility in the Altai Mountains and Kharkhiraa/Turgen river basin will be more stable under climate change. Organic carbon in the Ulz river basin soil is to decrease by 10-20% in the future (Table 3.10).

The decrease in aboveground biomass and net primary production in the Kharkhiraa/Turgen ruver basin will be more intense than the current level: a 63% decrease in 2020; a 52% decrease in 2050; and a 75% decrease in 2080. Compared to the Kharkhiraa/Turgen river basin, the Ulz river basin will have less of a decrease in aboveground biomass and net primary production: 27% in 2020; 23% in 2050; and 40% in 2080. Through assessing the future changes in pasture biomass by calculating the reductions in aboveground biomass as well as NPP and using the average pasture carrying capacity of the current pastures, the future change in livestock numbers that are suitable for the pasture carrying capacity in the Altai Mountains, Kharkhiraa/Turgen river basin, and Ulz river basin can be determined. These calculations suggest that there will be worsened conditions for nomadic animal husbandry in the Altai Mountains, Kharkhiraa/Turgen river basin, and Ulz river basin in the future. It also shows that it could be important to develop intensive animal husbandry and produce livestock fodder with irrigated farming.

For now, it is plausible to have animal husbandry compatible with its pasture carrying capacity in the Ulz river basin because there are relatively less number of livestock and less grazing pressure. However, the future reductions in soil organic matters are significant, which shows the vulnerability of soil and plants in this territory. Therefore, good management needs to be started in order to protect the soil.

In the country, soil and vegetation research studies have been conducted separately, and the pasture land has been treated only as a direct or indirect use tool. Therefore, through removing this deficiency, the introduction and establishment of the concept “soil and rangeland health” which is internationally used terminology, and the management based on this concept are required.

3.1.2 Forest ecosystem

Forest area and resources. Mongolian forest is characterized by low productivity, slow growth and it is vulnerable to anthropogenic and non-anthropogenic factors such as climate change, drought, fire, pests and thus, it can easily lose its ecological balance. It also has a relatively low ability for natural regeneration and expansion, all of which are due to its location in the southern boundary of the northern hemisphere’s cold forested region with a harsh continental climate. As of January 1, 2012, the total Mongolian forest land area is 18,592.4 thousand hectares which is 11.9% of the total territory of the country. This includes 12,552.9 thousand hectares (forest land 67.5%) of closed forest area, 5,124.7 thousand hectares (27.6%) of unforested area, and 905.8 thousand hectares (4.9%) of other area. Percentage of forest land is calculated by dividing the closed forest area by the total area of the country expressed in percentage. Mongolia’s percentage of forest land is 8.03% (Forest agency 2012). The closed forest area of the forest land consists of 80.2% (10,065.5 thousand hectares) coniferous, 13.2% deciduous (1,660.5 thousand hectares) and 6.6% saxaul (*Hectaresloxylon ammodendron*) (824.9 thousand hectares) forest, respectively.

The unforested area is comprised of open stand 3,476.7 thousand hectares (67.8%), burned dead forest 1,190.4 thousand hectares (23.3%), logged area 124.1 thousand hectares (2.4%), regrowth area 166.3 thousand hectares (3.2%), and the dead forest affected by pests 95.5 (1.9%). In terms of species composition, Mongolian forest consists of 63.1% larch, 10.5% birch, 5.8% siberian pine, 4.2% scotch pine, 14.2% saxaul, 1.3% willow, 0.4% aspen, 0.2% spruce, 0.2 poplar, 0.03% elm, 0.01% fir tree, and 0.002% Populus diversifolia. Mongolia's forest resource is 1,316.3 million cubic meter, of which larch contribute 78.6%, Siberian pine 9.2%, birch 6.4%, scotch pine 4.8%, spruce 0.3%, fir trees 0.02%, aspen 0.2%, poplar 0.1%, willow 0.2% (1.9 million.m^3) and elm 0.01%. Deciduous and coniferous forest resource is 1,315.5 million cubic meter. Khuvsgul, Selenge, Tuv, Bulgan, Khenti, UvurKhangai, Zavkhan aimags are rich with forests.

Forest changes under climate change. In the last 40 years, the environmental and socio-economic change has occurred rapidly due to anthropogenic factors and climate change. There is a tendency that the negative impact on forest ecosystems will increase. One of the main factors for forest loss was timber harvesting amounting to 1-2 million cubic meters per year between 1980 and 1990. Since 1993-1994, the logging rate declined by 2 to 2.5 times, thus, was dramatically reduced. However, due to climate change and the intensification of drought and aridity, the natural regeneration of forests slowed down and the number and extent of forest fires and pests have increased. This is the main cause for forest area and resource loss (Table 3.11). Between 1996 and 1997, 7 million hectares of forest were affected by forest fire and between 2000 and 2002, 3,330 thousand hectares of forest were affected by pests which is causing even greater damage in recent years than forest fires.

In 2011, using Landsat satellite images, GIZ calculated that in 1999, the area in northern Mongolia covered by forest was 9,851.19 thousand hectares. In 2009, this number was 9,627.93 thousand hectares which means the area was reduced by 223.25 thousand hectares or 2.27% with an annual forest loss intensity of 0.21 (GIZ 2011: Forest monitoring in the Northern Taiga of Mongolia). Between 1999 and 2012, 8.69 million cubic meters of timber was produced nationwide, 4.07 million hectares (291 thousand hectares per year) of forest was affected by fire and 8.14 million hectares (588 thousand hectares per year) of forest was affected by pests. Between 1999 and 2011, forest cover in Mongolia (natural and man made forests and shrubs) was reduced by 533 thousand hectares or by 4.1% which is a forest loss intensity of 0.34. This includes loss of natural forest area consisting of deciduous, coniferous and saxaul forest by 944.3 thousand hectares or 7.5% and annually 73 thousand or 0.62% (Table 3.12). From 1999 to 2011, forest area declined with an increase of area affected by forest fires by 768.5 thousand hectares, logged area by 96.9 thousand hectares and area affected by pests 95.6 thousand hectares.

Table 3.11 Area of forest affected by logging, fire, pests, and reforested area in Mongolia between 1999 and 2012

№	Year	Logged timber, thousand m^3	Area affected by fire, thousand hectares	Area affected by pests thousand hectares	Reforested area, thousand hectares
1	1980	2130	107	115	966.6
2	1985	2236	33	24.2	3202.6
3	1990	1200	650	33	4401.5
4	1995	636	34	130	3970.2
5	2000	569	660	1200	9030
6	2005	610	311	640	4859
7	2010	671	40	327	5056
8	2011	837	20	150	10926
9	2012	831	350	204	8399
Total		35833	12009	9923	170382
Average		1086	364	301	5163

Between 1999 and 2011, the area of shrubs within the closed forest area increased by 409.3 thousand hectares or by 98.5%. This is related to the permafrost thawing in the taiga and thus the increase of upper soil moisture which intensified shrub growth. Especially in narrow valleys characterized by temperature inverse, shrubs are expanding.

Table 3.12 Forest area change in Mongolia in the last 13 years (Forest agency 1999, 2012)

Type of area	1999	2011	Change	Percentage
Closed forest area, thousand hectares. Of which:	13086	12552.9	-533.1	-4.1
Natural forest, thousand hectares.	12670.3	11726.0	-944.3	-7.5
Shrubs, thousand hectares.	415.6	824.9	409.3	98.5
Manmade forest, thousand hectares.	0.05	2.0	1.95	3900.0
Unforested area, thousand hectares. of which:	3951.3	5124.7	1271.4	29.7
Open stand	2900.4	3476.7	576.3	19.6
Burned area	417.8	1186.3	768.5	183.9
Logged area	193.7	124.1	-69.6	-35.9
Regrowth area	438.8	221.3	-217.5	-49.6
Affected by wind	-	0.9	-	-
Reforested	0.5	9.2	8.7	1740.0
Dead from pest	-	95.7	-	-
Dried saxaul	-	10,5	-	-

Climate change impacts are visible in many ways such as the frequency of forest fires, forest disease, amount and distribution of pests, forest seeds, annual growth of biomass and forest vegetation change. Mongolia has a high risk of drought. In the high-mountain, forest-steppe and steppe regions of the country, drought occurs for 1-2 years in every ten years. Since 1940, 5 out of 6 severe droughts occurred since 2000 (MARCC 2009). Drought and aridity are not only the main condition for forest fires and increase of pests but it also affects the reforestation efforts in an adverse way. In 2009, large amounts of pine tree seedlings in Dugeree Nars and Tujin Nars area died due to drought and aridity. Another change observed in forests is the increase of forest fire frequency. In the last 50 years, the number of fires per year is dramatically increasing (Figure 3.1). About 90% of forest fires are caused by carelessness of humans and 80% of all fires occur in the dry period of spring, whereas 5-8% occurs in autumn. The number of spring fires are less if there was more snow in winter-spring and more if spring-summer was dry.

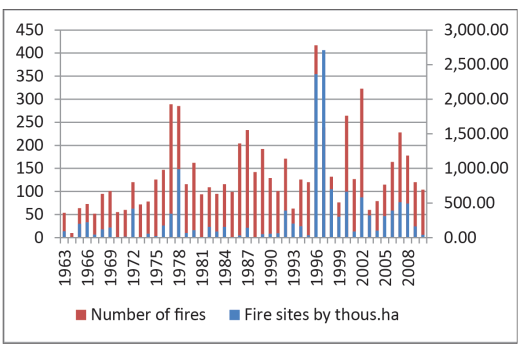


Figure 3.1 Number of forest fires, area affected by fire (thousand hectares), *Source: IMHE 2012*

Research shows that the forest fires are starting earlier in spring and stopping later in autumn and thus, the period with fire risk is getting longer (Chuluunbaatar 1990). In 2002, during the very severe drought, Bulnai range burned down in the middle of the summer. With climate change, there could be more forest fires in late spring and summer. Figure 3.2 shows in 12 years between 1999 and 2012, the area of forest that died from forest fire has increased by 64 thousand hectares or 13.3%. If measures against forest fires will be improved and the forest area affected by fire can be reduced by 50% from 2014 to 2030, the area covered by forest would decrease by 512 thousand hectares.

Natsagdorj L. (IMHE 2012) identified the correlation between the annual forest area affected by pests and summer drought index. He concluded the more droughts there are in the summer, the greater the area affected by pests (Figure 3.2). Using this correlation, the calculation with different greenhouse gas emission scenarios shows that between 2011 and 2039, 460-1149 thousand hectares, could be affected by pests, and between 2046 and 2065, 4390-5317.5 thousand hectares forest could be affected by pests (Table 3.13). This means the area affected by pests could increase significantly. Multi-year average shows approximately 324,3 thousand hectares of forest is affected by pests but this number could increase by up to 1.4 to 13 times.

Table 3.13 Forest area where pests could potentially spread, thousand hectares

Year	SRES A2	SRES B1
2011-2030	1149.3	460,35
2046-2065	5317,5	4389,9

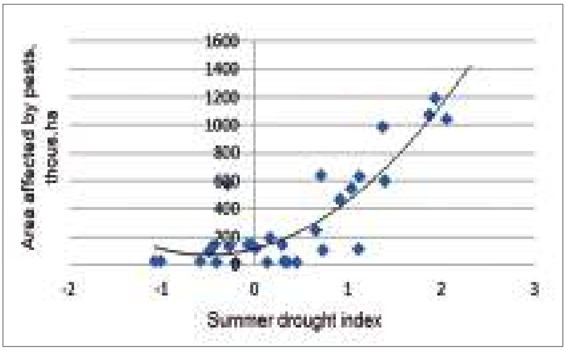


Figure 3.2 Correlation between summer-drought index and forest area affected by pests (Inputs as of 1980-2010)

The quality of forest seed and thus its natural regeneration ability might be deteriorating due to climate change and harmful human activities. This could be related, first to the effects of drier climate, drought and extreme heat, and second, to the grazing and haymaking at the forest edges which hinders natural regeneration. The quality of forest seed is determined by the average climate conditions of the given location. Therefore, a good seed is produced where the heat-moisture condition is adequate and poor quality seeds are produced in harsh climates. Research by Natsagdorj L. (2012) shows seed quality has significant correlation both to the summer-drought index and to the sum of active temperature. As a result, the observed trend of the quality of seed from deciduous and coniferous forests deteriorating since the 1980's (Figure 3.3), could be explained by the increase of drought and aridity due to a warmer climate in recent years.

Annual growth of forest biomass is dependent on a given year's weather conditions and this can be shown on the width of tree rings. Dulamsuren Ch. and German scientists observed that the width of the growth rings in the Siberian larch in Mongolia is becoming thinner since the 1940's of the last century (Dulamsuren et. al. 2010, Dulamsuren 2011). Numerous research on the annual growth of forest rings as well as the evaluation of forest resources on research plots by international and national researchers, shows that there is a trend that the annual growth of forest biomass is decreasing in Mongolia (this excludes saxaul forest). However, in the Altai mountain region, due to permafrost thawing, the soil moisture and the heat for vegetation growth could be increasing. There is also a tendency that the annual precipitation in that region is increasing. Therefore, evidence can be found that forest bio-productivity is increasing in this region (Natsagdorj 2013). Figure 3.4 shows the multi-year annual growth index of the Siberian larch in an area belonging to the Kharkhiraa-Turgen basin from a point at eastern longitude of $49^{0}42$\`, northern latitude of $91^{0}32$\`, at an altitude of 1570 m above sea level.

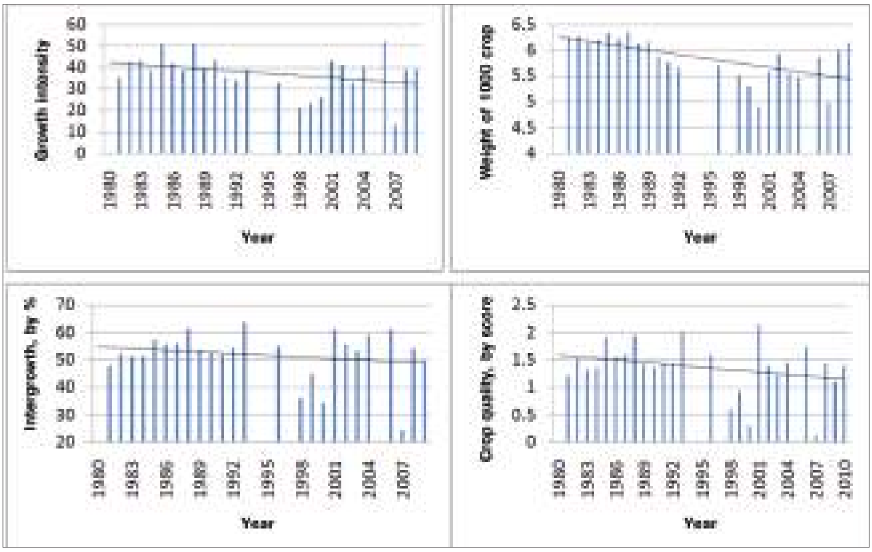


Figure 3.3 Multi-year trend of larch seed quality (national annual average)

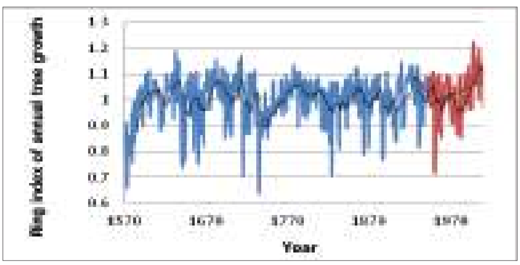


Figure 3.4 Multi-year trend of annual growth ring of Siberian larch in the Kharkhiraa-Turgen basin (in black 11 year average, line trend is based on data since 1940)

When this is compared with the multi-year trend of forest growth in northern Khentii, the picture looks the opposite. This is evidence for the difference of climatic factors inhibiting forest growth in two regions. Although specific research in this field is yet to be conducted, considering factors supporting or inhibiting photosynthesis, heat accumulation could be the decisive factor in the cold montane region of the high mountain taiga, whereas in steppe or in lower mountain regions, humidity factors could be significant. As in the areas in-between or in small mountain forests, the adequate combination of precipitation and temperature could be playing an important role. This is also visible from the bioclimatic classifications of forest regions (Natsagdorj, Beck 2013). When the multi-year trend of tree ring annual index in the Kharkhiraa-Turgen basin is compared with different climatic elements, the results are sufficient when the correlation between western region's summer temperature and the sum of temperature above 10^0C in Ulaangom is 0.47-0.49. Figure 3.5 shows the Siberian larch annual growth index in the basin and the multi-year trend of sum of temperature above 10^0C in Ulaangom.

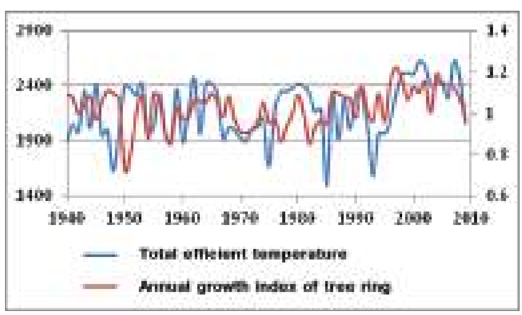


Figure 3.5 Siberian larch annual growth index and multi-year trend of cumulative temperature above 10^0C in Ulaangom

This corresponds with the fact that the aggregate temperature in Ulaangom has increased in the last 20 years (1991-2010). In Mongolia, climate warming, extension of growing season, and the increase of carbon dioxide in the atmosphere could possibly have positive effects on forest growth; however, the lack of moisture could override these factors, thus leading to a high probability of forest resource loss in the future. Furthermore, through the intensification of warming in the troposphere, forest could expand in the subalpine zone of high mountains so that the upper tree line could advance further. However, due to factors such as wind, storm, avalanche and soil erosion, large numbers of fallen trees could accumulate in the montane zone.

Scientists have used a number of humidity/drought indices to calculate change of ecological zones, subzones or biome distribution and came to the conclusion that with future climate change, the forest-steppe and high mountain taiga subzone would decrease and the probability of steppe and desert-steppe areas expanding to the north is high. For instance, the calculations using aridity level and different greenhouse gas emission scenarios show by mid-century, the montane subzones of high mountains would decrease up to 70-80% and forest steppe area by 18-41% compared to 1980-1999 (IMHE 2012).

Within the framework of the Adaptation Fund/UNDP funded “Ecosystem-based Adaptation Approach to Maintaining Water Security in Critical Water Catchments in Mongolia” project (MON/12/301), temperature and precipitation change in Kharkhiraa-Turgen and Ulz river basins were calculated using global climate models. The results show that in 2081 in Kharkhiraa-Turgen and Ulz river basins, seasonal air temperature would increase by 3.8-4.9^{0}C and in 2100 by 4.0-4.2^{0}C and summer precipitation would decrease in Kharkhiraa-Turgen by 11.9% and would increase in Ulz river basin by 2.1%. With changing climate, the forests in Kharkhiraa-Turgen basin would extend upwards until 2050 and then transition to steppe; and, in Ulz river basin, the distribution of larch and birch forest would decrease and pine and poplar area could increase. Due to observed climate warming in Mongolia, the upper tree line in high mountain subalpine zones could advance upwards. In the future, due to permafrost thawing in high mountain areas, and thus increased moisture at the upper soil level and increased heat accumulation during the growing season, the upper tree line could rise further up and the photosynthesis could intensify, whereas, the probability is high that in lower mountains and in valleys, conditions for forest growth could deteriorate. Alpine tundra and the taiga region could decrease by 0.1 to 5% by 2020 and 4-14% by 2050, and the forest steppe region in Khangai, Khentii, Khuvsgul, Altai Mountain regions could shrink by around 3% in the first quarter and 7% in the second quarter of the 21st Century (MARCC 2009).

3.1.3 Fauna

Research on how climate change is affecting biodiversity and how it will affect the future is relatively rare in Mongolia. Since 2000, researcher Ganbaatar T. has made attempts to assess the distribution trendsof locusts that are considered endemic to Munkhkhairkhan using present and future trends of certain bioclimatic indicators’ *geographic* distribution (Ganbaatar 2005). Within the framework of the science-technology project implemented at the

Institute of Meteorology, Hydrology and Environment between 2008 and 2010, distribution of certain pasture pests were evaluated using the *MaxEnt* program *(Maximum entropy modeling of species geographic distribution* - Philips et al.2006) (Turbat and Altantsetseg 2013). The results of the assessment using the MaxEnt model on key species of the Kharkhiraa-Turgen, Ulz river basins that were conducted within the framework of the Adaptation Fund/ UNDP funded project, "Ecosystem-based Adaptation Approach to Maintaining Water Security in Critical Water Catchments in Mongolia," is presented below (Project report 2013).

Mountain ungulates: Argali sheep (*Ovis ammon)*, Ibex (*Capra sibirica).* The mountain ungulates argali sheep and ibex are the main representatives of the Mongolian Altai mountain range ungulates. The number of the best ungulates in the Mongolian Altai range has reduced and its habitat shrunk dramatically due to poaching and hunting for many years of the best adult males with the longest and biggest horns. Research shows that in 2001, in the total area of the 5 western aimags covering 18,446.1 square km, 4000 argali sheep were counted, and in 2009, it was estimated that in a total of19,579 square km area, there are around 7,000 argali sheep (Institute of Biology 2009). Using the MaxEnt model, it was estimated that currently (1956-2000) or as of 2000, the habitat area of the mountain ungulates was about 81,364 square km.This assessment was conducted using data from ranger monitoring in the western region as well as research data by biologists and geographic location, and thus, is the most realistic result compared to previous research results (Figure 3.6).

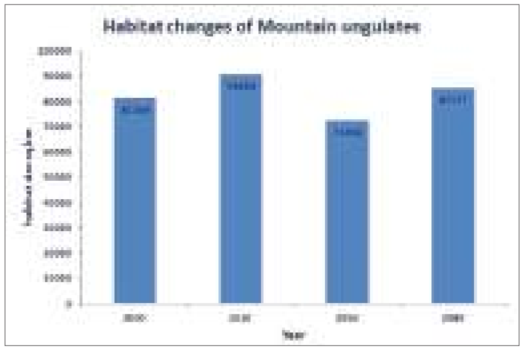


Figure 3.6 Habitat change of mountain ungulates in the western region (2000-2080)

The habitat of the mountain ungulates comprises about 20% of the Altai mountain range area in the western region. With climate change impacts, no sudden fluctuating change will be observed, and in 2020 (2011-2030), the habitat could expand due to favorable conditions. The current habitat or the base number could increase by 11% (9296 km^2) in 2020, but in 2050 (2046-2065), the habitat could again shrink at a similar rate of 11% (8946 km^2) which in 2080 (2081-2099) could increase by 5% (3813 km^2). With a small percentage of rise or decline, it looks as if climate change will not have a serious impact on the habitat of mountain ungulates (Figure 3.6 and 3.7), however, the habitat fragmentation in the Mongolian Altai range that starts around 2020 will be the main factor for species number, density and habitat. This fragmentation is more prevalent in 2020and 2050, but in 2080 due to favorable conditions, the historic habitat could be restored. If human activities such as infrastructure, arable farming, mining and intensive farming developments are taken into account when assessing the habitat change, it is clear that the change will be enormous.

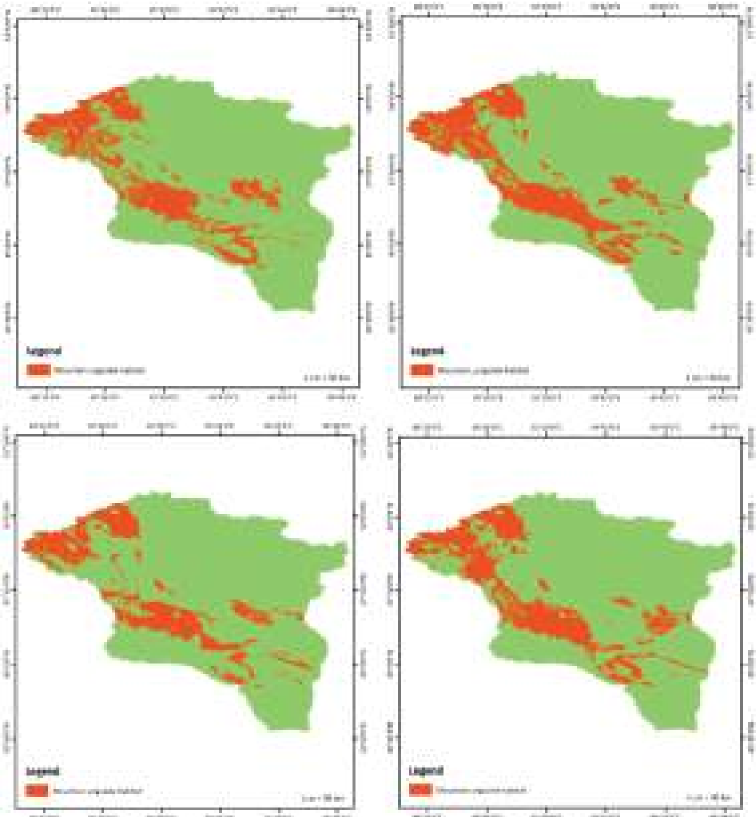


Figure 3.7 Mountain ungulate habitat change in the western region (2000-2080)

When the mountain ungulate habitat size decreases, the number and density of that specific population will also decrease. The increasing snow and cold in winter combined with increasing heat and decreasing precipitation in summer, will be the main cause for limiting fodder and habitat, and thus for migration and change of habitat. On the one hand, it could be a positive development with the shrinking of the habitat and with the declining number and density of mountain ungulates, the competition between ungulates and livestock for pasture and water would decrease. On the other hand, carnivores such as the snow leopard and wolf, which mainly prey on mountain ungulates, would have to compensate for the decrease in ungulates with livestock.

Marmot (Marmota sibirica, M.baibacina). The marmot is one of the most widely spread animals in Mongolia that is abundant and has good reproduction. There are two species of marmot in Mongolia; black marmot (Altai marmot) found in a small area in the northwestern part of the country and the Mongolian marmot, abundant in steppe areas. Marmot stock in Mongolia was estimated with the following results;

20 million in 1970, 16-17 million in 1989, and in 1990, the marmot study division of the Mongolian-Russian joint expedition estimated about 13 million whereas the experts of the National Center for Zoonotic Diseases estimated 10.7 million on 68.2% of the total territory or 1,068,000 square km area, which translates to 65 individuals on 1 square km. Examples of marmot distribution inaimags would be: 15,000 in Khan Khukhii, Uvs aimag in the western region on 5000 square km area with an average density of 0-100 and in Zavkhan 625,000 on a 14,400 square km area with an average density of 400 individuals (Adiya 2000).

Research using the MaxEnt model showed the current marmot habitat in the western region is 69,406 square km or 16% of the whole western region. The point data required for the modeling was only available in the western region; therefore, the marmot location is assessed only in this region.

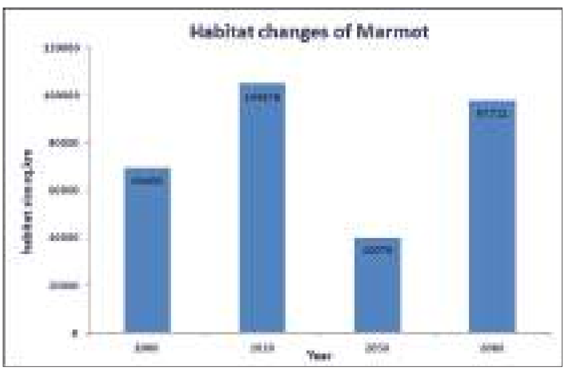


Figure 3.8 Habitat change of Mongolian marmot in the western region (2000-2080)

The future condition of the marmot habitat in the western region is not stable due to climate change (Figure 3.7, 3.9). For instance, there is a positive development of current marmot habitat increasing by 51% (35,470 sq km) in 2020, but in 2050 it could decrease by 42% (29,328 sq km) compared to 2000. It should be reiterated again that this calculation did not include human activities but only climate change impacts. The fact that in 2080, the habitat area could increase by 42% (28,305 sq km) is a clear example of what kind of impact climate change alone could have (Figure 3.8, 3.9). This kind of rise and decline poses considerable pressure on the growth of a given species.

From the 2020's when favorable conditions should be prevalent for the marmot habitat, marmot conservation management should be improved so that the species can not only be conserved, but also used in an environmentally friendly and economically sustainable manner. It could also provide the condition for soil generation in the Altai mountains and ensure the sustainability of the ecosystem. The modeling results for the future trend of marmot habitat in the western region confirms the current core marmot habitat around the Altan Khukhii and Kharkhiraa-Turgen mountain systems, Siilkhem, western part of the Khangai mountains and part of Altai mountain in Gobi-Altai aimag. It also shows the favorable environment for in-situ marmot conservation and re-introduction.

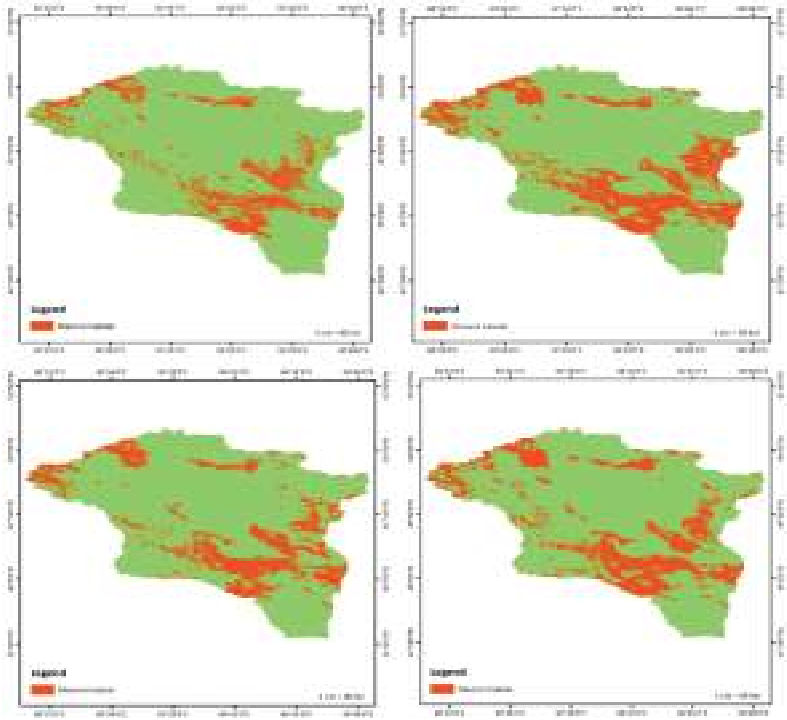


Figure 3.9 Marmot habitat change in the western region (2000-2080)

One would consider that due to the digging of holes by mammals, the micro-surface of the land, soil structure, water and moisture supply, that vegetation composition and yield of the sub-surface area all change, thus leading to a change in the general character of a given area, that the marmot is an important animal for the ecosystem and biogeocenosis of a given area (Adiya 2000).

Mongolian gazelle (Procapra gutturosa). Mongolian gazelle used to live in the desert-steppe and steppe regions of Mongolia in an area ranging up to 780,000 square km. The population is divided between the southern and central area of Mongolia. In the late 1980's and early 1990's, in the Khomin tal area of the Great Lakes depression, an isolated population existed which was supported by the population in the eastern part of Mongolia. Mongolian gazelle do not stay in one place too long, instead they migrate, and therefore, it looks as if the habitat was growing or constantly changing. Mongolian gazelle can also be found in the Russian Federation and China (Clark et al. 2006).

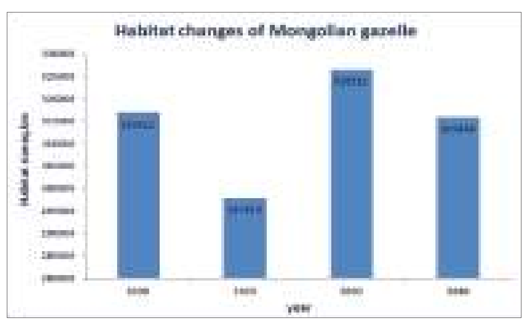


Figure 3.10 Habitat change of Mongolian gazelle (2000-2080).

With the help of modeling, it was determined that the habitat size of Mongolian gazelle was 316,812 square km. In other words, this much area was a suitable habitat for gazelles which corresponds to 21% of the total territory of Mongolia (Figure 3.10, 3.11).

There seems to be no change in the core habitat of the gazelles where they roam freely in a large area (Figure 3.11), however, some parts of the habitat in central Mongolia and Dornogobi and the Sukhbatar provinces, for instance, could

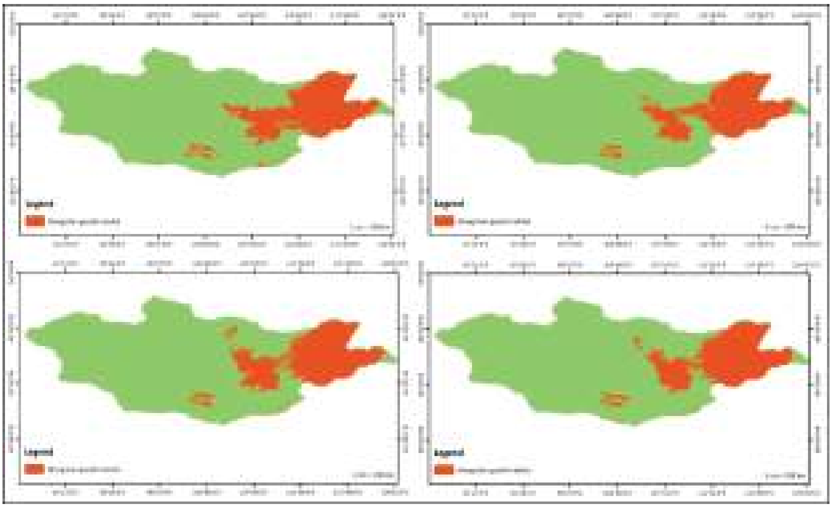


Figure 3.11 Habitat change of Mongolian gazelle (2000-2080)

get fragmented and shrink. Especially in Zavkhan aimag in the western region, as it is apparent that the small area that was favorable for gazelles will disappear in the future. This is a clear example of what kind of impact climate change can have when a small fragmented population of gazelles can no longer live in an area where they used to inhabit.

This number is in line with the average (362,500 sq km) research results that are available (Milner-Gulland and B.Lkhagvasuren 1998), such as the research on historical distribution and number of gazelles by Russian scientists that stated 250,000 square km in 1990 and aerial census of 1994 which estimated gazelle distribution at 475,000 square km. The habitat of Mongolian gazelles could in the future decrease due to the impact of climate change. For instance, the habitat size of gazelles in 2000 could decrease by 6% (18,998 sq km) in 2020, but it could increase by 3% (9,709 sq km) in 2050. In 2080 the size of the habitat could reach its current size 0% (974sq km) which is a decline compared to the 2050 (Figure 3.11).

White-naped crane (Grus vipio). This species breeds in the northeastern part of Mongolia where there are wetlands and wet meadows including reed beds, lakes with tall marshy vegetation, river valleys, islands on lakes and river sand steppe lakes surrounded by reeds.

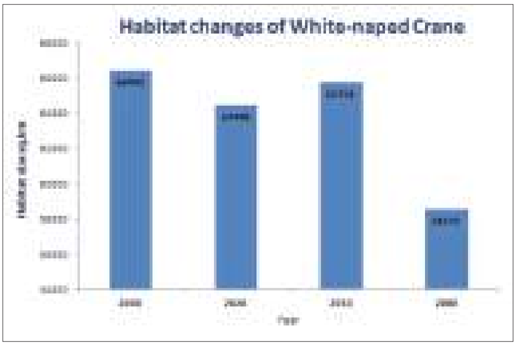


Figure 3.12 Habitat change of white-naped crane in Mongolia (2000-2080)

There are 6,500 pairs of white-naped crane in the world. Global breeding and resident ranges are estimated at 746,000 square km. There is limited research in Mongolia on the number and stock of white-naped cranes. However, there is data that suggests 800 individuals breed along the Onon, Ulz, Balj, and Kherlen river valleys. Forty percent of the world's white-naped crane population can be found in Mongolia. 1,400 white-naped cranes were counted in the Daurian area, which is 23% of the world's population. White-naped cranes are a migratory breeding bird. They arrive at the breeding grounds, which consists of wetlands around river valleys, wet meadows, low land steppes and lakes surrounded by reeds, around mid-April. Environmental degradation that also covers the breeding ground for white-naped cranes is a serious challenge. Drought, degradation of wetlands and reed rich lakes and pasture degradation in the riparian area are the main reasons for white-naped crane's habitat deterioration (Gombobaatar et al. 2011).

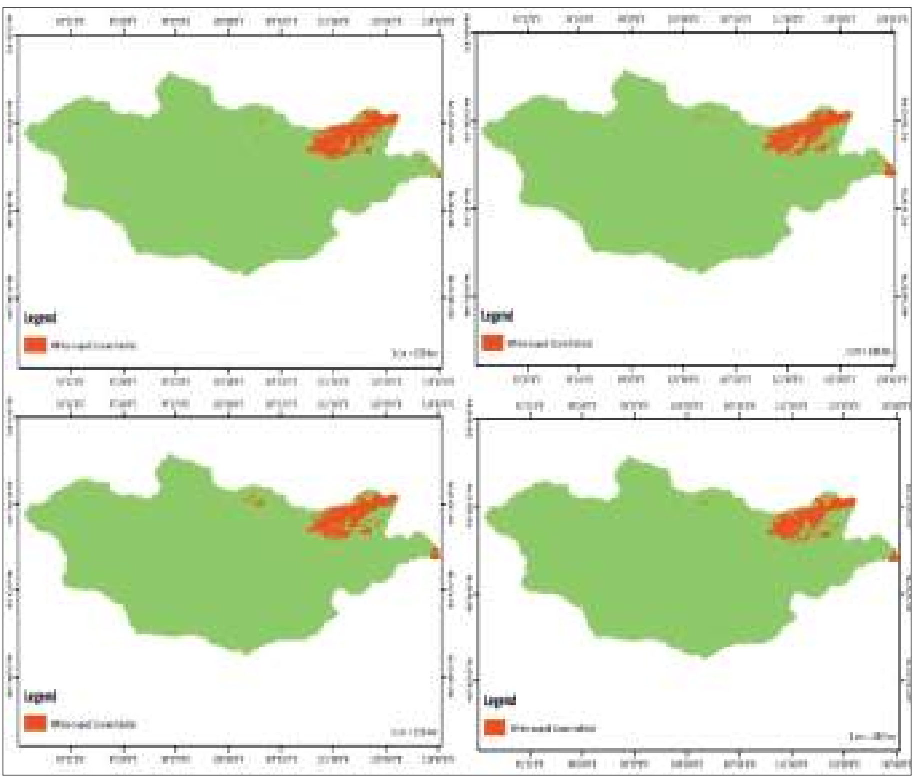


Figure 3.13 Habitat change of white-naped crane in Mongolia (2000-2080)

The habitat of white-naped cranes in Mongolia is decreasing due to climate change (Figure 3.12, 3.13). Compared to the current size, the habitat of the white-naped crane will decrease by 3% (1999sq km) in 2020, by 1% (684 sq km) in 2050 and by 12% (7899 sq km) in 2080. In addition, it can be observed that the habitat will be fragmented, and thus, will shrink from the south and southwestern side of the overall habitat.

Altai snowcock (Tetraogallus Altaicus). Altai snowcock is one of the rare species of bird in Mongolia that has been little researched.The Altai snowcock is a beneficial bird that produces legitimate medicinal products from an animal source that have been used in traditional Mongolian medicine for thousands of years. The information on the habitat of the Altai snowcock, its size, number and density, is limited and the research conducted by the scientists of Mongolia and the former Soviet Union are of limited use. Researcher Zorig G. published research about the distribution of Altai snowcock for the first time (Zorig 1989). This research of Zorig (1989) shows that Altai snowcock can be found in a 171,612 square km area in Mongolia, of which 110,344 square km belongs to the western region or the five western provinces. It also shows the Altai and Khangai mountains are important core areas of the Altai snowcock. With the help of modeling, it was found that the Altai snowcock's habitat size was 135,230 square km in 2000. This corresponds to 9% of the total territory of Mongolia which is 11% (36,382 square km) less than the estimated habitat size of Zorig G. (1989) and others.

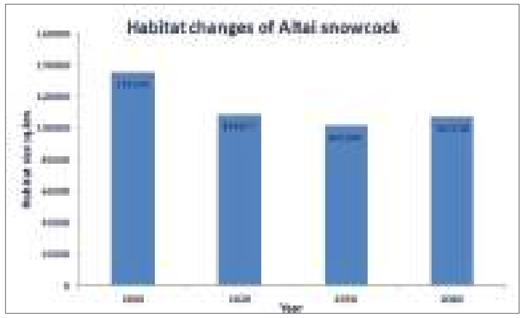


Figure 3.14 Habitat change of Altai snowcock in Mongolia (2000-2080)

According to the research on the distribution and habitat size of Altai snowcock (Zorig 1989), the Altai snowcock could be found at that time in Mongol-Altai, Gobi Altai and the mountains of Khangai and Khuvsgul. More than 70% of this overall distribution area belongs to the western region which shows the importance of this region for the conservation of Altai snowcock.

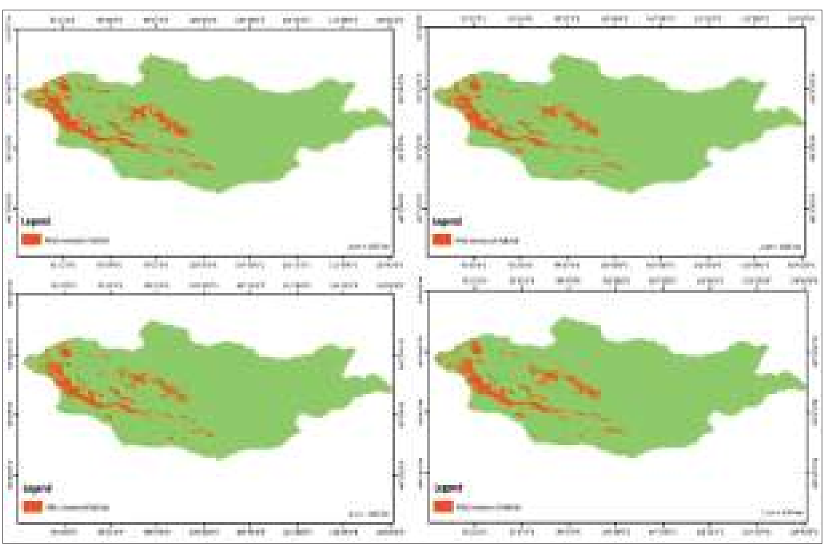


Figure 3.15 Habitat change of Altai snowcock in Mongolia (2000-2080)

Figures 3.14 and 3.15 show that the habitat of Altai snowcock would gradually decrease and become fragmented between 2000 and 2080. In other words, the Altai snowcock's habitat would decrease by 20% (26,553 sq km) in 2020, by 25% (33,840 sq km) in 2050 and by 21% (27,972sq km) in 2080. (Figure 3.14, 3.15). In terms of distribution, the habitat of Altai snowcock would dramatically decrease in Mongol Altai, Gobi Altai and the Khangai mountain range areas (Figure 3.15). The striking change of the Altai snowcock habitat is visible in Bayan-Ulgi aimag of the Mongol-Altai mountain range. In addition, the modeling result that showed a small area where Altai snowcock could live in Selenge aimag disappears in 2080. However, there is a positive development from 2050 to 2080 when the habitat of Altai snowcock would increase slightly.

Lark family species (Alaudidae). The Lark family ranges between 1-6 species which can be found in different ecological zones of Mongolia. The Lark family species is distributed in mountain-steppe, steppe and desert areas of open fields with sparse vegetation, which overlaps with the pasture area for livestock. These birds rarely come to forests and urban green areas. These birds feed on seeds and insects including locusts that are most commonly distributed in the steppe region, grasshoppers, crickets, and their eggs above ground and in the soil, and larvae, which make it an important species for protecting pasture vegetation.

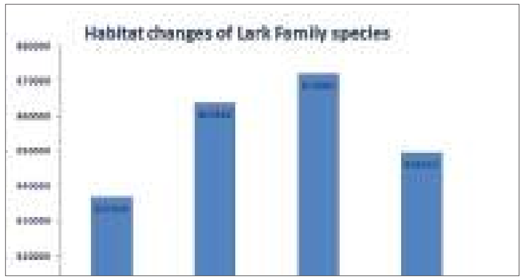


Figure 3.16 Habitat change of Lark family species in Mongolia (2000-2080)

Research results from the modeling show that the Lark family species are distributed in a 837,024 square km area in Mongolia (Figure 3.16, 3.17). Climate change would have a positive impact on the habitat of the Lark family species. Thus, the habitat size would increase in 2020 by 3% (26,892 sq km), in 2050 by 4% (35,061 sq km), and in 2080 by 2% (12,586 sq km), compared to the value of 2000. The habitat size would increase constantly between 2000 and 2050, but between 2050 and 2080, it could decrease (Figure 3.17). In the Eurasian steppe, the Lark family species dominates among the birds that feed on seeds of grassy vegetation, insects, larvae and other small animals in terms of the distribution, number of its species and individuals. There are hardly any areas in Mongolia where there are no species of the Lark family. In some areas, a number of species co-exists in a sympatric way (Mainjargal 2014).

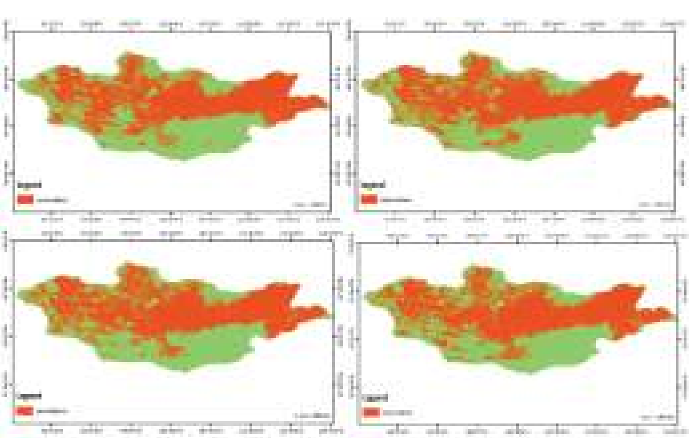


Figure 3.17 Habitat change of Lark family species in Mongolia (2000-2080)

3.1.4 Water resources, glacier and permafrost

Water resources.

The total surface water resources of Mongolia are composed mainly from water stored in lakes of 500 km^3/year (J.Tserensodnom, 2000) and glaciers of 19.4 km^3/year (G.Davaa, 2012). Only 6.2% of the total surface water resources, i.e. 34.6 km^3/year, are in rivers, with 1.9% in baseflow and 4.4% in direct runoff of rainfall and from snow melting as determined from a flow separation analysis. The amount of 34.6 km^3/year consists of the river runoff formed within Mongolia (30.6 km^3) and surface inflow water of 4 km^3/year from adjacent countries of Russia and China (B.Myagmarjav and G.Davaa, 1999). The amount of water resources in the renewable ground water (i.e., groundwater with smaller residence time that can be replenished relatively quickly) has been estimated as 10.8 km^3/year (N.Jadambaa, 2002). Surface water inventories were conducted in the very low flow years of 2003 and 2007, and the moderately low flow year of 2011, and indicate that the change in the number of dried up rivers, lakes and springs was relatively low in 2011 in correlation to the water flow condition of year (Table 3.14).

The total water use rate in 1996 was equal to 0.40 km^3, 25.2% of whichwas used for municipal needs, 25.8% for industry, 34.6% for livestock, 7.9% for irrigated arable land, and 6.5% for other needs (Myagmarjav and Davaa, 1999). The country's total water use was 326.3 mln.cub.m in 2010, and is projected to increase to 478.2mln. cub.m if the scenario of low water use in 2021 is used. The annual water use rate will increase by 26.8% in the scenario of medium water use and will increase by almost double in the scenario of high water use in 2021, in comparison with scenario of low use of water in 2021 (Table 3.15).

The impact of anthropogenic influences will result in deforestation, the compaction of soil, and the deterioration of vegetation cover. This leads to a change in the water regime, pollution and a reduction in biodiversity. The impact of climate change on water resources can be assessed in three main river basins - the Arctic Ocean Basin (AOB), the Pacific Ocean Basin (POB), and the Asian Internal Drainage Basin (AIDB) in Mongolia. The annual total river flow since 1978 varies, gradually increasing and reaches its maximum high of 78.4 cub.km in 1993. Then, the flow began decreasing and a long-lasting low flow period is observed from 1996 until 2012.

Table 3.14 Surface water inventory of Mongolia

Year	Number of rivers		Number of lakes		Number of springs		Number of mineral springs
	Total	Dry	Total	Dry	Total	Dry	Total
2003	5565	683 (12.3%)	4193	760 (18.1%)	9600	1484 (15.4%)	-
2007	5128	852 (16.6%)	3747	1181 (31.5%)	429	60 (14.0%)	-
2011	6646	551 (8.3%)	3613	483 (13.4%)	10557	1587 (15.0%)	265

Source: Integrated Water Resources Management Plan of Mongolia, 2012

Table 3.15 Current and future projection of annual water use rate of the country under three different water use scenarios

Water users, economic sectors		Water use rate, mln cub.m/year					
		2015 year			2021 year		
Scenarios		low	medium	high	low	medium	high
Drinking and municipal water use	Urban	66.4	70.9	78.6	67.2	72.9	81.8
	Rural	4.1	4.0	4.0	5.9	6.0	6.0
Social service	Social	4.8	5.6	7.6	6.3	8.7	17.2
	Domestic	5.7	5.9	6.8	6.0	6.5	8.5
Industrial water use and water for construction	Light and food industry	4.4	5.1	6.6	5.6	7.6	13.5
	Heavy industry	1.6	1.8	2.3	2.0	2.7	4.7
	Energy	1.6	2.0	2.4	2.1	3.2	4.5
	Mining	37.8	44.7	54.3	43.9	63.5	97.3
	Construction and construction material production	51.9	81.1	102.0	61.1	111.1	186.1
Agriculture	Livestock	90.2	94.9	109.4	103.1	108.6	117.3
	Irrigation	125.0	169.8	203.2	165.5	260.8	360.0
Others	Tourism	1.2	1.4	1.6	2.7	3.4	4.0
	Green park	2.5	2.6	2.6	2.7	2.9	3.0
	Transport	3.2	3.6	4.1	4.1	4.5	5.0
Total water use, mln.cub.m/year		400.6	493.4	585.6	478.2	662.4	908.9

Source: Integrated Water Resources Management Plan of Mongolia, 2012

The first time such a severe low flow period has been observed since the 1940. The lowest flow was observed in 2002. Fortunately, since 2012 a high flow period has started (Figure 18).

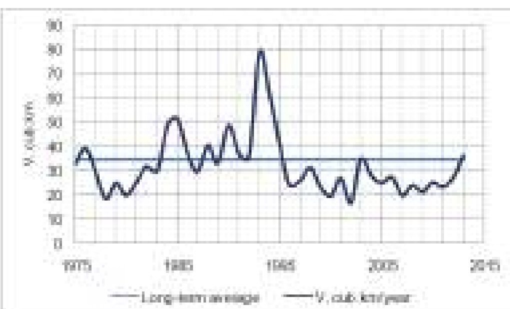


Figure 3.18 Annual total river flow variation in Mongolia, cub.km/year

According to lake area classification and lake morphology data acquired from a topographic map scaled as 1:100000, there are 1391 natural lagoons with an area less than 0.1 sq.km, 3399 extremely small lakes with an area of 0.1-1.0 sq.km, 287 very small lakes with an area of 1.0-5.0 sq.km, 75 moderately small lakes with an area of 5.0-10.0 sq.km, 29 small lakes with an area of 10.0-20.0 sq.km, 9 moderately medium lakes with an area of 20.0-50.0 sq.km, 9 moderately medium lakes with an area of 20.0-50.0 sq.km, 12 medium lakes with an area of 50.0-100.0 sq.km, 8 moderately big lakes with an area of 100.0-500.0 sq.km, such as, Achit, Dorgon, Boontsagaan, Uureg, Telmen, Sangiindalai, Airag, and Orog lakes, two big lakeswith an area of 500.0-1000.0 sq.km, such as,Buir and Khar lakes, and four large lakes with an area exceeding 1000.0 sq.km, such as, Uvs, Khovsgol, Khyargas and Khar-Us lakes.

Results of comparison analysis on lake morphology data acquired from the above-mentioned topographic map, compiled, based on air photos taken in the 1940s and LANDSAT TM and ETM satellite data of 1999-2002, 2009-2010 years show that there was no change in the number of large, big, and moderately big lakes, and the total areas of large, big and moderately big lakes increased by 13.7 sq.km, 3.8 sq.km and 100.8 sq.km, respectively. However, the total area of medium lakes, many of which are located in the steppe region, has decreased by 91.2sq.km. The number and total area of moderately medium, small, moderately small and very small lakes are quite unsTable and their total area has increased by 1.6-44.8 sq.km, respectively based on lake area classifications. The number of extremely small lakes has decreased by 1,689 due to a decrease in their area, and accordingly the number of natural lagoons (shaltoirom) have increased by 1690, even though the total area of lagoons has decreased by 18 sq.km in the period of 1940th till 1999-2002. Totally, 295 lakes dried up, 50 lagoons disappeared and the total lake area decreased by 373.4 sq.km or by 2.2% in the period. Lake areas even reduced in 2010 in comparison with previous periods (Table 3.16).

Long-term observation shows that the water levels of lakes were decreasing during the 1996-2011 period. However, the water levels of the following lakes increased in 2013: Terkhiin Tsagaan Lake located in the forest steppe zone increased by 12 cm, Ugii and Buir lakes located in steppe zone increased by 45 cm and 81 cm, respectively, and Khar-Us, Ganga and Duut lakes located in Gobi desert zone increased by 18 cm, 24 cm and 36cm, respectively. The water levels of other large, big and medium sized lakes, located in various natural zones, especially Khyargas, Boontsagaan and Orog lakes located in the Gobi desert,have still not recovered yet and tend to decrease (Figure 3.19). However, many of small and natural lagoons recovered in 2013.

Natsagdorj L, 2004, studied the change in potential evaporation over the last 60 years, and found that it has increased by

Table 3.16 Changes in number and areas of lake with respect to their areal classification

Size of lake	Size of lake area	Landsat ETM (2010)		Landsat ETM (2000-2002)		Topographic map, scaled S1:100000 (1940th)		Difference of lake area, sq.km (F2010-F2000)	Difference of number of lakes (N2010-N2000)
		Number of lakes	Sum of lake area, sq. km	Number of lakes	Sum of lake area, sq. km	Number of lakes	Sum of lake area, sq. km		
Large	>1000	4	8859.6	4	8815.214	4	8801.343	44.4	0.0
Big	≥500.0-<1000.0	2	1195.4	2	1196.1	2	1192.3	-0.7	0.0
Moderately big	≥100.0-<500.0	7	1593.2	9	1913.55	8	1812.8	-320.4	-2.0
Medium	≥50.0-<100.0	11	790.8	11	760.62	12	851.8	30.2	0.0
moderately medium	≥20.0-<50.0	7	199.0	9	256.421	9	254.8	-57.4	-2.0
small	≥10.0-<20.0	14	199.39	30	419.23	29	383.4	-219.8	-16.0
Moderately small	≥5.0-<10.0	36	256.1	71	489.38	75	444.6	-233.3	-35.0
Very small	≥1.0-<5.0	187	384.98	239	556.01	287	531.2	-171.0	-52.0
Extremely small	≥0.1-<1.0	1295	392.39	1710	531.355	3399	964.4	-139.0	-415.0
Natural lagoon	0.1>	2705	93.74	3081	96.79	1391	114.6	-3.1	-376.0
Total		4268	13964.6	5166	15034.7	5216	15372.07	-1070.1	-898.0

3.2-10.3% in the steppe and desert zone, and by 10.2-15.0% in the high mountain and forest steppe zone. By the first half of the 21st century, the increase in potential evaporation could exceed by six to ten times the increase in precipitation.

Lakes, located in flood plains and meandering areas of the rivers have not recovered yet.

These lakes are fed by in undated waters from big and bigger floods and due to the increase in evaporation and lack of bigger floods, have dried up and are getting more vulnerable to climate change. Therefore, it is necessary to take adaptive action, such as hard measures like a building a water allocation canal at the water level which would be less than the water level observed during big floods. Currently, the water levels of the Khovsgol and Terkhiin Tsagaan lakes, located in the forest steppe zone, the Buir and Khokh lakes, located in the steppe zone, and Khar-Us lake in the Gobi desert zone are higher than theirlong-term averages. The water level of the Uvs Lake is near its average value. The water levels of the Khyargas, Boontsagaan and Orog lakes are 1.10-2.20 m below their averages. The water levels of other lakes are below their averages due to an increase in evaporation (Figure 3.19).

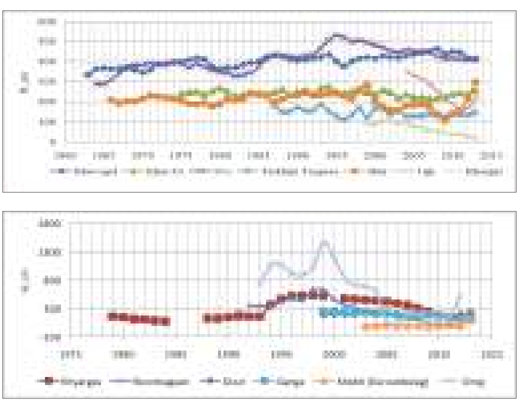


Figure 3.19 Water level variation of selected lakes in Mongolia, S*ource: Hydrology division, IMHE*

The biggest valley glaciers are Potanin and Aleksandr glaciers at Tavanbogd Mountains in Mongolia. The Potanin glacier retreated by 550 m in the period of 1945-1989 and by another 185 m in the period of 1989-2001. The retreat rate was 12 m/year during the first 44 year period and increased to 15.5 m/year in the second 12 years period (Figure 3.20).

Figure 3.20 Retreating features of the Potanin and Aleksandr glaciers at Tavanbogd

Photographs were taken by the 1910 Royal Geographical Society Expedition under the leadership of Douglas A. Carruthers, were reoccupied during a U.S.–Mongolian anniversary expedition in 2010, and the results showed a recession of valley glaciers. Kamp et al. (2013) compared the 1910 and 2010 photographs with a 1970/1971 Soviet topographic map based on 1968 aerial photography and with Landsat imagery from 1992 and 2010, and they quantified the recession: West Turgen Glacier receded by 403 m from 1910 to 1968 (approximately 7 m a–1), receded by 87 m from 1968 to 1992 (approximately 3.6 m a–1), and receded by 110 m from 1992 to 2010 (approximately 6 m a–1); in total, it receded by approximately 600 m during the 100 years from 1910 to 2010 (Figure 3.27). Kamp et al. (2013) also documented a surface lowering of around 70 m at West Turgen Glacier from 1910 to 2010. In contrast to these changes at many valley glaciers, the plateau glacier on Turgen Peak and other glacierized areas above an elevation of 3500 m a.s.l. appeared to be more or less unchanged.

In-situ observation in the period of 2004-2012 evidences that negative mass balance on the Potanin glacier has been observed and there is a tendency for more intensive ablation. Herren et al. (2013) reported the results of a 72-m long surface-to-bedrock ice core drilled on Khukh Nuru Uul, a glacier in the Tsambagarav mountain range of the Mongolian Altay (4130 m asl, 48°39.3380'N, 90°50.8260'E). The small ice cap has low ice temperatures and flat bedrock topography at the drill site. This indicates minimal lateral glacier flow and thereby preserved climate signals. The upper two-thirds of the ice core contain 200 years of climate information with annual resolution, whereas the lower third is subject to strong thinning of the annual layers with a basal ice age of approximately 6000 years before present (BP). It is interpreted that the basal ice age as indicative of ice-free condition in the Tsambagarav mountain range at 4100 m asl prior to 6000 years BP. This age marks the onset of the Neoglaciation and the end of the Holocene Climate Optimum. The ice-free conditions allow for adjusting the Equilibrium Line Altitude (ELA) and derive the glacier extent in the Mongolian Altay during the Holocene Climate Optimum. Based on the ELA-shift, concluded that most of the glaciers are not remnants of the Last Glacial Maximum but were formed during the second part of the Holocene. The ice core derived from accumulation reconstruction suggests important changes in the precipitation pattern over the last 6000 years. During the formation of the glacier, more humid conditions than presently prevailed and were followed by a long dry period from 5000 years BP until 250 years ago. Present conditions are more humid than during the past millennia. This is consistent with precipitation evolution derived from lake sediment studies in the Altay. These constructed climate conditions mostly may reflect prevailing summer conditions, because summer precipitation and snow drift accumulation plays a main role in accumulation and mass balance dynamics of the glaciers in Altay Mts.

Current changes in the water regime of rivers can be classified into four types of changes occurring- 1. Rivers where annual and seasonal flows are increasing, 2.Rivers where spring and summer flows are decreasing and autumn and winter flows are slightly increasing, 3.Rivers where only winter flow is slightly increasing, and 4.Rivers where all seasonal flows are decreasing. Rivers that belong to the first type of changes include those draining from the glaciers of the Altay Mountains, the Bogd River, draining from the Otgontenger Mountain, and rivers draining from the Munkhsaridag Mountains. Rivers draining from the Khangay and Khentey Mountains, which have continuous and discontinuous permafrost distributed, fall into second type of changes. Downstream areas of big and bigger rivers fall into the third type of changes. Rivers draining from the southern slope of the Khangay and Altay Mountains, draining from the Gobi-Altay Mountains and rivers and streams flowing in the dry steppe and desert steppe zones, belong to fourth type of changes.

Statistically significant changes occur in starting and ending dates of the occurrence of ice phenomena - ice cover in autumn and spring. Accordantly, their durations and ice depth are changing. A slight increase in annual and seasonal flows is observed in small and medium size rivers, draining from the northern slope of the Altay Mountains and also a slight increase in autumn and winter flow of the Selenge and Onon rivers.

Maximum ice depth has been increased by 40 cm, its observed date shifted by one month later compared with the date in the beginning of the observation period and the duration of occurrence of ice phenomena and cover has been extended by 10-20 days in these permafrost and glacier fed rivers, where the water temperature has been decreasing. Except for those rivers mentioned above, the maximum ice depth has decreased by 35 cm, its observed date shifted by half a month earlier and the duration of the ice cover period has been shortened by 5-44 days, 20 days on average, and the ice phenomena period has been shortened by 15 days in river basins of discontinuous permafrost and steppe zone. The water temperature has been increasing in these rivers.

Hydrological changes are driven by the climate change impact and anthropogenic influences are very complex and reflect also the glacier and permafrost melting effect. During the periods of 1997-2012 and 2000-2012, water levels in shallow ground water and unconfined aquifers of the forest steppe, steppe and desert zones, have been observed by boreholes drilled in Muren in Khovsgol, Arvaykheer in Ovorkhangay, and Ekhiingol in Bayankhongor. The observations show that the water levels have been decreasing by 0.63m, 2.3m and 0.36m, respectively. The water level is continuously decreasing at Muren, is stabilized at Ekhiingol, and has increased at Arvaykheer in 2013 (Figure 3.21).

The United States National Aeronautics and Space Administration (NASA) and the German space agency, Deutsches Zentrum für Luft- und Raumfahrt (DLR) jointly launched a pair of the satellite units as Gravity Recovery and Climate Experiment (GRACE) on the same orbit. A detailed estimation of the changes in earth's gravity field is made through precise measurements of the distance between the units. Since the measured gravity field, at monthly timescales, is the integration of that from the atmosphere, the ocean, the solid earth and the terrestrial water storage (TWS), the terrestrial water storage change (TWSC) can be derived through the independent estimation of the others. K.Kobayashi and J.Asanuma, 2013 derived TWSC having a horizontal resolution of approximately 300-400km, and a temporal resolution of about a month for the period of 2005-2011. TWSC from GRACE is the sum of changes in vertically integrated water mass, such as ground water, soil moisture, snow accumulation and so on. They used Level-3, gridded 0.5^{o} data set, including the northern part of China (Figure 3.22). TWSC and its linear trend were computed for each of the areas, shown in Figure 3.22. There are remarkable temporal changes of TWS in each region. In the region "a", including some part of the Altay Mountains, Great Lake hollow and northern part of China, continuous

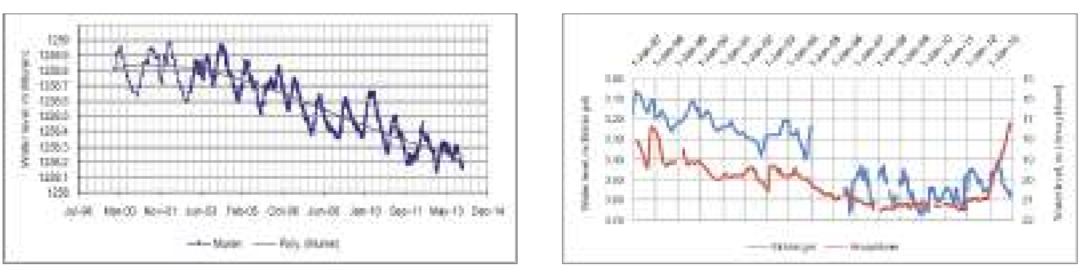


Figure 3.21 Water level dynamics in shallow ground water and unconfined aquifers at Muren, Arvaykheer and Ekhiingol, *Source: IMHE*

decrease in TWS can be found which can be attributed to the glacier retreat, lowering water level of lakes and ground water. TWS continuously decreases in the area "c" covering the Central Mongolian Economy region, centered by Ulaanbaatar. These are in marked contrast with the area "d" where TWS shows fairly constant. It is also noted that these four areas show a seasonal change of TWS. Among these, the area "a" exhibits the largest seasonal change in TWS and this can be partly consistent with seasonal snowfall and its melted water.

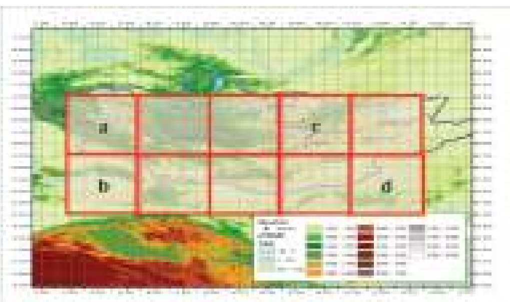


Figure 3.22 The target region and the sub-areas subject to the analyses

Future climate change impact on water resources

Assessment results of the climate change impact on river water resources show that when the air temperature isn't changed and precipitation changes, river runoff changes with changes in precipitation (Batima, P. 2005). For example, if one assumes that the annual amount of precipitation decreases by 10% and no change in the air temperature, then annual river flows in the Central Asian Internal Drainage basin, the Arctic Ocean and the Pacific Ocean basins would decrease by 7.5%, 12.5% and 20.3%, respectively. When the annual precipitation decreases by 20 %, the reduction in river flow is approximately the same in all basins, namely, the river flow decreases by 20.2% in the Central Asian Internal Basin, by 22.3% in the Arctic Ocean Basin, and by 29.3% in the Pacific Ocean Basin. The percentage of increase in river flow due to the 20% increase in precipitation is comparatively less than the decrease in volume of river flow when there is the same percentage decrease in precipitation. When there is no change in the volume of precipitation, but the air temperature increases, then on average the river flow in the Arctic Ocean basin decreases by 4-20%, and decreases by 15-30% in the Pacific Ocean Basin. This fact is explained by an increase in potential evaporation. Thus, the surface water cannot be supported by soil moisture or underground water. However, in the Central Asian Internal Basin, the river flow will increase by 6.7% with a one degree increase in the air temperature, and as the air temperature increases by 2°C the river flow decreases by 3.4%, and with a 3°C increase in air temperature, the river flow decreases by 0.2%. This fact shows that the initial temperature increase causes snow cover and glaciers to melt, thereby increasing the river flow. However, as the temperature continues to rise, the snow cover and glacier water resources could be exhausted; when the air temperature increases by 5°C, the river flow will be decreasing. Approximately 40% of the Mongolian river water resources form in the Central Asian Internal Drainage Basin, and its Great Lakes Depression stores another 20% of the total lake water resources in the country (Table 3.17).

Table 3.17 Changes in river flow in correlation with assumed changes in annual precipitation and air temperature, in %

	Changes in precipitation (P, % of its annual amount)					
		P=0%	P-10%	P-20%	P+10%	P+20%
Changes in air temperature (T, % of its annual average)	Central Asian Internal Drainage basin					
	T+0	0.0	-7.5	-20.2	21.2	37.3
	T+1	6.1	-5.9	-17.3	26.2	40.0
	T+2	3.7	-8.9	-20.2	21.3	36.3
	T+3	0.2	-12.1	-22.8	17.0	30.6
	T+5	-13.1	-21.7	-30.1	-3.2	6.2
	Arctic Ocean basin					
	T+0	0.0	-12.5	-22.3	12.8	27.4
	T+1	-3.8	-14.1	-23.5	9.1	22.9
	T+2	-9.3	-18.4	-27.2	1.9	14.5
	T+3	-13.5	-21.6	-29.0	-3.0	7.9
	T+5	-22.3	-17.6	-39.4	-16.7	-8.6
	Pacific Ocean basin					
	T+0	0.0	-20.3	-29.3	17.7	31.2
	T+1	-15.1	-26.9	-36.9	5.0	21.2
	T+2	-20.7	-31.9	-40.1	-5.5	8.2
	T+3	-23.1	-31.6	-42.1	-9.8	6.1
	T+5	-33.2	-37.1	-42.0	-22.9	-12.8

Climate change impact on water resources of Great lakes Depression was calculated by “WaterGap” /Water – Global Assessment and Prognosis, Version 2.1; Alcamo et al., 2003, Doll et. al., 2002/ model /Lener B., Batima P., 2004/. By using this model, the runoff of Khovd river was calculted and the model parameters were corrected, and runoff trend between 2011-2040 was identified by the result of Hadley center’s climate model. Specially, the runoff of Khovd and Buyand rivers tends to decline approximately by 25 percent. However, in “WaterGap” model, snow and glacier melting and its accumulation process and runoff that feeds the rivers and lakes were not considered, and only the future trend of temperature and precipitation was serced as a basis.

Current water balance elements in river basins were assessed using historical hydrological and meteorological record and conventional methods. Their future projections of changes were assessed based on the Hadley center climate model (HadCM3) output results in accordance to GHG emission A2, A1B and B1 scenarios in the periods of 2020 (2011-2030), 2050 (2046-2065) and 2080 (2071-2099) in comparison with average air temperature, humidity, wind speed and precipitation data for the period of 1980-1999 (Davaa G. 2009). It is projected that annual potential evaporation or evaporation from open surface of water will be increased by 2.5 times in mountainous areas, by 2 times in steppe zone, and by 1.5 times in the desert area in accordance to A1B GHG scenarios.

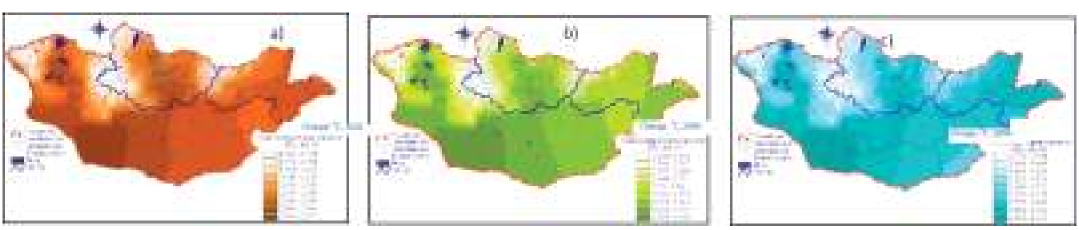


Figure 3.23 Change in water temperature, average for April-October period, °C/year, “a” is change in 2020, “b” is change in 2050, and “c” is is change in 2080 by the A1B scenarios

Water temperature is the key environmental factor for aquatic life. However, according to climate change A1B GHG scenarios, the average water temperature for warm periods of the year, April-October, is projected to increase above its average in the Arctic Ocean basin by 2.2 °C in 2020, by 2.8 °C in 2050, and by 3.5 °C in 2080, in Pacific Ocean basin by 2.3°C in 2020, by 3.0 °C in 2050, and by 3.8 °C in 2080, and in the Central Asian Internal drainage basin by 2.4°C in 2020, by 3.1 °C in 2050, and by 3.8 °C in 2080.It is obvious that these changes will lead to drastic changes in aquatic life in the future. The water temperature will be increasing even more than described above in accordance with A2 GHG scenarios and a smaller increase is projected in accordance with B1 GHG scenarioss (Figure 3.23). Results show that by the A1B GHG scenarios, river runoff in the Arctic Ocean basin will be increasing by 4 mm by 2020, by 8 mm by 2050, and by 13 mm by 2050. River runoff in the Pacific Ocean basin will be 5, 8, 9 mm, respectively, andin the Central Asian Internal drainage basin it will be 2, 3, 4 mm, respectively, in these years. However, the projected increase in evaporation from open surface water will be exceeding the increase in runoff by 138, 77, 48 times in the Arctic Ocean basin, by 115, 75, 101 times in Pacific Ocean basin, and by 144, 168, 111 times in Central Asian Internal drainage basin, respectively, in these periods. That will lead to more dry conditions and to an imbalance between inflow and outflow components of the water bodies.

The spatial distribution of changes in river runoff shows that there will be slight increases (3-10 mm) in the Mongolian Altay Mountains in the upper basin area of the Khovd river, in the Orkhon and Chuluut rivers draining from the eastern slope of the Khangay Mountains, and in the upper basin of the Tes and Shished rivers draining from Khuvsugul Mountains. However, river flow will be decreasing in the basins of the Khuvsugul lake, Eg, Uur, Zavkhan, Khungui, Ider rivers, Valley of lakes, Great lake's hollow, and in the steppe and Gobi regions (Figure 3.24).

Detailed assessments of future climate change and its impact on selected river basins, namely Buyant, Ulz, Kharkhiraa and Turgen rivers in Mongolia, were made. ECHAM5 global climate model output of Max Plank Institute, Germany, show a relatively well simulated climate of Mongolia compared to other global climate models (MARCC, 2010). Therefore, the model output at 30km of resolution has been used for initial and boundary conditions, obtained from the previous study. Then, climate model results are dynamically downscaled from the global scale (180-250 km) to the regional scale (30km), and finally, it is downscaled with RegCM3 at the river basin scale (10km). The climate baseline period selected is from the years 1981-2000 for the Buyant and from 1981-2010 for the Ulz, Kharkhiraa and Turgen rivers. Future climate change is determined in a river basin with respect to the climate baseline period. Climate change projection is based on A1B GHG scenarios, which use

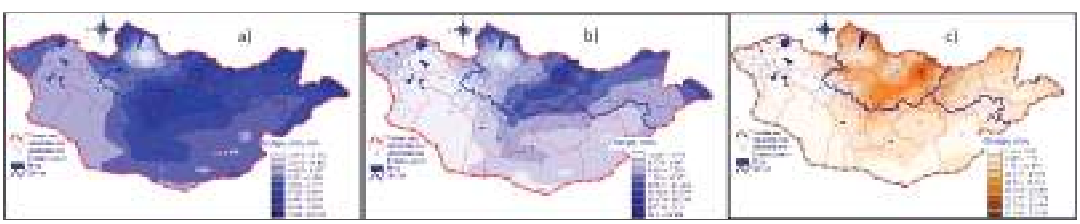


Figure 3.24 Runoff depth and its future changes, mm/year, "a" is change in 2020, "b" is change in 2050, and "c" is the change in 2080 by the A1B scenarios

the assumption that CO_2 concentration is expected to reach 720 ppm depending on world population, technology and development pathway (Gomboluudev. 2013).

The HbV model has been applied for the Ulz and Buyant river runoff modeling using an observed and model result's climate and hydrology data. Meteorological station data collected at Dashbalbar, Onon station and hydrological data of Ulzriver at Ereentsav have been used for model calibration for the period of 1993-1998 and for the verification (J.Odgarav, 2012).

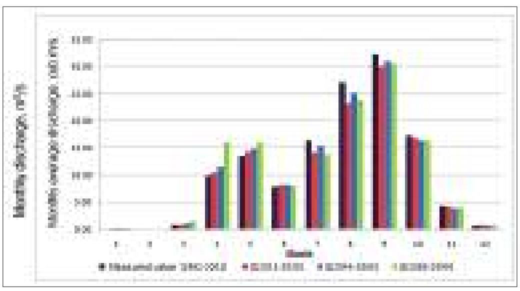


Figure 3.25 Current (1980-2010) and projected in future monthly average discharge values of the Ulz River at Ereentsav hydro-station, ECHAM5-GCM, A1B (2011-2030, 2046-2065, 2080-2099)

The HBV model output for greenhouse gases scenario A1B, according to the GCM ECHAM and RegCM3 was obtained for the Ulzriver at Ereentsav station. The results for the climate change impact modeling show that the Ulz river discharge in the months of April to October is nearly equivalent to the annual average discharge, which will decrease by 5.4% in 2011-2030, and could be increasing very slightly by 0.5% in the period of 2046-2065, and will be slightly decreasing by 1.1% in the period of 2080-2099 (Figure 3.25).

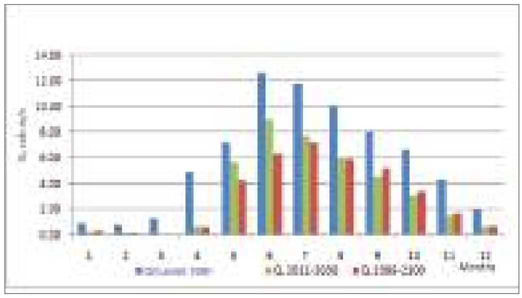


Figure 3.26 Current (1980-2000) and projected in future monthly average discharge values of the Buyant River, ECHAM5-GCM, A1B (2011-2030, 2080-2099)

The model output for greenhouse scenario A1B, according to the GCM ECHAM and RegCM3, was obtained for the Buyant river. The results for the climate change impact modeling show that the Buyant river discharge in the months of April to October will decrease by 43% in 2011-2030, and by 49% in the period from 2080-2099 (Figure 3.26).

Glaciers

Characteristics of the prevailing extreme continental climate condition locally differ with topography, and especially with respect to orography. Maximum air temperature reaches 11.6°C (2009-7-12, at 17^{00}), while minimum air temperature reaches -43.0°C (2010-1-20, at 15^{30}), observed in Ulaan Tsunkhegiin Tsakhir mountain, Munkhhairkhan Mountains. Air temperature inversion occurs in the Munkhhairkhan area in winter, and continued for 93 days in 2008 and for 86 days in 2009, compared to meteorological station data at the Hovd.

The coefficient of daily air temperature variation (C_v) is high as 1.2 at the Tavanbogd, measured with automated weather station (AWS) located at 3084m on Potanin glacier, 1.1 at 3600m on the

Ulaan Tsunkhegiin Tsakhir mountain, Munkhhairkhan Mountains, and 1.8 at 3567m on the southern ice cap of the Ulaan valley, Tsambagarav Mountains. This exceeds 5-10 times the coefficient of the variation of the daily average temperature observed in meteorological Ulgii and Hovd stations which are located in the valley and foothill areas of these mountains. The coefficient of correlation between monthly air temperature observed at Tsambagarav and Ulgii is 0.94. The same dependency is revealed between air temperatures observed at Munkhhairkhan and in the Hovd meteorological stations. These relationships enable observers to reconstruct air temperature time series in high mountains using long-term observation data at lower stations in Hovd and Ulgii. Thus, we derived above expressed equations for the reconstruction of past climate in selected glacier mountains by regression of the meteorological data obtained in the last several years. Hence, annual mean air temperatures at the Tavanbogd, Tsambagarav, Munkhhairkhan Mountains Hovd and Ulgii stations are -10.6, -12.6, -10.1, -0.5, -0.2 for the period of 1941-1970; -10.5, -12.5, -10.1, -0.2, 0.1 for the period of 1951-1980; -10.4, -12.4, -10.0, -0.2, 0.2 for the period of 1961-1990;-10.2, -12.0, -9.7, 0.6, 0.8 for the period of 1971-2000; and,-9.9, -11. 7, -9.4, 0.9, 1.1 for the period of 1981-2010,respectively (^{0}C). It indicates that the 30 year mean temperature increases by 0.2-0.7 ^{0}C/decade and by 0.2-0.3 ^{0}C/decade in glacier mountains.

Regional climate estimations are important for ungauged rivers and glaciers. Therefore, an altitudinal dependency curve has been established for geographic regions in the Mongolian Altay and Great Lake's hollow (Figure 3.27).

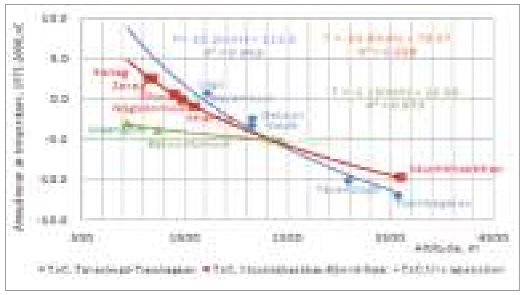


Figure 3.27 Altitudinal dependency of mean air temperature in Mongolian Altay Mts. and Great lake's hollow (1971-2000)

Mongolian glacier massifs are distributed within 42 mountain massifs and classified using glacier areas, derived by Landsat images in 2010 as follows: 1. large glacier massive area of which exceeding 100 sq.km area, that is only Tavanbogd with an area of 106 sq.km; 2. Big massive (A=50-100 sq.km) is Tsambagarav with an area of 66 sq.km; 3. Bigger (A=20-50 sq.km) are Kharkhiraa, Turgen and Munkhhairkhan with an area of 31.2, 29, 26.3 sq.km, respectively; 4. Moderately big (A=10-20 sq.km)are Underkhairkhan, Sutai and IkhTurgen (Asgat) with an area of 11.61, 11.95, 10.08 sq.km; 5. Medium (A=5-10 sq.km) are Khuremt, Nort range, Sair, Baatar, Upper Nariin river with an area of 7.98, 6.14, 7.44, 5.1, 7.99 sq.km; 6. Moderately small (A=3-5 sq.km) are Samartai, Tsengel, Saridagiindavaa, Takhilt, Khajmiinsalaa, Khatuugiinmunkhtsast, Gurvandosh Mts., Ikhturgen (Syrgali); 7. Small (A=1-3 sq.km) are Chandmani, Bayan-Ulaan, Khoitboorog, Tas, Umnokhairkhan, Deluun, Tsagaan-Uul, Khairtiindavaa, Khairtiin range, Gants modniidavaa, Asgatiindavaa, Siilkhem range, KhokhSerkh, Syrgaliin Upper BagaTurgen river; and, 8. Very small <1 sq.km, are Maraa, Bugat, Monhttsast Tsagaan, Otgontenger, Upper Salban river, Munkhsaridag (Khovsgol), Kholagash.

Detailed comparisons of areas of individual glacier massifs derived from different sources of data show that areas of glacier massifs tend to be overestimated by topographic maps compiled in the 1940th. The dynamics of glacier massif areas show that more intensive retreating occurs in flat top glaciers in the Tsambagarav, less retreating occurs in Corrie glacier dominated massif in the Munkhhairkhan, an average retreating rate is observed in glacier complexes of the Tavanbogd, Kharkhiraa and Turgen Mountains, and small glaciers are disappearing due to climate warming (Figure 3.28).

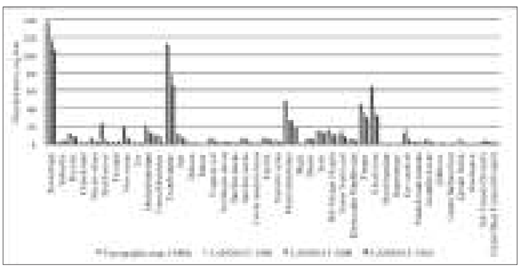


Figure 3.28 Dynamics of glacier massif areas

There are 580 glaciers, distributed within 42 massive mountainous glaciers. Four glaciers exceed 10 sq.km such as the Potanin, the Aleksandr valley glaciers and two others, eight glaciers are 5-10 sq.km, sixteen glaciers are3-5 sq.km, 75 glaciers are1-3 sq.km, and 477 glaciers are<1 sq.km. Detailed study on changes in glaciers shows that glaciers are retreating and shrinking as well, due to climate warming (Figure 3.29).

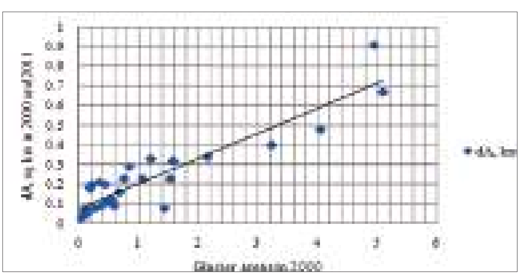


Figure 3.29 Glacier area dynamics derived from topographic map and LANDSAT data

There are 31 glaciers in the Kharkhiraa Mountains revealed by LANDSAT ETM data with a total area of 34sq. km in 2000, and 26.70 sq. km in 2011 (Figure 3.30). The glacier retreat rate is higher in bigger glaciers and small glaciers are disappearing in the Kharkhiraa Mountains. (Figure 3.30).

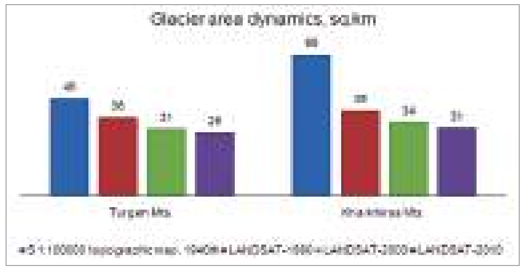


Figure 3.30 Glacier area change in the Kharkhiraavrs. with area of glacier in 2000

There are 50 glaciers in Turgen Mountains. revealed by LANDSAT ETM data with a total area of 32.74 sq. km in 2002, and 27.51 sq. km in 2011 (Figure 3.31). The glacier retreat rate is higher in bigger glaciers and small glaciers are disappearing in the Turgen Mountains. (Figure 3.31). The glacier numbered as 12 with an area of 0.96 sq. km in 2002 has disappeared in 2011. That has been excluded from the following graph.

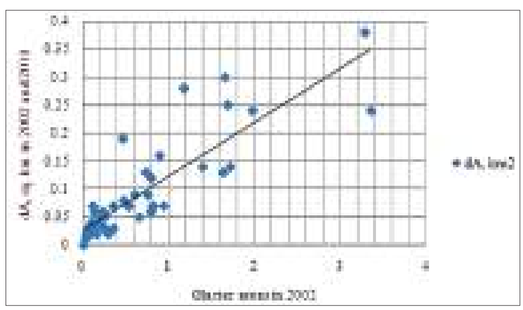


Figure 3.31 Glacier area change in the Turgen vrs. with area of glaciers in 2002

Glacier area and thickness measurements allow estimating glacier volume. Glacier volumes are 1.91 cub.km at the Potanin glacier, 0.44 cub.km at the southern ice cap at upper Ulaan Am valley, 0.25 cub. km, northern ice cap at upper Ulaan Am valley, and 0.22 cub.km at Baatar ice cap. G.Davaa et al. (2012) derived the equation for the estimation of the volume of glaciers in Mongolian Altay, including some neighboring glaciers in Russia. Therefore, total glacier volume has been estimated with an area of 580 glaciers in 2000 as 21.48 cub.km of ice, and accordingly, 19.4 cub.km of glacier water resources are in Mongolia. The average depth of glaciers in Mongolia is 31.3 m (G.Davaa et.al, 2012). That is comparable to glaciers located in the Russian and Chinese parts of Altay.

There were 829 glaciers with an area of 748 sq.km in 2000,and the total volume of glaciers is 34.5 cub.kmin Russian Altay (NarojnyU., and NikitinS. 2006), based on a topographic map, scaled as 1:100000 compiled in 1964. There are 403 glaciers with an area of 289.29 sq.km and the volume of water resources of 16.4 cub. kmin the upper Erchis river basin in China (Liu Chaohai, Wang Zongtai, Pu Jianchen, 2007). The total glacier area and water volume decreased by 7% and 10%, respectively, in the Russian Altay 1952-2003 (Narojny U., and Nikitin S. 2006). The total glacier area in the Mongolian Altay decreased by 27.8% in the last 70 years. Therefore, he total volume of Mongolian glacier water could be decreased by around 40%.

The cumulative ablation rate at the altitude of 2977-2998m, 3033-3057m, 3116-3123m, 3234-3247m, and 3339-3366m was 29.44-33.72m, 25.34-28.06m, 21.68-25.37m, 19.54-23.00m and 13.05-19.24m, respectively, on the Potanin glacier, in the period of 2004-2011 (Figure 3.32).

The mass balance of the Ulaan-Am south ice cap in the Tsambagarav is reasonably simple due to the fact that ablation takes place at the top of the ice cap. The cumulative mass balances of the ice cap in the period of 2005-2011 were 10.94m at the altitude of 3607 m, 9.28m at 3621m, 9.17m at 3700m, 7.89 m at 3732m, 5.41m at 3771m and 5.35 m at 3814m, respectively (Figure 3.32). That allows for establishing the regional equation of annual mean ablation verses with an altitude for estimation of mean ablation in ungauged glaciers.

Figure 3.32 Accumulative ablation of Potanin and Ulaan-Am south ice cap glaciers in 2004-2011 and 2005-2011 periods

Southern glacier melting parameter of Tsambagarav mountain reaches an average 0.44 cm ice/ ^{0}C day in warm season in 2010, 0.001 during new snow and 0.76 cm/^{0}C when there is no snow on glacier surface. In 2011, this parameter ranges from 0.65 cm/ ^{0}C or 0.40-1.22 cm/^{0}C on average. Melting parameter of Potanin glacier will reach 12.06 mm/^{0}C (Konya et.al, 2010). These equations, curves, observed hydrological data of the Kharkhiraa and Turgen streams, and current climate data, simulated with regional climate model, was used for SRM (snow runoff melt) model calibrations and verification of the current daily discharge of the Kharkhiraa river.

Glaciers in Kharkhiraa and Turgen Mountains are distributed in several river basins. However, in 2011, 10.2% of the glacier area in the Kharkhiraa Mountains and 53.4% of the glacier area in the Turgen Mountains are located in the Kharkhiraa river basin. Topographic maps and Landset ETM+ data from various dates have been used for the estimation of change in the glacier area in Kharkhiraa and Turgen river basins. The glacier area in the Kharkhiraa river basin has decreased from 23.29 sq.km in 1992 to 17.06 sq.km in 2011. Consequently, the fraction of the glacier area in the Kharkhiraa river catchment of 738 sq.km above the Tarialan hydro-station has decreased from 3.16% in 1992 to 2.31% in 2011 (Table 3.18).

Estimated glacier thickness ranges in 29.9-55.6 m and 42.07 m on average in Kharkhiraa Mts. in 2000 and decreased by 7.10-0.3 m in the period of 2000- 2011. While the thickness ranges in 28.8-52.70 m, 40.42 m on average in Turgen Mts. in 2002 and decreased by 3.6-0.3 min the period of 2002- 2011. That describes basically a regional mass balance, which is the difference between accumulation and ablation rates in these glacier massifs.

The annual ablation rate has been estimated with a regional equation. It ranges in 110.9-270.9 cm, (170.7 cm on average) in 2000, and 111.3-252.2 cm, (165.4 cm on average) in 2011 at Kharkhiraa Mts. These are 118.8-298.4 cm, (185.1 cm on average) in 2002 and 119.2-276.9 cm, (179.2 cm on average) in 2011 at Turgen Mts. However, regional climate model (RegSim) simulation results with 10 km spatial resolution gives climate data for the highest elevation of 3180 m in RegSim DEM in the Kharkhiraa basin. Therefore, the glacier ablation rate, estimated with this elevation and regional equation, is 326.5 cm/year on average for the period of 2005-2011. The annual average number of degree days or Sum ($+T_{daily\ average}$), simulated by RegSim for 2005-2011, is 692.0ºC/d. Accordingly, the degree-day

Table 3.18 Total glacier areas in Kharkhiraa and Turgen Mts. and Kharkhiraa river basin, sq.km

Data source	Total glacier area in Kharkhiraa Mts.	Kharkhiraa Mts. glacier area in Kharkhiraa river basin	Total glacier area at Turgen Mts.	Turgen Mts. glacier area in Kharkhiraa river basin	Total glacier area in Kharkhiraa river basin
Topographic map, scaled as S1:100000	64.20	6.74	45.06	24.15	30.89
Landsat ETM+ 25/6/1992	39.18	4.31	36.10	18.98	23.29
Landsat ETM+ 10/9/2000	34.06	3.62	31.27	16.69	20.31
Landsat ETM+ 4/07/2002	33.15	3.49	37.75	19.70	23.19
Landsat ETM+29/8/2010	31.20	3.19	29.41	15.71	18.90
Landsat ETM+ 6/08/2011	26.73	2.43	27.49	14.63	17.06

Glacier retreat occurs in combination with glacier shrinkage. An estimation of glacier shrinkage rates has been calculated using glacier volume with an equation that uses the average thickness of glaciers as a ratio of the volume of glaciers to their areas. A change in glacier volume and thicknesses in the mentioned above period gives an idea about glacier shrinkage. A change in glacier volume correlates with their volume at Kharkhiraa and Turgen Mts. in 2000 and at Turgen in 2002. Linear equations are: $dV_{Kharkhiraa}=0.150V_{2000}+0.003$, RI=0.897 and $dV_{Turgen}=0.109V+0.001$, RI = 0.790.

factor related to this elevation of 3180 m on the Kharkhiraa and Turgen glacier is 0.47 cm.$^{0}C^{-1}.d^{-1}$] indicating the snow and ice melt depth resulting from a one degree-day, that has been used for the glacier mass balance, changes in glacier area and SMR simulations.

The annual ablation (M) and accumulation (A) of glaciers in the Kharkhiraa river basin have been estimated using air temperature, precipitation data, simulated by RegSim and the annual change in area of glaciers, estimated with Landsat ETM+ data for the period of 1992-2011 (Table 5). The change in glacier area and annual glacier mass balance (B), which is in another words the change in glacier thickness, are linearly well correlated and that allows for an estimate of the annual total glacier area in the Kharkhiraa river basin.

The mean annual accumulation rate has been estimated as 1.43, 1.45, 1.64, 1.56 m/year in the period of 1982-2010, 1911-2030, 2046-2065 and 2080-2099, respectively. The annual accumulation rate in the period of 2011-2030 is projected to be nearly the same as an ablation in the current period, and that will increase by 14.3% in 2046-2065, and 8.9% in 2080-2099 period, in comparison to the current.

The mean annual ablation rate has been estimated as 3.11, 3.21, 4.04, 5.19 m/year in the period of 1982-2010, 1911-2030, 2046-2065 and 2080-2099, respectively. The annual ablation rate in the period of 2011-2030 is projected to slightly increase by 3%, that will increase by 29.9% in 2046-2065, and 67.0% in 2080-2099 period, in comparison to the current. Accordingly, the mean annual mass balance has been estimated as -1.68, -1.76, -2.40, -3.63m/year in the period of 1982-2010, 1911-2030, 2046-2065 and 2080-2099, respectively. Its mean annual value in the period of 2011-2030 is projected to decrease by 5%, will decrease by 43.3% in 2046-2065, and will decrease by 116% in 2080-2099, in comparison with the current (Figure 3.33).

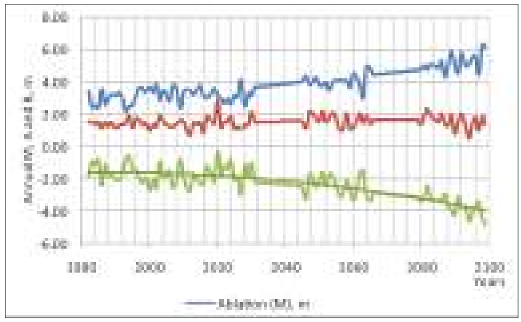


Figure 3.33 Dynamics of annual ablation (M), accumulation (A) and mass balance of glaciers in the Kharkhiraa river basin

Total glacier in the Kharkhiraa river basin is projected to decrease to 13.7 sq.km by 2030 and will disappear by 2049 (Figure 3.34).

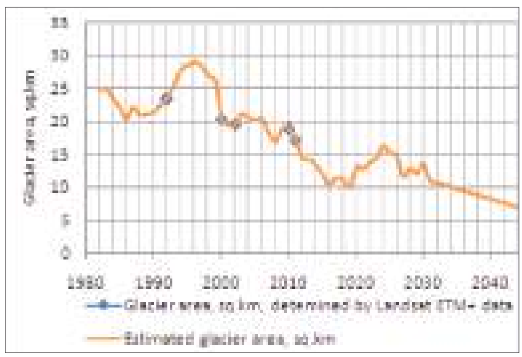


Figure 3.34 Dynamics of total glacier area in the Kharkhiraa river basin

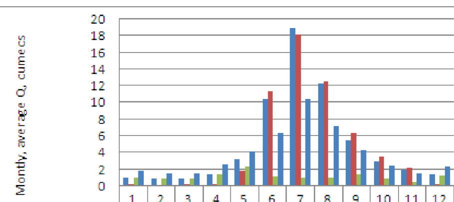
Kharkhiraa and Turgen Rivers drain from these glacier mountains and these are located in the same climate hydrologic conditions. Therefore, the water regime of these rivers is quite identical and it is assumed that the future projection of changes in water regime and daily discharges are similar. The changes in the Kharkhiraa river flow could represent the changes that could occur in the Turgen river flow. SMR model parameters were calibrated and verified with hydrological observation data of the Tarialan hydro-station at Kharkhiraa River for the period of 1980-1999 and 2001-2010. The runoff coefficient (C_{Sn}) of snow and ice melt ranges from 0-0.99 and 0.04 on average, and the runoff coefficient of rainfall ranges (C_{Rn}) from 0-0.90. Degree-day factor (a) is 0.47 $cm.^{o}C^{-1}.d^{-1}$, and the ratio of the snow and ice covered area to the total area(S) is 0.02-0.80, its average is 0.5. The recession coefficient indicating the decline of discharge in a period without snowmelt or rainfall has been estimated with observation data.

The Nash-Sutcliffe efficiency ranges between 1 (perfect fit) en -∞. In our Kharkhiraa river case the efficiency criterion reaches the value of 0.98; the simulated discharge is too close to the observed discharge. The main disadvantage of the Nash-Sutcliffe efficiency is the fact that squared differences between observed and simulated discharges are used. As a result larger discharge values have a stronger influence on the model performance. This problem can be reduced by using logarithmic runoff values, which flatten the peak flows and leave the low flows more or less the same. Another option is to only use observed discharge values that are above or below a certain threshold. The relative volume error criterion (*RVE*) is a criterion based on the degree of similarity in the water balances of the simulated and the observed runoff.

A disadvantage of this criterion is the canceling of errors of the opposite sign in the numerator. This can result in good scores according to the *RVE* criterion with a correct water balance over the whole period, but with completely wrong water balances on the smaller time scale. Therefore, the *RVE* criterion is seldom used alone. Combination with another criterion is almost indispensable. The *RVE* criterion is often used in combination with the Nash-Sutcliffe efficiency *E*, because a maximization of *E* alone can lead to a significant, often negative, volume error. The combination is an example of multi-objective assessment criterions. The relative volume error, *RVE*, is quite small as 0.007 for the Kharkhiraa River flow simulation.

The annual mean discharge of the Kharkhiraa River at the Tarialan hydro-station is projected to be slightly decreased by 6.18% in the period of 2011-2030, significantly decreased by 76.9% in the period of 2046-2065 and moderately decreased by 24.0% in the period of 2080-2099, in comparison to the current 1980-2010 discharges (Figure 3.35).

The monthly average discharge will be increased by 9.0% in June, 2.2% in August, and slightly decreased to 4.0% in July, 2011-2030. In rest periods, June, July and August(JJA) discharges will be decreased by 88.5%-94.8% in 2046-2065 and by 39.3%-44.9% in the period of 2080-2099 due to glacier melt and disappearance. The Kharkhiraa river flow will be slightly improved due to increases in snow and rainfall in the period of 2080-2099 (Figure 3.35).



	1	2	3	4	5	6	7	8	9	10	11	12
Q average-1982-2011	1.0	0.8	0.8	1.5	3.2	10.	19	12.	5.5	3.0	1.9	1.4
Q average-2012-2030	0.2	0.2	0.2	0.3	1.8	11.	18.	12.	6.3	3.5	2.2	0.2
Q average-2046-2065	1.0	0.8	0.8	1.5	2.3	1.2	0.9	1.1	1.4	0.9	0.5	1.2
Q average-2080-2099	1.8	1.5	1.5	2.6	4.1	6.3	10.	7.2	4.3	2.4	1.5	2.2

Figure 3.35. Current (1982-2011) and projected in future monthly average discharge values of the Kharkhiraa River at Tarialan hydro-station, ECHAM5-GCM, A1B (2012-2030, 2046-2065, 2080-2099**)**

Permafrost

The global permafrost area is about $41.4 x 10^6$ km^2 or approximately 25-28% of the global land area (including ice sheets but excluding ice shelves). Permafrost exists in 48 different countries. The top five countries by permafrost extent are Russia, Canada, China, USA, and Mongolia. Mongolia is the fifth country by permafrost extent. Due to global climate warming the changes in permafrost have been recorded everywhere. Permafrost temperature increases in the polar region (Romanovsky, 2010) were noted in the active layer detachment, in the deepening of summer thaw, and in the disappearing of shallow permafrost in the southern fringe of the permafrost region. Some scientists and travelers through Mongolia have noted permafrost distribution in Mongolia, however, a systematical permafrost study has been performed at the geographic department of Science Institutes of Mongolia in 1950s (Tsegmid, 2003). According to the permafrost distribution map of Mongolia, permafrost is concentrated in the mountainous regions such as Altai, Hangai, Hentii, and Hovsgol mountains and in northern Mongolia. In other words, Mongolian permafrost distribution changes according to geomorphological and microclimate conditions and is characterized by arid land mountain permafrost with temperatures close to zero degrees. Due to global climate warming this permafrost with temperatures close to zero degrees is not only warming, but also disappearing (Bernd Etzelmuller, 2006). The construction of major projects such as the connection of regional centers on the paved road and the new center of soum must take into account the distributions, features and changes of permafrost, not only for environmental reasons, but also for the social and economic side.

Changes in permafrost: The main parameters of permafrost change are its temperature at some depths and its thickness. Permafrost is the product of climate change and it is more sensitive to climate change. Due to climate warming, permafrost with temperatures close to zero degrees has not only been warming, but also disappearing, and the processes such as active layer detachment, deepening of summer thaw, disappearing of shallow permafrost have been determined in the southern fringe of permafrost region. Permafrost temperatures as low as -23.6^0C have been observed in the Antarctic, but in Mongolia, permafrost temperatures generally range from -3^0C to 0^0C. Permafrost temperatures have been recorded as low as -3^0C in Tsagaannuur soum of Hovsgol aimag and Gurvanbulag soum of Bayanhongor aimag (Jambaljav, 2013).

In Mongolia, permafrost studies have been conducted since the 1950s, however, continuous measurements of permafrost temperature began mostly in the last 1-2 decades. A national permafrost network has recently been established with more than 120 boreholes in Mongolia within the framework of foreign and national programs and projects. The continuous records of temperatures in boreholes of the permafrost network is not too long, however, some boreholes have temperature measurements at least once between the 1960s to the 1980s. Therefore, comparing the early measurements with recent records, some scientists have determined the temperature changes in some depths of boreholes during the last 20-30 years. In northern Mongolia, permafrost temperatures have increased in some degree, however, there were detachments of active layers, deepening of summer thaw, disappearing of permafrost in the southern fringe of Mongolian permafrost. Permafrost degradation under the influence of climate warming in Mongolia has been more intense during the last 15-20 years compared to the previous 15-20 years (1970-1980) (Sharkhuu, 2011). In northern Mongolia, at Darhad depression, permafrost temperatures have increased at the rate of 0.52^{0}C-0.95^{0}C at a depth of 10- 15m during the last 23-26 years (Bat-Erdene, 1995, Jambaljav, 2013)

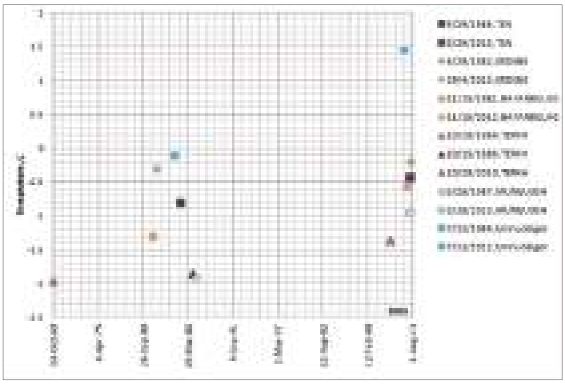


Figure 3.36 Temperature changes of permafrost in Mongolia (temperature at depth of 10-15m), *Note: TSN-Tsagaannuur, Bayan-Ulgii, ERDENE-Erdene, Gobi-Altai, BAYANBULAG-Bayanbulag, Bayanhongor, TERKH-Valley of Terkh river, MUNGUUSH-Mungush valley, Darhad depression, Umnudelger-Umnudelger, Hentii aimag*

In Northern Hangai, the temperatures at a depth of 10- 15m have been warmed by 0.39^{0}C -0.44^{0}C during the last 24 years, and in Southern Hangai the temperature at a depth of 10m has increased by 0.64^{0}C for the last 30 years in Bayanbulag soum of Bayanhongor aimag. The temperature at a depth of 8m has increased insignificantly about 0.1^{0}C for last 30 years in Gobi-Altai region, which is on the southern fringe of the Mongolian permafrost region. However, according to in-suite temperature measurements, the active layer thickness is more than 7.8m in the Erdene borehole of Gobi-Altai aimag. The temperature at the depth of 10m has been warmed by 0.38^{0}C during the last 23 years in Tsagaannuur of Bayan-Ulgii aimag (Northern Altai Mountain). In eastern Mongolia, near the Airag lake, in Umnudelger soum of Hentii aimag, there was permafrost in 1984. However, after 28 years, in 2008 there was no permafrost and the temperature at a depth of 10m was +1.45^{0}C (Jambaljav, 2013).

Changes in seasonally frozen ground and in active layer thickness: Seasonally, frozen ground is the soil layer that freezes during low temperatures and remains so only during the winter season. The active layer is a soil layer overlying permafrost that thaws during the summer season. A key parameter regarding seasonally frozen ground and active layer is the thickness. One of the key parameters of construction design for foundations is the thickness of seasonally frozen ground and active layer thickness. In accordance with geographical location and weather conditions, the active layer thickness and seasonally frozen ground is deeper, about 2-6m in Mongolia compared to other permafrost regions. Due to global climate warming many observations indicate that an increasing trend of active layer thickness has been recorded and the depth of refreezing cannot reach to the thawing depth of the previous summer. In other words, measurements have revealed a talik in the southern fringe of the Mongolian permafrost region. The thickness of active layer has been observed as 7.8m in borehole of Erdene soum of Gobi-Altai aimag. As shown on Figure 3.41, there is a closed talik at a depth of 4m near the Hoh Burd Lake in Bayan-Ovoo soum of Bayanhongor aimag (Jambaljav, 2013).

3.1.5 Natural disaster

Climate related disasters

Heavy rains, snowfall, strong winds, sandstorms, snowstorms, hails and flooding often bring substantial damage to life and property of the community. Devastating weather hazards, such as zud and drought, are a well-known affliction of the nomadic herder. Zud is the Mongolian term for an extraordinarily harsh winter that deprives livestock of grazing, a specific phenomenon that takes its toll in the winter-spring season as high numbers of livestock die of starvation. Winter snow cover in Mongolia by the end of 2009 reached 90% of the territory, while it was only 50% during the winter of 1999-2000 when Mongolia experienced one of the worst zud situations in the country, which killed several millions of domestic animals (NAMEM 2012). As at the end of April 2010, over 10 million, or about 22% of the country's entire livestock in Mongolia were lost as a result of the 2009-2010 winter zud disaster (zud is a Mongolian word used as a term for extreme weather events in cold seasons which caused significant loss of domestic animals) and the livelihoods of over 200 thousand rural herdsmen living in the most affected regions were severely threatened. The social costs of the zud are difficult to estimate.

Frequency of atmospheric related extreme events in Mongolia

In Mongolia, more than 10 types of natural disasters occur that affect humans and animals, and are causing significant damage to the economy. The major disaster can be ranked by social-economic risks as follows - drought, zud, forest and wild fires, snow and dust storms, floods and cold surges. In the most recent 10 years, economic losses from natural disasters are costing 50-70 billion Tugrugs (national currency) each year, and when compared to the previous decade, the damage has risen 10-14 times. The correlation coefficient between frequency of atmospheric disaster and annual average temperature during 1989-2011 is around 0.36 in Mongolia (Figure 3.37).

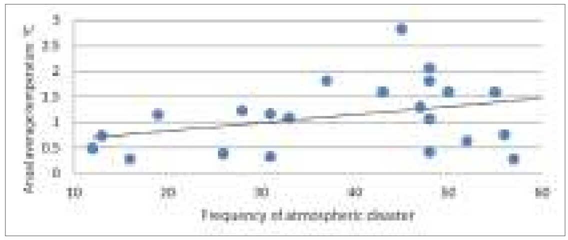


Figure 3.37. Correlation coefficient between frequency of atmospheric disaster and annual average temperature during 1989-2011

In other words, it corresponds to global research results which prove that intense global warming leads to an increase in atmospheric disaster occurrences (Natsagdorj L., et.al, 2012). Results from both intense and weak climate change models of the HADCM3 global model of Hadley climate center of the British weather service, which has best expressed the past climate change of Mongolia, indicates atmospheric disaster frequency could be increased by 23-60% in the middle of this Century (Natsagdorj L., et. al, 2012). Figure 3.38 shows the atmospheric disaster frequency of Mongolia in 1989-2013, which is recorded at the Institute of Meteorology, Hydrology and Environment (IMHE) by national meteorological observation network data. The extreme weather information data from the national meteorological observation network was verified with information from the National Emergency Management Agency (NEMA) on every occasion, therefore, this disaster frequency data best represents reality.

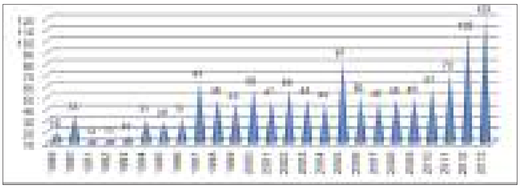


Figure 3.38 Atmospheric disaster frequency of Mongolia in 1989-2013

In the country, climate induced disaster occurs 51 times per year on average. If we divide the last 20 years into two decades, the climate related disasters amounted to around 45 per year on average in the first decade and that number has increased by 1.5 times in the last decade. Excluding drought and *zud*, 15 types of atmospheric disasters registered in Mongolia. Table 3.19 includes annual average occurrences of each of 15 types of phenomena.

Box 3.1 On May 26 & 27, 2008, the Eastern region of Mongolia was struck by the strongest combined wind, dust and snow storm that has ever been recorded in the last 20 years and the wind speed reached 28-34 m/s in the Eastern region and 40m/s at Erdenetsagaan station of Sukhbaatar province. However, the people of Mongolia could have been warned three days earlier about the approaching heavy storm; unfortunately, 52 people died during this event. Also 110 buildings, 221gers, traditional houses, were damaged and 362,195 head of livestock were killed.

Livestock driven by the strong storm and died by the in river and trees were fallen from roots due to the storm. Photo taken at Bayan-Ovoo sum of Khentii aimag on 28th May 2008.

Table 3.19 Annual average occurances of weather disasters

Name of the phenomena	Strong wind and Storms	Heavy snow	Heavy rain	Squall	Thunderstorm, flash flood	Hail	Lightening	Hot wave	Cold wave	Frost surface	Cold rain	Wet snow	Spring flood	Avalanche	Wild and forest fire
Number of occurrences /Annual average/	14.3	2.9	3.4	6.4	12.1	4.1	9.2	1.5	0.8	2.9	0.9	1.7	1.2	0.6	160

Forest fires, strong wind storms, thunderstorms, flash floods and lightening are the most common disasters in Mongolia. Excluding forest fires from all disasters, strong wind storms, thunderstorms-flash floods and lightening accounts for 24%, 21% and 13%, respectively, of the total natural disasters. In the last 11 years, 412 people were killed due to atmospheric disasters, 41.2% of those were associated with strong wind storms and 22.4% were due to thunderstorms and flash floods.

Some extreme events such as strong winds, snow and dust storms, heavy rain, heavy snow, freezing rain, wet snow and surface frost cover large areas of territory and may persist for a long time; therefore, they might cause severe damage to agricultural sectors. Convective phenomena, which persist comparatively for a short time (1-4 hours) and cover small areas of territory, include squalls, hail, lightning, thunderstorms and flash floods, and they consist of 53.3% of the total atmospheric disasters. Among those phenomena, flash floods comprise 41.1% as the dominant convective event. A number of studies show, under the impacts of global warming and climate change, that the atmospheric disaster occurrence, especially in frequency of those convective disasters, are expected to rapidly increase in the world. Similarly, in Mongolia, squalls, hail, lightning, thunderstorms and flash floods are becoming more common hazardous events, and they have doubled in the last two decades. According to a disaster's duration, we have classified total atmospheric disasters into two types, long and short term phenomena. Figure 3.39 illustrates the number of occurrences of long and short term phenomena in last 20 years.

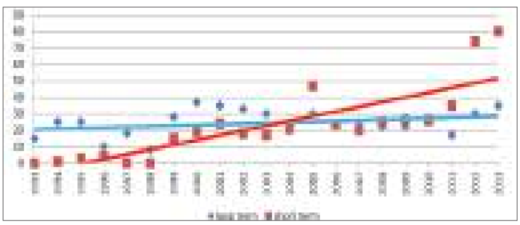


Figure 3.39 Long and short term weather disasters in Mongolia for last 20 years

On the background of global climate change, the percentage of thunderstorms in atmospheric disasters has increased and it leads to the increment of daily rainfall amounts. (Natsagdorj L. et al., 2008). 20 years' occurrence of thunderstorms and flash floods are shown in Figure 3.40.

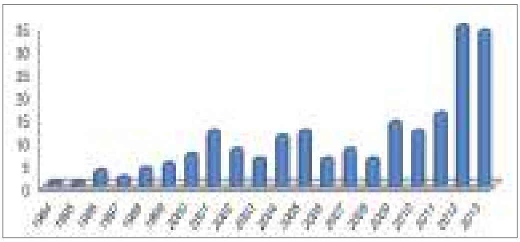


Figure 3.40 Thunderstorm and flash flood occurrences in Mongolia for last 20 years.

Due to climate change impacts, frequency as well as intensity of severe storms, floods, lightning and other weather disasters are expected to increase, and it may lead to changes in their space and time distribution.

Losses and Damages Caused by Atmospheric Disasters

In the last 11 years, 412 people were killed, livestock mortality totaled 24.5 million, and total damage amounted to 562.7 billion Tugrugs. The winter of 2009-2010, all of Mongolia experienced excessive snow and persistently cold temperatures that caused the harshest winter conditions, named *zud*. The 2009-2010 *zud* affected 80.9 percent of the total territory (175 soums from 18 provinces). In terms of its extent and damage, this *zud* was more disastrous than those in recent years. Nationwide, 22.4% of total livestock (9.7 million) were lost and it caused damages of 562.7 billion Tugrug on average market valuation, which comprises 93% of the total damage in the last 10 years. The *zud* loss was estimated only by worth of dead animals, and other damages were not accounted for. 2008 was the worst year for human death caused by natural disasters. Losses caused by natural disasters, as a percentage of GDP, are shown in Figure 3.41.

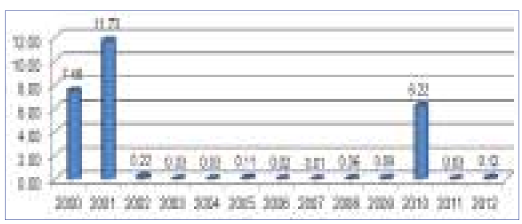


Figure 3.41 Losses caused by natural disasters, as a percentage of GDP

In 2000, 2001 and 2010, as a percentage of GDP, the total damage caused by atmospheric disaster was high,

Box 3.2 On July 16, 2009, Tseel sum of Govi-Altai province faced a heavy flash flood. Due to this flood 18 people were killed and the total damage amounted to US$93.7 million. And the capital city Ulaanbaatar experienced a heavy flash flood which killed 7 people on July 17, 2009, with losses billions o fMNT.

Tseel sum of Govi-Altai province. Broken houses and car, goats killed by a strong flood water surge. July 16, 2009

and it can be explained that, in these years large numbers of livestock were lost due to severe drought and *zud*.

Drought and Zud: Drought and *zud* are the disasters which brought most of the losses to Mongolian society and economy. It is not easy to estimate the amount of damages caused by drought and *zud*. Particularly, the drought damage still remains unknown. According to the study by Natsagdorj L., drought occurs 1-2 times per 10 years in most areas of the high mountain, forest steppe and steppe regions, once per 2 years in the Gobi desert area and once per 3 years in between desert and steppe areas (Natsagdorj L., Dulamsuren J., 2002). The long term trend of a nationwide averaged index of drought-summer condition is shown in Figure 3.42. (Natsagdorj.L.). From Figure 3.42, since 1940 drought has generally increased, and it's seen that drought years have occurred continuously since 2000. Drought in the summers of 2000 and 2002 were the most severe droughts that have occurred in recent years.

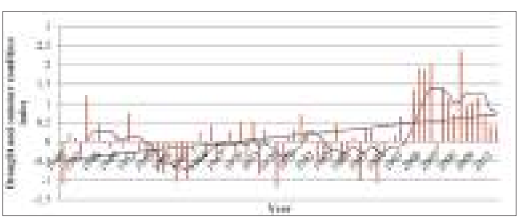


Figure 3.42 Long term trend of nationwide averaged index of drought-summer condition, deviation from the norm of 1961-1990, positive side of the axis shows good summer condition, negative side shows drought

Box 3.3 During June, July and August in 2002, due to continuous hot waves and lack of rainfall, air and soil conditions were extremely dry, causing inhibition of pasture plants, and 70% of the Mongolian territory was in a severe drought situation. In such hot and dry conditions, during the summer, forest and wild fires occurred more frequently, and large pasturelands were under fire causing degradation of pasturelands, particularly in the Arkhangai, Khuvsgul and Zavkhan provinces. In the summer, small rivers and brooks get dry, so there is a lack of drinking water sources for livestockas well as significant increases in various pests. The total losses amount to 31 billion MNT.

During summer of 2002, forest and wild fires occurred 323 times, and most pasture land area was bare.

Depending on their cause, zud can be categorized as white or black. White zud is mainly caused by heavy snow fall, with an average depth of snow on pasture land from above 21 cm in the mountain areas, to above 10 cm in semi-desert regions, and black zud is due to lack of water during summer, followed by lack of snow during winter. White zud occurs every two years in the basin of Tes river, and once every three years in the mountain regions of Khangai, Khentei, Khankhokhii, Kharkhiraa, and Turgen, and one to two times per 10 years in the hilly mountainous region at the foothill of the Altai, Khangai, Khuvsgul and Khentii ranges. Zuds frequently occur in the northern part of Dundgovi province. (Natsagdorj.L, Sarantuya.G., 2003)

The winter index values for the winter period of November to February, which estimates the differences between normalized deviation of air temperature and normalized deviation of precipitation, has some relation to large cattle losses (Natsagdorj. L et al. 2001). In Mongolia however, winter snowfall amounts have been increasing and winter severity has been decreasing since 1940. Nevertheless, there is an appearance of increasing frequency of harsh winters since the start of the new millennium. Figure 3.43

illustrates the long term trend of a nationwide averaged winter index.

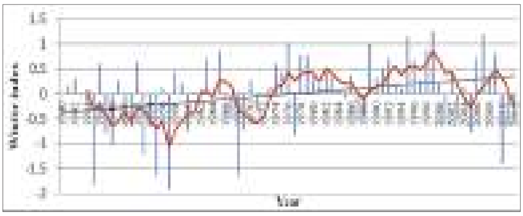


Figure 3.43 The long term trend of nationwide averaged winter index. Deviation from the norm of 1961-1990, the positive side of the axis shows the good winter conditions, and the negative side shows harsh winter conditions.

When a previous summer was in a drought condition, the following winter was harsh for livestock which might cause large amounts of livestock loss. Therefore, the combination of summer and winter climatic conditions must be considered in zud assessment (Natsagdorj.L, Dulamsuren.J. 2001). From Figures 3.42 and 3.43, zud intensity has increased in Mongolia since the start of the 21th century.

Forest and wild fires: Forest and wild fires are one of the most common disasters in Mongolia, however, they can be caused by human activity, although air and ground dryness is the main cause of these fires. The frequency of forest and wild fires in 1988-2013 is shown in Figure 3.44.

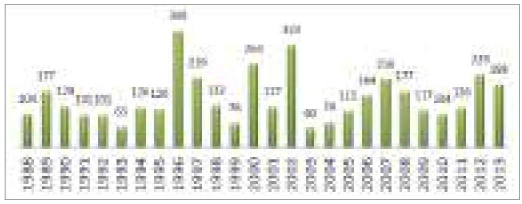
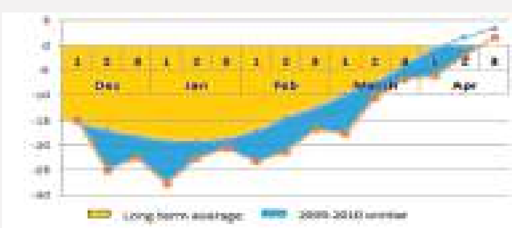


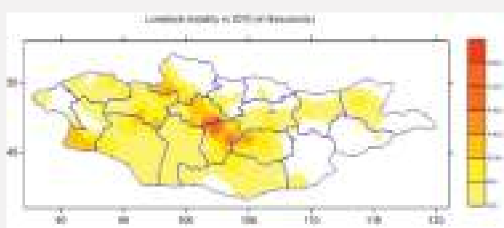
Figure 3.44 Forest and wild fire occurrences in Mongolia

1996, 2002 and 2007 were drought and dry years, therefore, fire occurred much more than in other years. Forest and wild fires occurred 160 times per year on average, which is the largest contributor to the increasing depletion of natural resources and economic loss.

Box 3.4 The Winter of 2009-2010 recorded the coldest winter since 1945. During this winter, in some places, the number of extreme cold days was two times more than the long term average and in places where it does not get very cold this number is even 10 times greater than the normal. [Natsagdorj.L, Sarantuya.G, Extreme cold may result in loss of livestock. Papers in Meteorology. IMHE. 2011]. From November 2009, snow fell persistently and snow cover started to form earlier than usual. By the end of November 2009, about 75% of the total territory had snow and the snow depth kept increasing. Even so, in summer of 2010, about 60% percent of the total territory was in drought condition which would have caused insufficient pasture and fodder. Due to these droughts in summer and harsh winter conditions, 80.9% of the total territory (175 soums from 18 aimags) faced a zud situation, and affected 57.3% of the total herder households (97,500 households) and inflicted two human casualties, and a loss of 9.7 million livestock. In terms of its extent and damage, this zud was more disastrous than those in recent years.

In January 2010, the monthly average temperature was below normal over most of the country, especially in the southeastern part and in the Uvs, Khuvsgul, Bulgan, and Arkhangai provinces. The monthly average temperature was colder than normal by three or more degrees, and above normal snow fell over most areas during this month. By the end of January 2010, more than 90% of the total territory had snow cover and 30% of the territory with snow cover had an average snow depth of 30. The following Figures depicts long term average and the 2009-2010 value of each ten day average air temperature from December to April, and livestock mortality in 2010.





During the winter of 2009-2010, 10 days average air temperatures was colder than normal throughout from second 10 days of December until second 10 days of April. Central part of the country, particularly Uvurkhangai, Arkhangai, Dundgovi aimags lost more livestock. Maximum livestock mortality recorded in the Hotont sum of Arkhangai aimag.

3.1.6 Land Degradation and Desertification

The United Nations Convention to Combat Desertification defines desertification as "...degradation of land in arid, semi-arid and dry sub-humid areas. It is caused primarily by human activities and climatic variations" (UNCCD, 1994). In a broad sense it can be understood as "A process when fertile land turns into a desert because of the irrational use of natural resources in vulnerable lands, which are affected by successive droughts due to global change and the resulting climate fluctuations, thus leading social activities to be under natural forces". From this point of view, modern environmental issues related to land degradation, desertification and drought are becoming a global level concern, which interrelates and incorporates political, social and economic problems. The assessment of the state of land degradation and desertification, and analyses of its drivers, were conducted four times in Mongolia since the 1990s.

Aridity Change. To assess the humidity of the climate, different empirical equations were evaluated for their usefulness and their advantages and disadvantages, including the radiative dryness index by Budyko, aridity index by Thornwaite, and the water and thermal coefficient of Selyaninov (Natsagdorj 2004 and 2012). It was concluded that the spatio-temporal distribution of the V.S.Mezentsev's humidity coefficient developed for Western Siberia is much more close to the annual productivity of different ecosystems. The use of this empirical equation, thus, was selected to assess aridity and delineate regions susceptible to land degradation and desertification. For the territory of Mongolia the Mezentsev's humidity coefficient range between 0.02 to 0.6, and the small area far to the north has a value greater than 1.

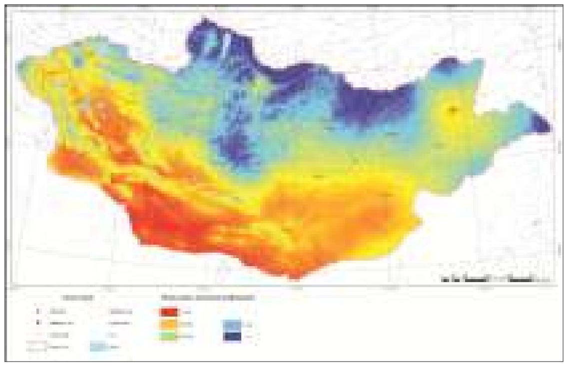


Figure 3.45 Distribution map of Mezentsev's humidity coefficient

The temporal analysis of Mezentsev coefficient, which was calculated for all meteorological stations, showed that it has a decreasing trend, or the climate becomes arid. An overall decrease of humidity started to intensify from the end of the 1990s and the average index of humidity level decreased by 3-4 percent. The greatest decrease within last decade was marked in 2002, 2005, 2007 and 2009 when the annual humidity level dropped by 7-9 percent.

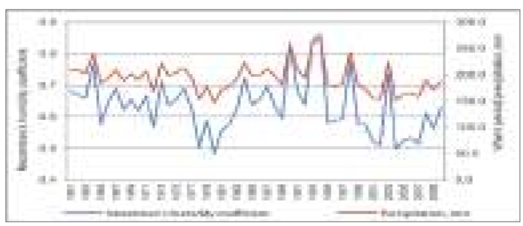


Figure 3.46 Time-series of Mezentsev's humidity coefficient

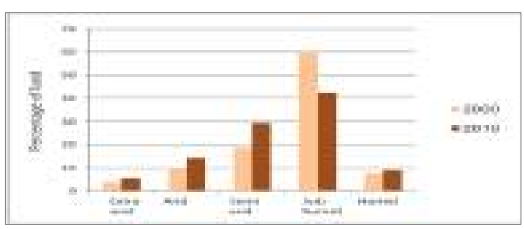


Figure 3.47 Change in climatic zones calculated using Mezentsev's humidity coefficient

The long-term average value was calculated and compared with baseline average from the period of 1961-1990. This comparison showed that since 1995 the humidity level of the climate significantly decreased. Considering that humid and dry periods are successively changed every 11-12 years we can assume that since 2008 the humid period of the climate had started; however, according to the meteorological observations and outputs of empirical equations, the humidity level doesn't exceed the average of the baseline years. From this it we can summarize that land degradation and desertification process in Mongolia is highly influenced by climate and its fluctuations.

In terms of spatial distribution, the dryness of the climate gradually increases in steppe and desert steppe regions; the annual change rate during the period of observation is 0.01-0.05 unit/year. Interestingly, it was found that there are slight increases of humidity in arid and extra-arid deserts. During the period of 1961-2010, according to the meteorological data obtained from stations, the dryness increased in stations like Orkhon, Eruu and Baruun-Kharaa, which are considered the main agricultural regions. If the climate continues to change at the current pace it will become necessary to define new policies and adopt new technologies in the agricultural sector.

Drought impacts on land degradation. Drought is a climatic anomaly condition that occurs seasonally in particular territories (Natsagdorj L., Dulamsuren M., Tsatsral B., 2002), and can occur in any part of tropical and middle latitude zones. The UNCCD defined drought as "The naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems." This agrees with the common understanding: drought is a growing season phenomenon - a combination of weather and biological factors, where the soil moisture reserve has been depleted because loss of water by high evaporation and transpiration rates and precipitation deficiencies for prolonged periods of time negatively affect agricultural crop growth and high temperatures.

Since Mongolia lies mostly in the dry climate zone it belongs to drought-prone territory. In the major parts of the high mountain belt region, forest steppe and steppe zones, there is a probability of 1-2 drought occurrences in a 10 year period, in the desert steppe zone there is drought every other year, and in the middle ground between the steppe zone and desert steppe zones drought occurs once every 3 years. The drought frequency increases from north to south, east to west, and corresponds to Mongolia's humidity distribution patterns.

Drought conditions and changes are calculated based on satellite data, therefore the normalized drought difference index (NDDI), which is a MODIS data standard index, was analyzed. Comparative analyses of drought changes in the years 2000 and 2010 indicate significant increases of drought in the Great Lake Depression, Lake valley and Southern parts of Gobi. In the Khangai mountains, Orkhon Selenge valley and Southern Altai Gobi the drought condition are slightly decreasing (Mongolian desertification atlas, 2013).

Also, drought changes were calculated and mapped using drought data from the last 11 years. It indicates that major parts of the territory experience drought conditions of 2-3 years within the 10 year period. In the southern parts of the Gobi desert and Kherlen River region drought occurs for 4-5 years within the given period, and in the Great Lake depression and Lakes valley the drought conditions occur 8-10 years and or almost every year. However, in the Khangai mountains and Eastern parts of Gobi over the period of 1 – 5 years the drought intensity had decreased (Khudulmur, Bayasgalan et al., 2013).

Water erosion and change. One of the main drivers of land degradation and desertification is water erosion, which there is a need to assess in order to distinguish the natural side of this complex phenomenon. There is not much research conducted in Mongolia to assess the influence of water erosion and water erosion rate. A limited number of surveys were done to evaluate this process at the regional level during 1980s (Sanjmyatav, 1993; Sugar, Sanjmyatav, 1987). Based on available environmental data, an attempt to use a widely recognised physical model in order to evaluate the erosion process has been implemented.

Using a physical model called the Revised Universal Soil Loss Equation (RUSLE), the annual soil loss from a unit of land has been calculated in relation to climatic and land cover conditions for the periods of 2000 and 2010. The results indicated that approximately 300-400 tons of soils per annum are lost due to the active influence of flowing water. The comparison of results for the selected two years revealed that water erosion in average has increased and about 500-600 tons of soil lost. This information can lead us to draw conclusions that water erosion might influence land degradation and desertification.

The spatial distribution of water erosion area and intensity is high in mountainous regions and along piedmonts, especially in Mongol Altai, Gobi Altai, Gobi type piedmonts and the southern parts of Khangai and Khan Khukhii mountains, and the intensity of erosion is very high. The main causes of intensive water erosion in the above mentioned regions is related to vegetation cover, surface slope, soil development and rainfall erosion, which may act independently or in correlation among themselves. The moderate erosion observed in the middle part of the country occupying a vast area of grassland and major river basins, while the slight erosion marks can be identified in the Great Lake depression, Lake valley and eastern parts of the Gobi, mainly represented by low height mountains and depressions.

Within the last 10 years, soil erosion due to water has increased in the northern parts of the country, which are probably determined by intensive rainfall and decreased vegetation cover. The change analysis of land affected by water erosion states that about 3 percent of total land affected by water erosion could be classified as extremely eroded. Overall, the water erosion process has not significantly changed during the past decade, and it can be concluded that in most of the territory water erosion has a slight impact.

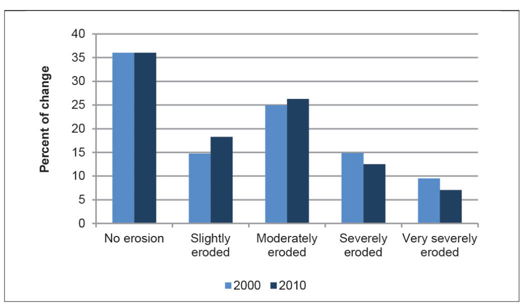


Figure 3.48 Comparison of water erosion in 2000 and 2010

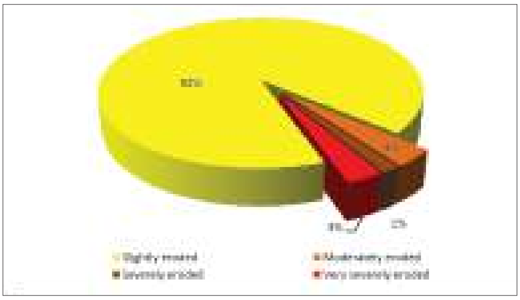


Figure 3.49 Percentage of areas affected by water erosion

Wind erosion and change. One of the signs that land is degraded is the occurrence of dust storms, which are for many reasons explained as a driver of the soil degradation and desertification process. The impact of wind on soil surfaces has various forms, but dust storm should be understood as the most severe form of erosion. Although the impact of wind on soil and vegetation cover has to be an integral part of desertification research, such survey has been abandoned in Mongolia. The only research to address this is by L.Natsagdorj, who researched the erosive impact of wind and wind velocity, and attempted to explain it in relation to current climate conditions.

The wind erosion for the entire territory of Mongolia was assessed for the first time using the wind erosion equation (WEQ). Soil erosion maps for the years 2000 and 2010, calculated using these factors, demonstrate that there is a high degree of wind erosion along the desert zone, Great Lakes Depression, and the Lakes Valley. Especially soil around the Baruun Khuurain Khotgor, Southern Altai Govi, Ulaan Nuur Lake, Mandal-Ovoo territories has the highest degree of wind erosion. These areas have a limited vegetative cover, a slight surface slope, and limited barriers and etc., which play a role in the wind erosion process. Otherwise, all the indexes calculated for these areas have high values. Mongolia's steppe, desert steppe zones, especially steppes of Dornod and areas of Zamyn Uud and Sainshand belong to lands with a moderate degree of soil erodibility. Mountain regions fall under areas in which soils are not affected by wind erosion or these factors have improved when compared to previous years.

Wind erosion changes can clearly be observed in the southern part of Govi-Altai, Bayankhongor, and Omnogovi Aimags, particularly, in the valleys and depressions of desert areas like Sharga, Nomin, Ingen Hoovor, Galba and Borzon Deserts. When comparing the years 2000 and 2010, it was calculated that 165.7 tn/ha soil was carried away in these areas. However, there is evidence of the wind erosion process decreasing on the west side of the Great Lakes Depression and the territory along the Khar Us Lake and the Buyant River Basin. Soil loss in these areas for the given period tended to decrease.

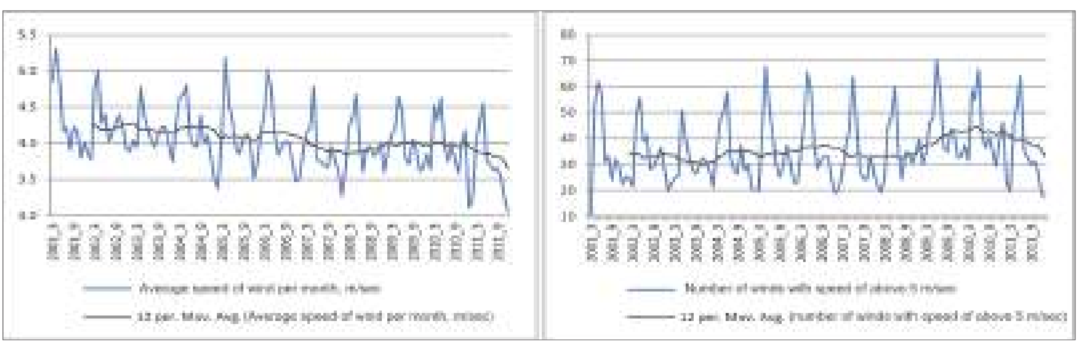


Figure 3.50 Wind velocity and its change (during 2000-2010)

There is a general notion that wind erosion is mainly defined by wind velocity, thus the dynamics of wind speed over the territory were analysed. From the analysis it was concluded that wind velocity is gradually decreasing; however, frequency of wind with speed above 5 m/s is slightly increasing. Besides wind velocity, any erosion process is determined by land cover conditions. According to Japanese researchers, the occurrences of spring dust storms depend on the soil moisture content and vegetation conditions in previous years (Kurosaki, Shinoda, 2011). This may apply to those regions where wind erosion during the last decade has decreased.

Vegetation cover change. The value of NDVI in Mongolia is different from region to region: in the Gobi desert region it is 0.05-0.18, in the steppe and forest-steppe region it is 0.2-0.35, in the forest steppe and forest region it is 0.4-0.5.The time-series analysis of NDVI within the period of 2000-2010 revealed that during 2000-2003,the value of NDVI decreased for the whole territory, but from 2005 its value fluctuated but overall had aslightly increasing trend. The analysis of the NDVI value in different natural zones indicated its high variation in steppe and desert regions, and from 2005 an average value become close to these which represents real deserts. From this it can be concluded that the desert steppe (or Gobi) region is has more of a desert-like look.

According to the observation from growing seasons, the duration of plants growing period has shortenedin forest steppe and steppe zones, but in the southern parts (desert-steppe, semi-desert and desert zones) the growing period tends to increase. The results obtained were similar to research done at the global level, and prove that in the northern hemisphere a plants growing season has prolonged as a consequence of the warming.

The vegetation cover change analysis indicated that during the last decade, vegetation cover steadily increased in regions such as the Mongol-Daurian steppe, Eastern Gobi hollow, Southern Gobi undulating plains and along the Khangai mountain chains. The negative changes; however, marked in the Khubsgul region, Orkhon-Selenge low height mountain region, Central Khalkha highlands and in the Eastern Steppe regions, were where NDVI value decreased 1-2 times.

Although the general picture of vegetation cover change has been seen as unequal during the last ten years, the vegetation cover has had a continuously decreasing trend more in the Mongol Altai mountains, Great Lake Depression, western parts of Khubsgul mountain, Orkhon-Selenge river basin, Central Khalkha highlands, Southern Gobi and Dariganga regions.

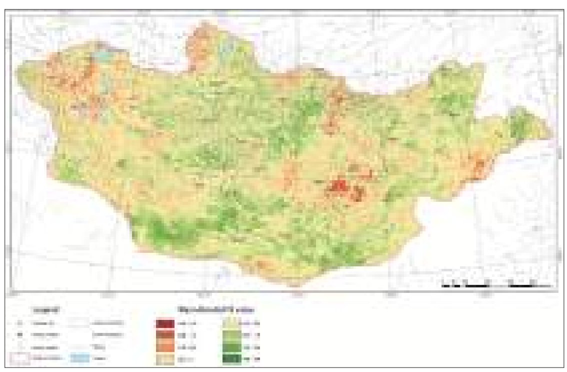


Figure 3.51 Mann-Kendall trend analysis of MODIS-NDVI time series for Mongolia

Livestock and Overgrazing. In the past, livestock numbers have not remained constant and fluctuated in a “growing-declining-growing-declining” pattern. Such unstable growth of livestock is highly determined by natural and climatic factors which directly affect nomadic pastoralist systems of livestock breeding. The significant reductionsin livestock numbers happened in 1983, 1993, 1999-2002 and 2009-2010, mainly due to the severe drought and the zud (Open Forum, 2004; Natsagdorj L. and Sarantuya G., 2003). Natural disasters such as droughts, zuds, strong winds, storms, and extreme cold temperatures that have beenreported since 1999, resulted in a sharp decline of livestock numbers, especially with the1999-2002 successive occurrence of drought and zud, which continued for two years,and occupied between 60-70 percent of the Mongolian territory, and resulted in a loss of 11 million heads of livestock and deprived and devastated 12 thousand herder families from their main source of livelihood. The latest hardship occurred in 2009-2010 due to the Zud; during which a total of 8.5 million livestock were lost, from 220 totally affected households, of which 44 families lost their whole flock and 164 families lost half of their flock. The influence of climatic change, especially in the form of frequent natural disasters, has highly impacted the livestock sector, which is visible in livestock live weight, flock structure and herders' livelihood.

In spatial distribution, about 32 percent of the total livestock of Mongolia lives in the Khangai region, 29 percent in the western region, 15 percent is herded in the eastern region, 14 percent in the Govi region and 9 percent is in the central part of Mongolia. Livestock density is quite sparse throughout the nation. The highly dense places are Myangad, Dariv Soums of Khovd Aimag, Bayan-Uul, Jargalan and Delger Soums of Govi-Altai Aimag, Khureemaral, Buutsagaan Soums of Bayankhongor Aimag, Bogd, Bayangol Soums of OvorkhangaiAimag, Erdenedalai soum of Dundgovi Aimag, Khatanbulag soumof Dornogovi Aimag, Bayandelger, Erdenetsagaan Soums of Sukhbaatar Aimag and Tsagaan-Ovoo soum of Dornod Aimag. The situation was repeated in most of the regions by 2000. However, comparing the livestock number to the years of 2000 and 2010, there is a change in the central and eastern parts of Mongolia. Especially the growing livestock density, which can affect the pastureland capacity and resources remaining in such places: Gurvanbulag, Rashaant Soums of Bulgan Aimag, Khatanbulag soum of Dornogovi Aimag, Bayandelger, Erdenetsagaan Soums of Sukhbaatar Aimag, Bayankhutag and Kherlen Soums of Khentii Aimag and Choibalsan Soum of Dornod Aimag.

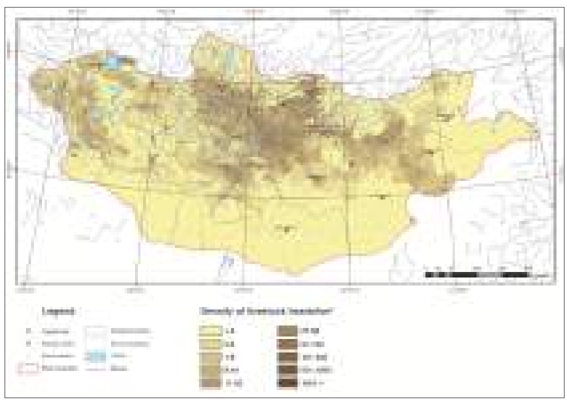


Figure 3.52 Livestock density for 2010, in head/sq.km

Spatial changes in population settlements. Demographically, the other factor to influence the land degradation is the population distribution. With society development, the urbanization process is an inseparable part of the historical development of civilization. Mongolia started to talk about the centralization of the population since the 1970s under the state policy targeted at developing industries rather than developing cities. However, population centralization itself becomes the main cause of land deterioration, as well as the strengthening agricultural industries in those places according to the laws of the market.

The settled population in Mongolia reached 2,407,500 as of 2000, and raised to 2,780,800 by the end of 2010. This is a difference of 373,300, or 13.4 percent growth. This is surely related to the growth of the birth rate,as the births per 1000 people is 22.9, which increased by 2.5 compared to the estimate from 2000. Similar to this estimation, there was quite a change in the population's settlement and location. In the last two decades, the population moved from rural areas to cities, 41.4 percent of the Mongolian population lived in Ulaanbaatar by 2010. Nationally, 63.3 percent of Mongolia's total population, or 176,040 people, live in urban areas. (Statistical Information Bureau, 2000-2010) Especially, more than half of the population in Dornod, Dornogovi, Govisumber, Orkhon and Darkhan-Uul Aimags live in urban or settled areas.

According to demographic changes, populations in urban areas, towns and Soum centers are growing and contributing to population centralization. This trend is clearly going to continue in the near future. These changes in the population's settlement may become the causes of land degradation, and affect the ecological status of places near urban areas.

The level of desertification and prevailing factors of land degradation was estimated and mapped in 2013, through the analysis of the above mentioned processes.

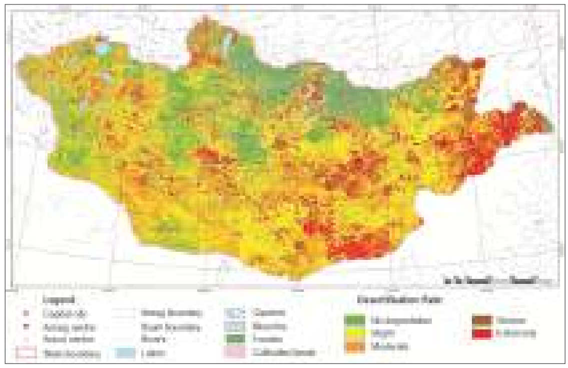


Figure 3.53 Land degradation and desertification in Mongolia for 2010.

As a result of this research it was reported that 77.8 percent of the total territory affected by degradation, of which 35.3 percent was defined as slightly degraded, 25.9 percent was moderately degraded, 6.7 percent severely degraded and 9.9 percent extremely degraded. Comparing this result with the previous assessment, it can be concluded that overall the land degradation situation has little changes; however, spatial distribution of lands heavily and extremely affected by degradation have changed significantly. Especially, there are many new places where extreme degradation situation is newly formed.

Various factors that change over space and time determine the desertification process. Such factors include indirect factors such as population increase, socio-economic, political, and international trade, and direct factors such as land utilization method, and climate change. Today desertification issues stem from inappropriate usage of limited natural resources. Then the issue becomes even more crucial from the effects of climate change. Based on the numeric index from the desertification map, a map of factors of major affects towards desertification was developed. The map of factors shows that 10.4% has no effects from factors or offer no sign of desertification, 1.9% is attributable to the human action factor, 16.0% is a natural factor, 13.8% is a climate factor, 20.8% is a wind erosion factor, 0.1% is a water erosion factor, 13.1% is a combined factor of human action and climate, and 23.9% is a combined factor of wind and human actions. It means 10.4% has no sign of desertification or no factors, 39% is from human actions prevailed or combined, and 50.6% is from natural factors prevailed or combined. In other words, natural factor contributes 56% and anthropogenic factors contribute 44% in areas that suffer from heavy or very heavy desertification (Mongolian desertification atlas, 2013).

Researchers mentioned that an increase of degraded land may cause adverse effects on regional climate (Xue Y., Shukla, 1993; Xue, 1996; Gomboluudev, Natsagdorj, 2004). Gomboluudev and Natsagdorj (2004) pointed out that large-scale changes occurring in land cover will subsequently impact moisture regime in regional climate. If degradation processes continue to gradually develop and area of barren land increases, the amount of precipitation and evapo-transpiration will decrease resulting in intensive aridification of the climate. Researchers reported that an increase in aridity may be significant in Central and Eastern parts of the country, which they proved by regional climate model outputs.

3.1.7 Dust/sand storm

Recently, researchers studied dust phenomena with new quantitative measurements and published some study results (Jugder et al., 2011, 2012, 2014, Igarashi et al., 2011; Ishizuka et al., 2012; Kurosaki and Mikami, 2004; Park et al., 2010, 2011, Shinoda et al., 2010). Shinoda et al., (2010) studied a dust event observed in the steppe of Mongolia that is near the Bayan Unjuul Soume, Tuv Aimag. During the dust event (from 13:00 to 18:00 LST on April 24, 2008), the threshold wind speed was at 1.54 m height, which is the minimum wind speed inducing saltation of particles ranging from 30 to 667 μm in diameter, was 8. m s^{-1} on a land surface with 7.2% vegetation cover with dead brown leaves, a small roughness length (0.0058 m), and a very dry sandy soil at 0-5 mm depth (water content, 0.002 g g^{-1}) (Shinoda et al., 2010). Dust mass concentrations of PM_{10} and $PM_{2.5}$ from four monitoring stations (5 events for the period from March to August in 2010. The maximum hourly mean dust concentrationof the dust event was found to be 4,107 μg m^{-3} in May in 2009, and 4,708 μg m^{-3} in March in 2010. Park et al., (2011) calculated friction and convective velocities and derived optimal regression equations for the estimation of dust concentration of dustevents for each month. A study (Kurosaki and Mikami, 2004) defines the effect of snow cover on the threshold wind velocity of dust outbreak using data from 1988-2003. A threshold wind velocity for dust emission increases with the snow cover fraction (Kurosaki and Mikami, 2004). Small amounts of precipitation and snow cover in the Gobi Deserts influence spring soil moisture and causedry soil conditions. For example, a study (Munkbat, 2010) using data from 70 meteorological stations in 1975-2009 showed that the snow fall amount for winter months (December to February) were 1-2 mm in the Gobi Deserts and the Great Lakes Depression. As well as, a period with steady snow cover in those regions was less than 50 days per year (Munkbat, 2010).

Dry land surface plays a great role on the dust emission. The soil moisture index and the Thornthwaite precipitation-evaporation index were less than 0.30 and 20 in the Gobi Desert area, respectively (Natsagdorj, Gunbileg, 2009). The spring drying was between April and May (Nandintsetseg, Shinoda, 2010) and this soil drying period coincided well with dust frequencies. Vegetation cover can influence dust emissions. A study using NDVI data from NOAA satellite in 1982-2003 (M.Bayasgalan, 2005) determined that NDVI was less than 0.29 in the Gobi region and less than 0.06 in the Desert region in Mongolia. Simulation results demonstrated that the highest net primary productivity (NPP) of 83.2 g C/m^2 and the lowest NPP of 12.6 g C/m^2 over the growing season (April-September) occurred at Darkhan (steppe) and Mandalgovi (desert steppe), respectively (Bat-Oyun et al., 2010). A study (Igarashi et al., 2011) showed that specific activities of both radionuclides as well as the ^{137}Cs/^{90}Sr ratio in the surface soil were well correlated with annual average precipitation in the Mongolian desert-steppe zone. Higher specific activities and a higher ^{137}Cs/^{90}Sr ratio were found in grassland regions that experienced greater precipitation. These findings suggest that the increased specific activities and the activity ratio detected in atmospheric depositions in Japan during years with frequent Asian dust transport events in the 2000s are a sign of grassland degradation.

Distribution and trend of dust events in Mongolia. The number of days with dust storms is less than 10 days over the Altai, the Khangai and the Khentei Mountain regions and more than 50 days in the Gobi Desert and the Great Lakes Depression (The National Geography Atlas of Mongolia) (Figure 3.54). The greatest occurrence of dust storms arises around the Altain Uvur Gobi and the Mongol Els area in the west (Figure 3.54). The number of days with dust stormsobtained from 32 meteorological representative stations in 1960-2013 has an increasing trend and it tripled during the period (Figure 3.55).

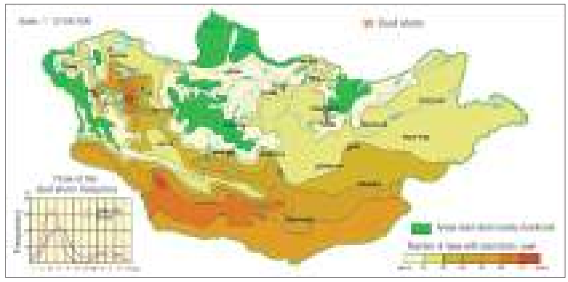


Figure 3.54 Distribution of dust storms /1960-2008/

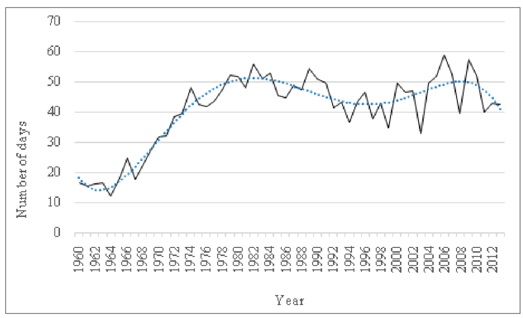


Figure 3.55 Time series of dusty days and its trend /1960-2008/

Dust concentrations of PM_{10} ($PM_{2.5}$) during dust events in the Gobi Deserts: In this section, study results of data were analyzed for Dalanzadgad, Sainshand, Zamyn-Uud, and Erdenesites in the Gobi region.We mainly used mass concentrations of PM_{10} ($PM_{2.5}$), visibility, wind speed, and relative humidity measured at 2 m above ground level, at these four sites during 2009–2010, although we used some data from 2008 for a case study (Jugder et al., 2011). The relationships among the PM mass concentrations, duration of dust storms, and visibility represented by meteorological optical range (MOR) are illustrated for Zamyn-Uud and Dalanzadgad in Figure 3.56. PM_{10} and $PM_{2.5}$ concentrations and visibilities were averaged by duration period of dust storms. PM_{10} and $PM_{2.5}$ concentrations increased gradually with dust storm duration. Averaged concentrations of PM_{10} ($PM_{2.5}$) for these duration periods of the dust events varied from 204 (101) µg m^{-3} to 452 (170) µg m^{-3}. The maximum daily mean PM_{10} ($PM_{2.5}$) concentrations during dust storm periods were 821 (500) µg m^{-3} at Dalanzadgad, 308(129) µg m^{-3} at Zamyn-Uud, and 1328 µg m^{-3} at Erdene. Hourly maximum PM_{10} ($PM_{2.5}$) concentrations for all dust events at our four stations during 2009–2010 ranged from 1333 (517) µg m^{-3} to 6626 (2899) µg m^{-3}. The highest of these values was measured at Dalanzadgad (Jugder et al., 2011). Minimum relative humidity varied from 16% to 36% together with the increase in PM_{10} concentrations during dust events at Erdene (Figure 3.57). PM_{10} and $PM_{2.5}$ concentrations increased because of dust storms in the Gobi, when the air was very dry. For example, for about 60% of dust events at the Erdene site, relative humidity was less than 20% with the increased PM_{10} concentration (Jugder et al., 2011).

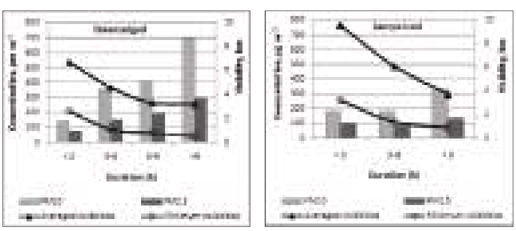


Figure 3.56 Relationship between concentration of PM10 (PM2.5) and visibility with duration of dust storms at Dalanzadgad and Zamyn-Uud in 2009–2010.

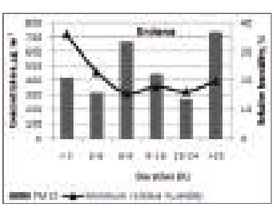


Figure 3.57

Relationship between concentration of PM10 and minimum relative humidity with duration of dust storms at Erdene in 2009–2010.

Polarization-sensitive Mie-scattering lidars measurements. Lidar is a remote sensing technology that detects base and top heights of clouds, rain, biomass burning smoke, aerosols including dust, pollutants and transported dust etc. (Sugimoti et al., 2008). A study revealed dust, biomass burning smoke and anthropogenic aerosols transported from neighboring countries and some other places of the country using Lidar measurements (Jugder et al., 2012). For example, the lidar measurements at Ulaanbaatar indicate that biomass burning smoke existed during the period of June 7-9, 2008 in the layer from the ground level up to 2.5 km AGL (Figure 3.58). The Mie lidar observations detected dust layers elevated in the atmosphere that traveled from the Taklimakan Desert and the Gobi Deserts of the northern and western areas of China (Jugder et al., 2012). A transported dust layer in the air over Sainshandon February 24-25, 2010 was shown in Figure 6.59 The base and top heights of this elevated dust were about 0.75 and 3.0 km AGL, respectively (Jugder er el., 2012).

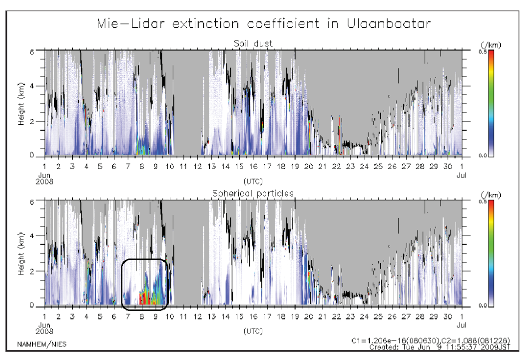


Figure 3.58 Biomass burning smoke detected by lidar extinction coefficient for June, 2008 over Ulaanbaatar city. Note: Time (UTC) in the horizontal axis and height in the vertical axis.

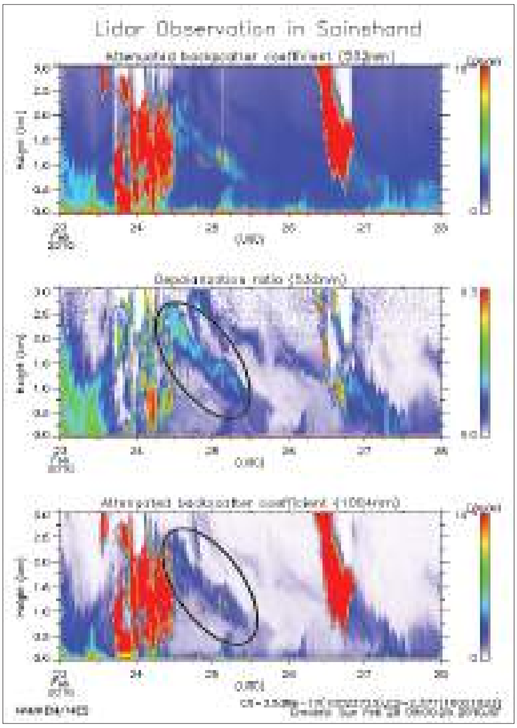


Figure 3.59 The transported dust layer in the air over Sainshandon February 24-25, 2010.

A severe dust event was observed on May 19-20, 2008.The maximum concentrations of PM_{10} ($PM_{2.5}$) were as high as 1409 (384) and 1139 (404) µg m^{-3} at Sainshand and Zamyn-Uud, respectively, with maximum winds of 18-22 m s^{-1} (Figure 3.59). Horizontal visibility reduced to 1 km or less during a 7-8 hour period (Figure 3.63). Lowest visibilities were 189 m at Sainshand and 319 m at Zamyn-Uud. As for Ulaanbaatar, dust layers rose up to 2.0 km AGL May 19-20, 2008. An increase in dust concentration was also apparent; the maximum PM_{10} ($PM_{2.5}$) were 355 (251) µg m^{-3} on May 19-20. The extinction coefficients were high as 0.68-0.74 $km^{-1}$and categorized as the high dust density (Jugder et al., 2012). The lidar extinction coefficient can distinguish spherical (pollutants) and non-spherical particles (soil dust) that are shown in lower and upper panels, respectively, in Figure 3.60. Four cases of dust storms and a case for air pollution in May, 2008 were detected by lidars at Ulaanbaatar, Sainshand and Zamyn-Uud, while two cases of transported dust layers by the lidar at Sainshand (Figure 3.60) (Jugder et al., 2012).

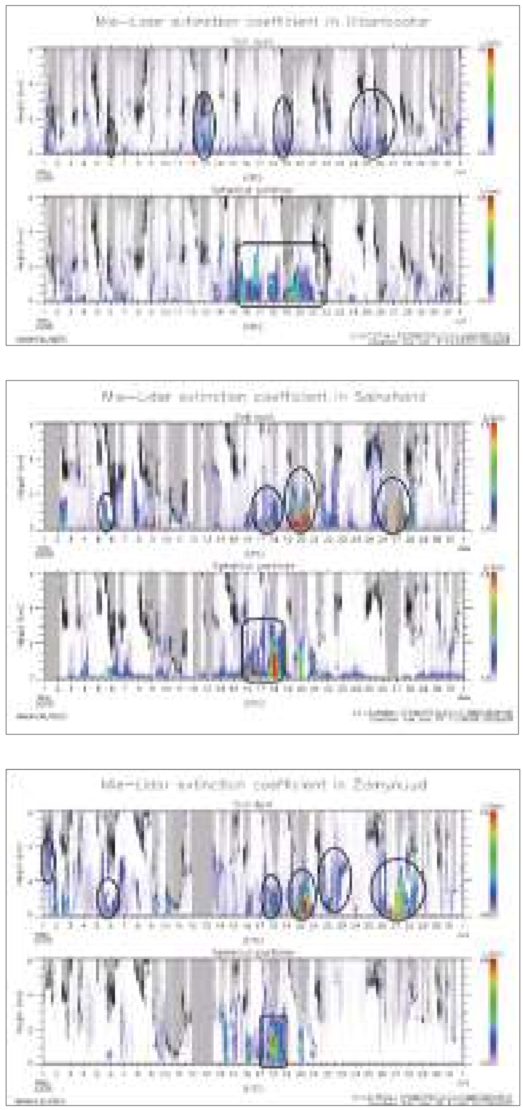


Figure 3.60 Dust storm and transported dust (upper panel)and air pollution (lower panel) detected by lidars at laanbaatar, Sainshand and Zamyn-Uud in May, 2008.

3.2 Climate change impact on society and economy

3.2.1 Animal husbandry

Animal husbandry still plays a vital role in the economy, employment and export revenue of Mongolia. The total agriculture production of which 75.3% was comprised of livestock production, contributed 11.7% of the Gross Domestic Production (GDP) in 2013. Although the contribution of livestock production to the GDP has decreased, animal husbandry provides about 29.8% of the total employment which is a major livelihood source for 30% of the total households. According to the statistical information cited, Mongolia produced 249.7 thousand metric tons of meat, 575.2 thousand metric tons of milk, 22.1 thousand metric tons of wool, 5.6 thousand metric tons of cashmere and 10.9 million skin leather in 2013 (Statistical Yearbook 2013 of Mongolia). In the last three years, the major types of livestock products have increased by 18 to 25%. Climate change can impact pastoral livestock in two ways: directly and indirectly. Hot weather, storms and heavy snows are direct negative factors influencing animal grazing. Under these conditions animals cannot gain sufficient weight in the summer and autumn and would ultimately face challenges to overcome harsh winter and spring seasons. Also, indirect factors can effect pasture production which impacts the weight and mortality of animals.

The total animal numbers and composition of herds. Since the 1990s, the total number of animals generally increased and reached 45.1 million head in 2013. The total animal numbers decreased by 9 million in the *zud during the* winter of 2009 – 2010, but has increased annually ever since.

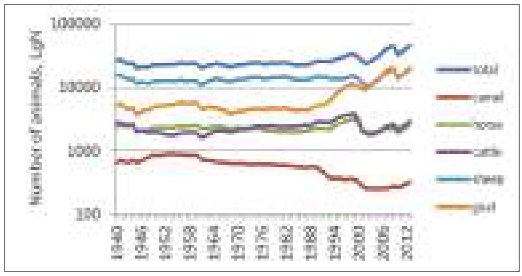


Figure 3.61 The total number of animals at the end of year / Vertical axis is base ten logarithmic scale of N – the total animals/. *Source: Statistical database, NSO, 2013*

Figure 3.61 shows that the number of camels has seen a decreasing trend since the sixties. The highest production animal - cattle - increased until the drought and zud conditions in 2000, and then declined in numbers. The number of goats had a steady growing trend and makes up almost 43% (2013) of the total herds. In the last 20 years, the traditional composition of livestock of Mongolians has changed. Cattle, which graze on high grasses pastureland, were 9.7% of total animals during 1960-1990, but dropped down to 6.6% after the zud winter of 1999-2000. On the contrary, the composition of goats was 19.5% and became almost 42-46% since 2008 which is the same as sheep. Obviously, the goat number growth was caused by the cashmere needs at markets. But, the camel number reduction was explained by the increasing meat demands in urban areas.

Variation of animal numbers caused by droughts and zuds. According to climate change scenarios, rain would not change much during the growing season and drought will occur more due to warming. Even though winter would be warmer, the increase in winter precipitation would cause more extended zuds in terms of frequency as well as magnitude. Annual drought and zud indexes and their relation to the animal mortality rate (includes only adult animals) were studied and a high correlation was found in research done by Natsagdorj L and others (AIACC, 2005). However, the correlation rate between drought and zud indexes and the animal mortality rate has declined while the traditional herd composition has been distorted. This means that the animal mortality rate has increased currently in relatively mild conditions rather than in the more severe winters of the 1940's (Natsagdorj L, 2014). The ratio between dead animals and the total animal numbers had a slightly decreasing trend from 1940-2011, and increased by 0.05% and 0.254% per year for the period of 1961-2011 and 1991-2011, respectively (Figure 3.62).

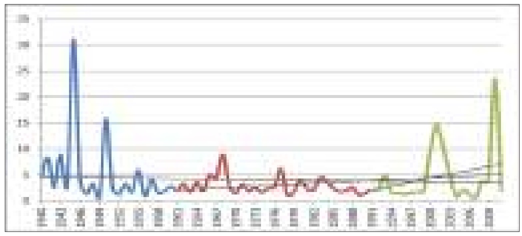


Figure 3.62 Multiyear ratio between annual mortality rate of adult animals and the total animal numbers *Source: Natsagdorj L., 2012, Impact, vulnerability and risk assessment of climate change on forest, water and agriculture sectors*

As mentioned previously, the intensity of the drought and *zud* will be increased in future climate change scenarios. Drought and *zud* indexes were calculated and animal mortality rates were estimated (Table 3.20) for future periods of 2011-2030 and 2046-2065 under high and low emission (A2 and B1) scenarios of the Global Climate Model of UK Hadley centre- *HADCM3,* which estimated the past climate of Mongolia with the highest accuracy.

Table 3.20 Drought and *zud* indexes and animal mortality rate for past and future periods

SRES A2

Period	Drought- summer index	Winter index	*Zud*index	Animal mortality rate, %
1980-1999	-0.24	0.45	-0.69	2.1
2011-2030	2.0	-0.08	2.08	8.18
2046-2065	2.63	0.66	1.97	9.39

SRES B1

Period	Drought- summer index	Winter index	*Zud*index	Animal mortality rate, %
1980-1999	-0.24	0.45	-0.69	2.1
2011-2030	1.0	-0.13	1.13	4.28
2046-2065	2.45	0.1	2.44	10.1

Source: Natsagdorj L., 2012, Impact, vulnerability and risk assessment of climate change on forest, water and agriculture sectors

If the animal mortality rate exceeds 5%-6%, it will impact not only herders livelihood, but also will trigger many socio-economic challenges including food security, the migration from rural to urban areas which will boost the urban population, and the depletion of social services.

Animal productivity. Due to climate change in the last 20 years, pasture net primary production declined by 5%-13% more than the average of 1961-1990 in the central and the western parts of the eastern region. The reduction of the pasture biomass and the increase of hot waves which cause heat stress on animals (Natsagdorj., 2008) make animals smaller because they cannot gain sufficient weight through grazing. Figure 3.63 presents multi- year measurement of cattle weight in the forest steppe and the steppe. vulnerability of animals to environmental factors has been increased.

Besides meat production, the wool productivity of sheep had a decreasing trend, too, due to animal weight decline. Sheep weight change was estimated for future periods under climate change scenarios of high and low emissions (AIACC, 2005). The estimation demonstrated a decline in sheep weights in the forest steppe and the steppe in the middle and end of the century (MNET, 2009). The calculation of sheep weight changes in

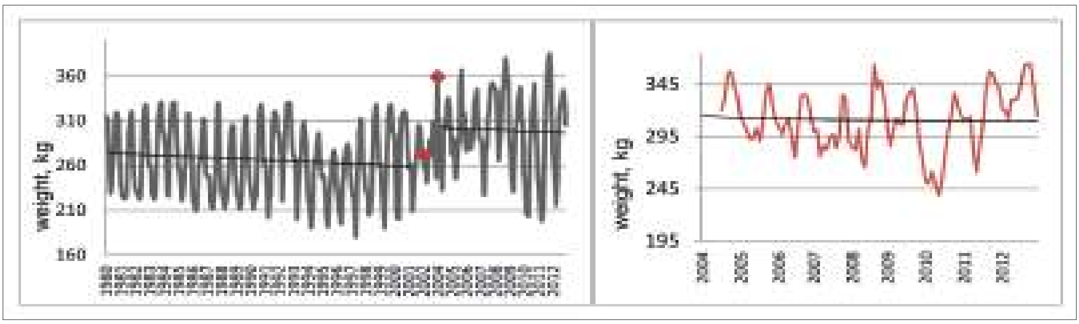


Figure 3.63 a/ Orkhon soum, Bulgan aimag; b/ Bayan-Unjuul soum, Tuv aimag
Source: Zoo meteorological measurements, Institute of Meteorology, Hydrology and Environment.

As shown in the above Figure, the average weight of an adult Mongolian cow had a declining trend in the period between 1980 and 2001. After three years of consecutive *zud* in 2002 to 2004, the measurement was shifted to a different cattle herd and the homogeneity of a time series was lost. Since 2004, the weight of cows was slightly decreased in the last 7-8 years at both zoo meteorological posts in Bulgan and Tuv aimags. Moreover, the variation of cow weight between summer/ autumn and winter/spring seasons was expanded. A decline of cow weight was higher in the winter/spring season than summer/autumn, and the seasonal variation of weight was amplified. Eventually, the the winter and spring seasons are very challenging because of the prediction of snow thickness and density on pastures. However, snow amount would increase by 20%, with a 40% increase in snowfall in the middle of the century and a 50% increase at the end of this century. Winter precipitation increase will be a factor that decreases animal weight in the winter and spring. There were some attempts to conduct economic cost-benefit analysis by researchers under Impact, vulnerability and risk assessment of climate change on forest, water and agriculture sectors in 2012. For example, based on the calculation of sheep weight changes in 2020, 2030 and 2050 under SRES B2 scenarios, the total economic loss of meat production was estimated while the number of animals and composition were considered to be the same as the average of 2008-2010 (Figure 3.64).

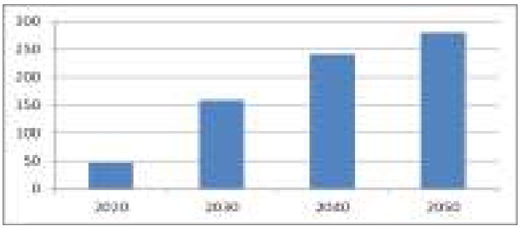
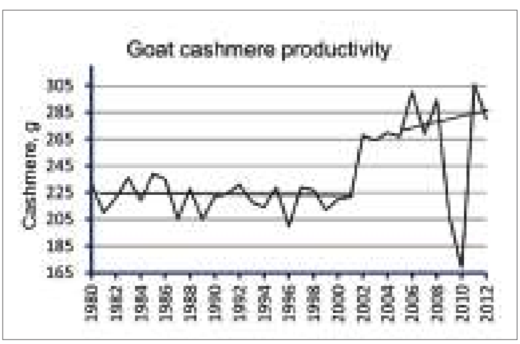


Figure 3.64 The total loss of meat production in billion tugrugs *Source: Enkhtaivan L., 2012, Impact, vulnerability and risk assessment of climate change on forest, water and agriculture sectors*

Even under low emission scenarios, meat production loss was estimated at less than 50 billion Tugrugs in the first decade and as 160 billion Tugrugs in 2030, which would be three times higher than the first ten years. If there is no action taken, in 2050, the above loss would reach up to 280 billion Tugrugs which would be a decrease by 5.4% of the total livestock production (Enkhtaivan 2012). This estimation was mainly based on meat production and would be higher if other production of animals and animal loss of zud were considered. The harvesting dates for goat cashmere and sheep wool were shifted earlier by ten and five days, respectively.

The amount of cashmere from goats was at a steady level in the period between 1980 and 2000, and increased in the last five to six years. Measurement and trend analysis was ignored for the years 2002-2004 because after the zud in 2002, measurements started to be done on different herds. In the recent years herders have paid more attention to goat breeds with high cashmere productivity due to increased market demands and the high cost of cashmere. On the contrary, wool productivity had a decreasing trend and the annual variation was increased in general.

Herders. The number of herding families was counted as above 100 thousand. About 250 thousand people herded about 23-25 million heads of animals in the socialist period. After the 1990's the number of herders raised rapidly when livestock were privatized and employment dropped in urban areas. However, herders decreased after the zud in 3 years of 1999-2002 and in 2009-2010 because many rural families lost their animals. As of 2013, there were 210 thousand families with herds and 286 thousand herders according to the statistics (Figure 3.66). Young herders have especially been declining in numbers in recent years.



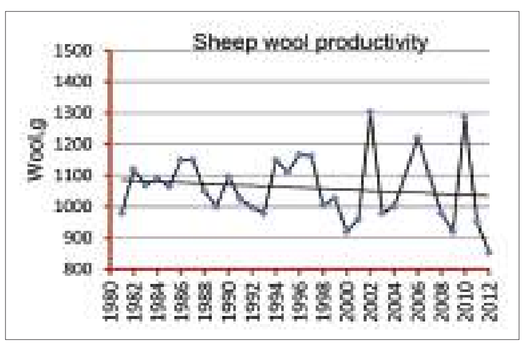


Figure 3.65 The average productivity of goat cashmere and sheep wool, measured at zoo meteorological post in Bulgan aimag. *Source: Zoo meteorological measurements, Institute of Meteorology, Hydrology and Environment.*

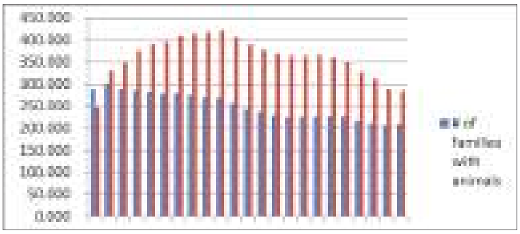


Figure 3.66 Multiyear number of families with animals and number of herders. *Source: Statistical database 1991-2013, NSO (http://1212.mn)*

Migration to urban areas, urbanization and related challenges continue to impact negatively on herders' livelihood due to increased natural disaster such as drought and zud, decline in animal production, and the remoteness from markets. Consequently, the number of animals per herding families increased as demonstrated in Figure 3.67.

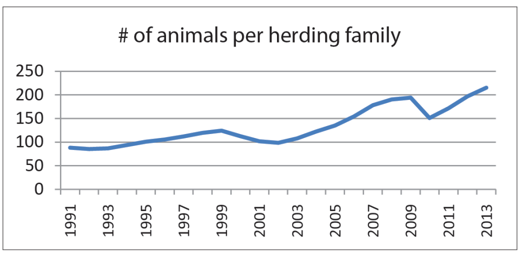


Figure 3.67 Number of animals per herding family
Source: Statistical database 1991-2013, NSO

According to the statistics, the number of herders with more than a thousand animals has doubled in the last four years. The average livestock density per 100 hectare of pasture was counted as 40 and 60 sheep heads in 1967 and 2012, respectively. In addition, in the Khangai region and near Ulaanbaatar, livestock density per 100 ha of pasture was counted as 102-325 sheep heads which was higher by 42-265 heads than the national average density. As a result, the pasture carrying capacity has been exceeded in semi-urban areas with close market access and in areas of water resources. This shows an increasing trend of animal density which causes intensified pasture overgrazing and degradation in areas of high density of livestock.

Animal health: The study of climate change impact on animal health is quite a challenging task with many uncertainties. (Mauricio Ret.all, Juan L, and Thornton P, et all, 2013). Climate change and general anthropogenic factors together alter both the farming and the natural landscapes and in the process impact the health of animals in multiple ways, such as disease ecology and transmission dynamics.There is a lack of research with evidence and detailed studies regarding this topic in Mongolia. According to available reports and international research, the following risks would be faced in the future:

- Extension of animal epidemics related with climate change, natural disasters and anthropogenic activities;
- Trans-boundary transmission of new and comeback infections and epidemicsin animals
- Remaining risks, host landscape and extension territory of current emerging epidemics of animals;
- Increasing risks of outbreak of new and comeback diseases and epidemics in terms of types, incidence and distribution; and
- Viruses change and mutate bringing new challenges in animal epidemiology.

According to animal health researchers, 26 types of animal disease were newly registered, 8 types of diseases returned, and 6 types of diseases were extended in terms of territory in Mongolia in the recent decades (Orgil., et all.,2013). However, a study of animal diseases with climate change and environmental factors is greatly required in Mongolia.

Water supply for animals: Water supply plays a key role in pastoral animal husbandry. According to statistics, there were about twenty thousand motorized wells out of the total of forty thousand wells. The remaining wells were manual wells and 60% of pastureland was supplied with water by the total wells. A census of water sources in 2009 counted about ten thousand motorized and seven thousand manual wells. Thus, the water supply for animals has declined (Nergui D, 2011). Research of climate change on water resources (Davaa G. and others, 2005 and 2012) noted that cryosphere was depleted significantly and the numbers of small lakes and natural ponds disappeared as a result of past climate change. Numbers of small lakes and ponds varied greatly and as of the census in 1999-2002, 295 lakes were dried up and 50 very small lakes and ponds had disappeared. Due to global warming, water temperature will increase; riparian ecosystem production will be improved in cold mountainous belts which can have favored effects on the water supply for animals. However, intensified potential evapotranspiration would lead to more dryness in the total territory of the country (Impact, vulnerability and risk assessment of climate change on forest, water and agriculture sectors, 2012). Eventually, one of challenges caused by climate change will be water resources, which has an impact on the water supply for pastoral livestock.

3.2.2 Arable farming

Mongolia has 1.279 million hectares of arable farming land, of which 70.9% is in the central region, 15.9% in the agricultural region of the east, and 13.2% in the western region, respectively. In terms of crop yield, 85.9% comes from the central region, 5.7% from the west, and 8.6% from the eastern region. In terms of potato yields, the central region produces 77.3%, the west produces 13.3%, and the eastern region produces 4.4%. The aimags that are located in the gobi region—such as Dornogobi, Umnugobi, Gobi-Altai, Bayankhongor, Khovd, Bayan-Ulgi, Dundgobi, and Gobisumber—cultivate potatoes, vegetables, and some fodder plants using only irrigation. In 2013, the total arable farming land in these aimags was 1.38% of the national total, which implies the crop yield of these aimags have no serious impact on the national crop production. UN Food Security Assessment of 2006 concluded that 30% of the Mongolian population is consuming food that does not meet safety standards during the most difficult periods of the year. Therefore, food security is a challenge for Mongolia even without the impacts of climate change. Research results show that the agricultural region is expanding to the north, thus the arid steppe zone of eastern Mongolia is pushing the forest-steppe zones to the north. As a result, the size of the high mountain and forest-steppe zone is decreasing, and the steppe and desert-steppe zone size is increasing (Tserendash et al. 2005, Mandakh et al. 2007).

Climate change is having negative impacts such as loss of pasture, limiting the yield from cultivated and pasture crops, decreasing the productivity of livestock, thus decreasing the regional and national food production capacity (Batjargal et al. 2000). There are many factors that affect the agricultural productivity and these factors could become limiting factors due to climate change. Researchers have noted since the first cultivated land until the 1980s, the amount of machinery, technology, fertilizer, pesticides and herbicides in arable farming has multiplied several times. However, the crop yield per hectare fluctuated with weather conditions. In other words, the arable farming practiced in Mongolia is characterized by high risk, as the crop yield can fluctuate up to 50% depending on the weather or it can even be lost altogether (Altansukh N., Dorj B, Mijiddorj J.1999). The impact of climate change on arable farming is most visible in non-irrigated farming of food and fodder crops; therefore, this report will focus on non-irrigated crops; especially how climate change affects wheat and potato farming which are mentioned in the “Law on food” as strategic food products. The report uses data from the Institute of Meteorology, Hydrology and Environment and National Statistical Office.

Studies cover climate change impacts on arable farming starting from the 1960s,when land was cultivated in Mongolia and arable farming was developed as an independent agricultural sector, and when numerous collective farms and fodder farms were established along with meteorological stations in order to provide the conditions for achieving self-sufficiency in wheat, potato, and vegetable production—until the year 2013. The western, central, and eastern regions’ arable farming sectors are covered using parameters such as mean daily temperature, precipitation, precipitation in growing season, sum of active heat for plant growth (above 10^0C), number of days hotter than 26^0C, and change of frost time in the spring and autumn. The report includes results from the dynamic DSSAT model of cultivated plant growth to find out what impact future climate change in Mongolia (2011-2030, 2046-2065, 2080-2099) could have on non-irrigated wheat and potato crops. The report also mentions adaptation options including technological developments that could help prevent harmful impacts for the arable farming sector from past achievements of science and industry and experiences from other countries with similar climatic conditions.

Present state of Mongolian arable farming.

Arable farming takes an important place in the agriculture sector which is one of the main sources of the Mongolian economy. At the end of the socialist system in 1989, Mongolia harvested 8,239.1 thousand tons of wheat, 155.6 thousand tons of potato, 59.5 thousand tons of vegetables, and 551.0 thousand tons of fodder plant, respectively. With the transition to a market economy and the privatization of large state industries combined with diminishing government support for the sector, the arable farming sector collapsed so that in 2007, 109 thousand tons of wheat, 114 thousand tons of potato, 76.4 thousand tons of vegetable, 14 thousand tons of fodder were produced, thus supplying 27.5% of wheat, 88.7% of potato, 48.8% of vegetables and 1% of the fruit demand, respectively.

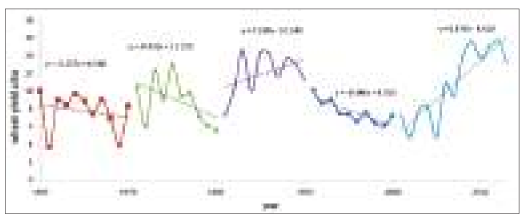


Figure 3.68 Multi-year trend of wheat yield per hectare (national average, NSO data)

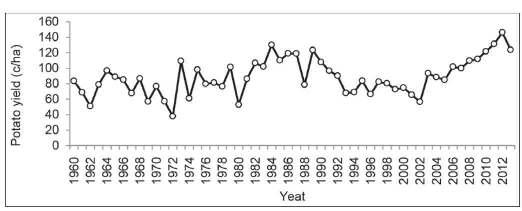


Figure 3.69 Multi-year trend of potato yield per hectare (national average, NSO data)

Since crops are cultivated in Mongolia almost 100% without irrigation, the year-to-year crop amount is determined by the weather conditions of that year. Experience from other countries show that as agricultural practices improve, generally the yield per unit of land tends to increase and it fluctuates a little bit due to the precipitation-heat ratio of a given year. Since the 1960s, the wheat yield per hectare generally tended to increase, then between 1960 and 1990, there was a rapid increase at a rate of 0.053 c/ha and a sudden decrease of 0,151 c/ha between 1991 to 2005. This decline is related to the lack of support by the government for the arable farming sector and also to the drought that continued for several years between 1999 and 2002. Since 2008, weather during growing season has been generally favorable and the government gives special attention to the reforming of the arable farming sector (Figure 3.68, 3.69).

The main factor for determining the amount of crop in Mongolia is the amount of precipitation during growing season. In addition, the rise of extreme hot days during mid-summer that is increasing in recent years hinders plant photosynthesis, thus providing the condition for decreasing crop yield. Figures 3.70, 3.71, and 3.72 show wheat crop yield and the precipitation trend in the growing season (May to September) in the western, central and eastern agricultural regions.

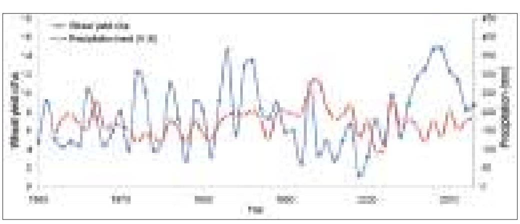


Figure 3.70 Multi-year trend of wheat yield, precipitation during growing season in the western region

Crop yield and precipitation trends in the central region (Figure 3.71) show that the amount of precipitation during growing season remained more or less constant with an average of 295 mm from the 1960s to the mid-1970s. After this period, the amount of precipitation decreased down to an average of 205 mm. The wheat crop yield in the central region shows two declines in crop yield since the 1960s. The first crop decline could be observed between 1976 and 1980, which roughly followed the precipitation trend. These years had about 100 mm less precipitation on average than the previous years. The next decline was observed from the early 1990s until mid-2000. This decline is related to Mongolia's transition to a market economy and privatization of large state enterprises, and also the diminishing government support to the sector, and thus, to the temporary collapse of the arable farming sector and number of consecutive droughts since 1999, the effects which lasted until 2007 (Figure 3.71). However, such decline is not observed in the western region where there is relatively less cultivated land compared to the central and eastern region. Here there seems to be no correlation between crop yield and precipitation which indicates the effect of other factors (Figure 3.70).

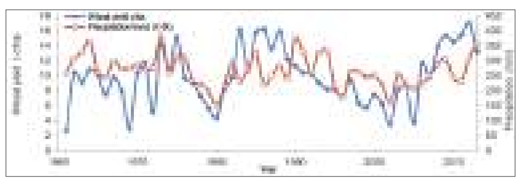


Figure 3.71 Multi-year trend of wheat yield, precipitation during growing season in the central region

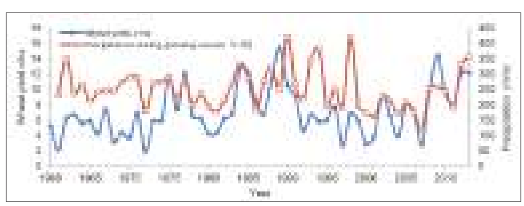


Figure 3.72 Multi-year trend of wheat yield, precipitation during growing season in the eastern region

The ratio of wheat yield in the central and eastern region to precipitation in growing season is 0.42-0.45. This means precipitation plays an important role (Figure 3.71, 3.72); however, since summer precipitation is hardly going to change (about -4....+10%), precipitation change alone cannot indicate future change in crops.

Observed Climate change Impacts on Spring Wheat and Potato Growth and Yield

Hot days: Important climate indicator that affects crop yield is the number of hot days inhibiting plant photosynthesis (IPCC, 2001). Therefore, the change in hot days is analyzed in June and July, a period when cultivated crops are vulnerable to water and moisture. Hot days are those that are above +26^{0}C that negatively affect wheat growth (Gobin 2012). The relation between the number of days with maximum air temperature above +26^{0}C and wheat yield is shown in chosen stations in arable farming areas (Table 3.21). In Baruunturuun in the western region and Tarialan, Khuvsgul stations only in June and July, the higher the temperature, the bigger the chances that wheat yield decreases, thus making hot days one of the factors that affects wheat yield.

There is a general trend that air temperature would increase which means the number of hot days would also increase. It is clear that this will not have a positive impact on the non-irrigated arable farming sector of Mongolia.

Frost. This research shows that the frost period in late spring in western and central regions has become 14-15 days earlier, whereas in the Khangai and eastern regions this number is 6-9 days during the years included in the research. On the other hand, research shows in these regions that the frost period in early autumn happens 4-11 days later. In terms of the duration of the frost period, it has become 24-25 days or almost one month longer in the western and central region, and 14-17 days longer in the eastern region. The number of days without frost has increased by 10-25 days in the above-mentioned regions and the trend line shows this could increase even more; therefore, it could be possible to cultivate crop sorts that require a longer time for ripening, thus increasing the yield per unit.

Heat supply (the sum of active temperature above +10^{0}C). In order to find out how the heat supply during the

Table 3.21 Correlation coefficient between the number of days with maximum air temperature above +26 ^{0}C and wheat yield

Station name	Arable farming region	Number of days hotter than +26 ^{0}C	
		June	July
Darkhan	Central	-0.59*	-0.66*
Baruunkharaa	Central	-0.32*	-0.33*
Eroo	Central	-0.37*	-0.40*
Orkhon	Central	-0.44*	-0.46*
Tarialan	Central	-0.26*	-0.19
Baruunturuun	West	-0.35*	-0.19
Dadal	East	-0.38*	-0.44*
Binder	East	-0.41*	-0.51*
Khalkhgol	East	-0.43*	-0.30*

*Note: * 99% statistically significant relation* growing season is changing and how it affects wheat growth, the sum of active temperature above +10^0C was calculated in each of the chosen stations and its multi-year trend and change is shown in stations representing each region. When the average of the sum of active temperature above +10^0C between 1961 and 1990 is compared with the average of 1991 to 2013, there has been an increase of 170-280^0C in the selected regions for the research. Thus, due to the warming in recent years, the possibility has arisen to grow wheat in some cooler regions. However, because of moisture supply deficiency, this cultivation land could still be limited.

The future trend of climate change shows an increase in air temperature which could in turn increase heat supply of crops. Therefore, conditions could become favorable for cultivating some crops which prefer heat (rice, gourd family plants, etc.) with irrigation. However, high temperature fluctuation and extreme heat inhibits photosynthesis and halts growth.

Correlation between multi-year change of heat-moisture coefficient and wheat yield: Air temperature and precipitation do not affect the crop growth by itself. Instead, they affect the certain conjunction of moisture and temperature. This is presented in different moisture-heat indicators (called ratio, index, etc.). The most commonly used such indicators in Mongolia are Selyanov's water-heat ratio and Budyko's aridity radiation index. These indicators have good relation to biocapacity of a given area including soil fertility and annual plant yield. In other words, there is a good relation to primary productivity of an ecosystem (Natsagdorj L. 2012).

Researchers have studied the maturing process of wheat crops in relation to mean air temperature, total precipitation and heat-moisture coefficient and found a statistically significant correlation between wheat yield and heat-moisture ratio in May and June (Dagvadorj D. 1989, Oyun J. 2001). Selyanov's heat-moisture ratio was used to analyze the correlation between wheat yield and heat-moisture indicators in arable farming regions in Mongolia. When the statistical significance of these results were evaluated, the highest statistical correlation between wheat yield and heat-moisture ratio was found in June (Figure 3.73).

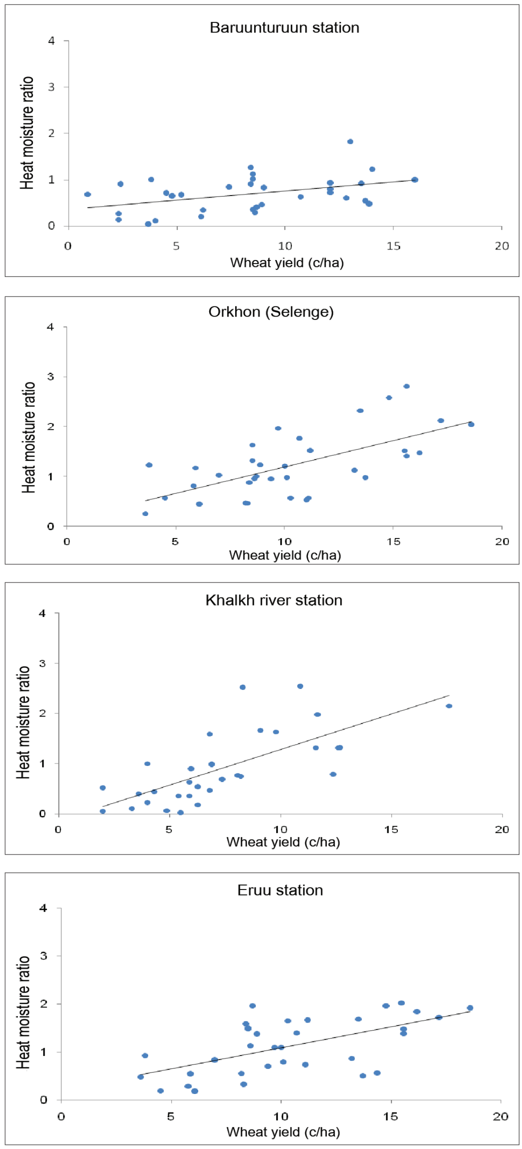


Figure 3.73 Correlation between heat-moisture ratio in June and wheat yield

Due to climate change, heat-moisture indicators are changing and it is becoming drier in most regions of Mongolia (Figure 3.74). This change was evaluated using Selyaninov's water-heat ratio which is one of the indices for climate change moisture and aridity with data from 70 meteorological stations between 1979 and 2013. The results including calculation of "a" (gradient) coefficient of linear regression equation are shown in geographic distribution of multi-year change (Figure 3.74).

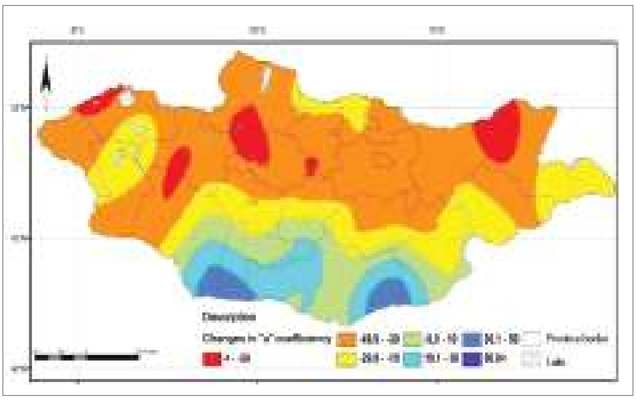


Figure 3.74 Change in heat-moisture indictor of last 31 years (Selyaninov's moisture-heat ratio)

The Figure 3.74 shows, in the research period or the last 31 years, aridity (value of the "a" coefficient) has increased in the research regions. Especially, in Khangai and northern part of the eastern region, aridification is more intense. In order to assess the aridity and moisture condition in Mongolia, Natsagodrj L. used indices such as Budyko's aridity radiation index, Thornweit's aridity degree index, Mezentsev's moisture ratio, and Selyaninov's water heat coefficient, and evaluated their relation and advantages and disadvantages of these indices. With the help of aridity radiation index, he evaluated the aridity in Mongolia with the difference of averages of two periods (1961-1990 and 1991-2010). He concluded that aridification is occurring everywhere in Mongolia except in the Gobi region of Altai and especially in arid steppe and Gobi region or the eastern and southern part of the central region,aridification is more intense (Natsagdorj L. 2004,2012). Therefore, it is clear that aridity has increased almost everywhere in Mongolia, and with the predicted increase of air temperature by 2-4^{0}C combined with the minor increase and decrease in precipitation, aridification will surely increase. This could negatively affect the growth of non-irrigated wheat crops.

Impact from potential evaporation. One of the objectives of agrometeorology is to assess moisture supply of plants. In order to do this, the assessment of evaporation and transpiration (evaporation from aerial parts of plants) are of great significance. Evaporation is one factor of the equation for calculating soil water balance and therefore it is important for soil moisture, irrigation system, plant yield model and other types of research (Douglas et al. 2009). ambaajamts B. assessed evaporation in Mongolia using Budyko's method. He calculated the sum of annual evaporation and evaporativity of the entire country in different zones and concluded that the future trend of total annual evaporation could be 10 times more than the precipitation increase in 2020 and 2050 (Jambaajamts B. 1989, Bolortseteg and Gantsetseg 2002). The future increase in air temperature combined with the slight change in precipitation will surely increase potential evaporation. This in turn will have a negative effect on the soil moisture supply and water balance of cultivated plants.

Future climate change impacts on cultivated plants

Using the DSSAT model in the chosen 16 stations representing arable farming regions, the wheat yield change was assessed in year 2020 (2011-2030), and 2050 (2046-2065) in following scenarios;if monthly mean temperature increases by 1, 2, 3, 4, 5 degrees; if the carbon dioxide content in the atmosphere reaches 440ppm and 520 ppm; if precipitation decreases by -30, -20, -10%; and, if precipitation increases by 10, 20, 30%. In terms of the future change of wheat yield, if air temperature increases by 3^0C, its negative impact on crops cannot be compensated by 20% increase in precipitation in eastern and central regions. However, in the western region, if precipitation increases by 20%, it could have slightly favorable impact on crops.

Mean air temperature could increase by 2.6-5.7 degrees in 2020, 2050, 2080 compared to current levels. There is a tendency that the heat supply during growing season would increase in all arable farming regions which could make earlier sowing and later harvesting possible. However, if an increase in the number of extreme hot days and the fact that total potential evaporation could exceed precipitation increase by 7-fold to 10-fold are considered (Dagvadorj D., Bolortsetseg B., Tuvaansuren T. 2001), the negative impacts on cultivated plants could potentially outweigh the positive ones. Climate change scenarios show 12.3% increase in precipitation in spring months which could provide the condition for earlier sprouting. However, this could depend on the biological characteristics of a given plant and in recent years, it was observed, the extreme heat during the growing season

Table 3.22 Wheat yield change compared to current state ,%

Atmospheric CO_2 content /350ppm-average of 1981-2000/				Future atmospheric CO_2 content CO_2, 2020 /440 ppm/				Future atmospheric CO_2 content CO_2, 2050 /520ppm/			
Precipitation change %	Temperature change, ^{0}C			Precipitation change %	Temperature change, ^{0}C			Precipitation change %	Temperature change, ^{0}C		
	t+0	t+2	**t+3**		t+0	t+2	t+3		t+0	t+2	t+3
Central arable farming region											
0	0	-4	-2	0	4.0	-1.6	-2.2	0	5.3	0.3	-0.6
+10	1.8	-1.5	-1.2	+10	1.6	-1.1	-0.5	+10	2.2	0.4	1.4
+20	6.5	1.2	1.4	+20	4.9	1.5	1.9	+20	5.1	4.0	3.9
-10	-3	-4.8	-3.4	-10	3.0	-4.7	-3.2	-10	2.5	-2.7	-1.5
-20	-6.7	-8.5	-7.6	-20	-6.9	-8.5	-7.4	-20	-6.3	-7.3	-5.6
Eastern arable farming region											
0		-5	-14	0		1	-9	0		7	-1
+10	9	2	-9	+10	15	6	-6	+10	21	13	2
+20	15	7	-6	+20	22	11	-1	+20	28	17	4
-10	-5	-13	-19	-10	3	-5	-12	-10	9	1	-6
-20	-11	-17	-20	-20	-2	-9	-15	-20	3	-4	-9
Western arable farming region											
P=0%		-2	-1	P=0%		0	1	P=0%		2	2
P+10%	2	-1	0	P+10%	4	2	2	P+10%	6	2	3
P+20%	3	1	3	P+20%	5	2	3	P+20%	8	3	5
P-10%	0	-3	-2	P-10%	2	-2	-1	P-10%	5	-1	1
P-20%	-1	-5	-3	P-20%	1	-3	0	P-20%	3	-2	0

related to the consecutive droughts led to drying and withering of plants, a trend that could continue in the future. Generally, the amount of precipitation could slightly increase, however, due to air temperature increase which leads to decline in moisture supply necessary for plant growth, could have an unfavorable impact on plant growth.

Future trend of cultivated plant crops. The future change of cultivated plant crops can also be calculated using mathematic models (MARCC, 2009). Using A1B scenario with medium greenhouse gas emission and DSSAT 4.0 model, it was calculated in 2008-2009 that average yield per hectare in 2011-2030 could decrease by 13% compared to the multi-year average and in the western arable farming region (Baruunturuun) and in the southern part of the central region (Ugtaal), it could decrease up to 24-33%, respectively. Therefore, it could be concluded without appropriate use of fertilizer, the yield of non-irrigated field could decrease by 10-15% with climate change (Figure 3.75). This research shows due to climate change, the yield per hectare would decrease and thus, it will have negative impact on crops and arable farming.

3.2.3 Poverty and Human development

Poverty

A nationwide comprehensive study of climate change impacts on poverty and livelihood of the population has not yet been conducted in Mongolia. It's generally limited with certain research studies carried out by a few number of researchers and experts. Climate-related hazards, including subtle shifts and trends to extreme events, directly affect poor people's lives through impacts on livelihoods, such as losses in crop yields, destroyed homes, food insecurity, and loss of a sense of place, and indirectly through increased food prices (IPCC, 2014). According to the Poverty Map of Mongolia, a report jointly developed by the National Statistical Office and UNDP, based on the 2010 Population and Housing Census, the provinces having the highest poverty level are Khovd and Govi-Altai aimags from the Western region, and Khuvsgul, Zavkhan and Uvurkhangai aimags from the Khangai region (Figure 3.76). The proportion of the population in Mongolia with a standard of living below poverty line compared to total population in 2012 is 27.4%, of which 23.2% of the urban population and 35.5% of

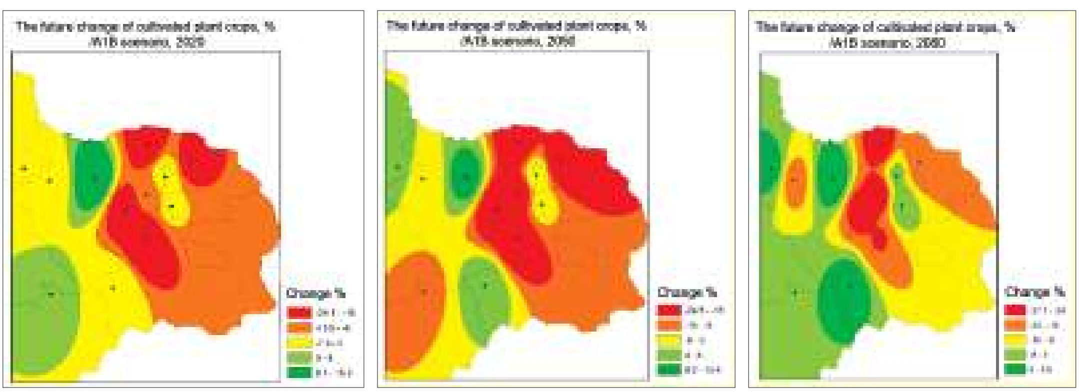


Figure 3.75 Future change of wheat yield, % /A1B scenario/

the rural population are the poor. This fact shows that the population of the country is sensitive and vulnerable to climate change. Even though specific livelihoods and poverty alone do not necessarily make people vulnerable to weather events and climate (IPCC, 2014), at the individual or rural level it deepens the dependency on nature, and increases the risk of migration to big cities due to the loss of permanent income sources like livestock and unemployment caused by drought and zud events (Chuluun T. et al, 2012).

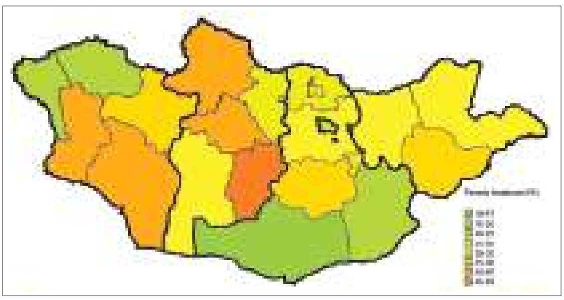


Figure 3.76 Poverty Headcount, by aimags. *Source: Experts' calculation based on the Mongolia 2010 Census*

This can be seen from 1999-2002 and 2009-2010 zud events and its consequences. Due to 1999-2002 zud events, livestock sector in the country experienced losses worth 91.7 billion Tugrug, and living standard of herders' households declined as poverty and unemployment dramatically increased in the countryside, as 2,369 herders' households lost all of their livestock and more than 10,000 households were left with no more than 100 heads of livestock (Altanbagana M., 2011). After three years of zud, the national gross agricultural output of the country in 2003 decreased by 40% compared to that in 1999 (Murray et al, 2012). Furthermore, the 2009-2010 zud caused a loss worth 527 billion Tugrugs; 97.5 thousand herders' households were affected, and 9.7 million heads of livestock were killed (NEMA). Herders have suffered from natural disasters like drought and zud events occurring in the agriculture sector since 2000, and it has caused an increase in migration to big settlements or cities, particularly the capital city of Ulaanbaatar (Bayanchimeg et al. 2012). However, it has not only been an adverse impact on the agriculture sector or on the herders' livelihood, but also on the urban residents through aggravated environmental and social problems including air and soil pollution, peri-urban pasture land degradation, unemployment, and burden on social services caused by an increasing number of migrants (Oyun 2013). As of 2013, 46.8% of the total population of Mongolia lives in Ulaanbaatar (NSO, 2014), and 26.9% of the urban population is settled in major cities like Erdenet, Darkhan, and other towns and settlements. Below, the total population of Mongolia is shown by its location.

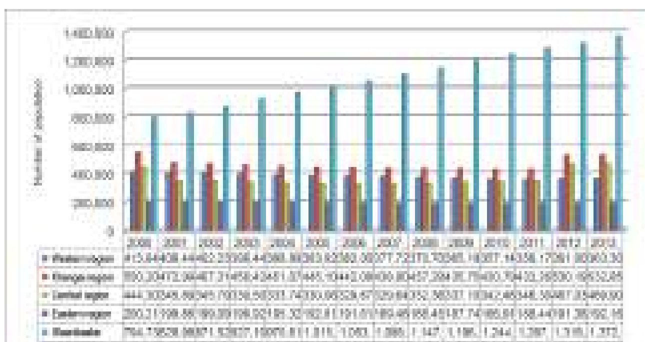


Figure 3.77 Population of Mongolia, by location *Source: NSO, 2014*

Above facts show that the rural population who worships nature and environment is clearly the most vulnerable to climate change. They are exposed to weather-related natural phenomenon and many years of zud and droughts and therefore are at the greatest risk of losing their livestock, which is the main source of their income generation. Due to snow covered roads, they are sometimes left with no access to medical services, their children drop out of school, and these families are further impoverished through the shortage of food supply, et cetera. Consequently, these conditions intensify the migration to the central region and bigger cities because of the availability of workplaces or jobs, access to the market, and the access to good rangeland and water. From one side, it creates nationwide climate/ecological migration and additionally it has become the main reason behind the worsening of social issues of the cities. Climate induced variability is likely to increase water stress and lack of access to improved water and sanitation facilities is likely to put poor people at greater risk of infectious diseases. Lack of access to health services for remote rural communities is likely to put certain vulnerable groups such as pregnant women during prenatal and neonatal stages and the infants and the elderly members at greater risk (GoM, 2011). Furthermore, for urban and rural poor households, they are likely to be net buyers of food and would, therefore, be worse off if food prices increase (ADB, 2013). Thus, they might fall into persistent chronic poverty from temporary poverty.

Human development.

In the long term, climate change threatens human development and causes economic loss (Altanbagana M., 2011). As described in the 2007-2008 World Human Development Report, there are five key transmission mechanisms through which climate change could stall and reverse human development, and that includes i) agricultural production and food security, ii)water stress and water insecurity, iii) rising sea levels and exposure to climate disasters, iv)ecosystems and biodiversity, v)human development. It might be translated as that climate change directly or indirectly affects human development of Mongolia though these mechanisms. In the framework of the Mongolia Human Development Report -2011, a survey of 100 households from four aimags, namely Khuvsgul, Uvurkhangai, Tuv, and Orkhon was conducted.

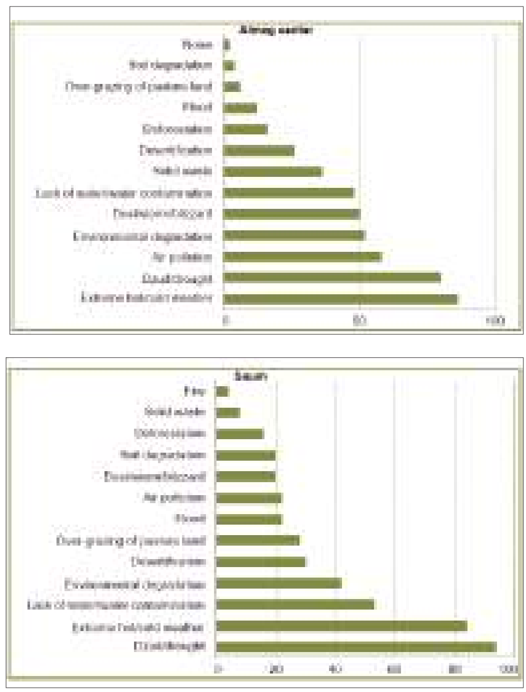


Figure 3.78 Climate change and environmental factors that affect the daily life of people, by percentage. *Source: GoM, 2011 (Human development report of Mongolia)*

According to this suvery, a disaster or zud is emphasized as a priority issue among the climate change and environmental factors that affect the daily life of people (Figure 3.78). In addition, in the survey of 100 urban households in ger districts of Ulaanbaatar, climate change is also considered to be an important issue (GoM, 2011).

Box 3.5 ***People trapped around Khuvsgul lake***

According to the multi-year data (40-70 years entry) of four meteorological stations around Khuvsgul lake, mean temperature of this region has increased almost by 2⁰C. Due to warming, the number of cold days has decreased while the number of hot days (>25⁰C) has increased. However, no significant change was observed in the amount of precipitation of the last 43 years, and it is approximately 300 mm/year. The growing season has advanced almost by a month compared to that of the previous 10 years, and the total loss of water to the ecosystem has increased as evaporation increases. The growth of steppe vegetation is dependent on annual soil moisture and the growth of forest, mostly Siberian larches are also dependent on it too. Overall growth of vegetation is decreasing due to grazing, and the occurrences of steppe-grasses and litter have become rare as well as it has an adverse impact on the resistance of the ecosystem to warming. Permafrost melting has started and it has deepened to 1.5 meter in under rated soil of the Southern part and up to four meters in degraded parts. The melting process of permafrost itself influences the soil moisture and increases decomposition of organic substances and soil respiration, as well as it affects the increase of CO_2 emission.

How does it affect the livelihood of people?

Approximately 40 herders' households are settled in tributary valleys. In general, Mongolian herders use pastureland by schedule over the four seasons; however, it is impossible on the east coast of Khuvsgul lake. Even if there is no adverse impact on the environment, there is an impact on the people because their movement is enclosed byi) Mongolia-Russia border in the North, ii) taiga and high mountains in the East, iii) the east coast of Khuvsgul lake in the West, iv) Khuvgul National Conversation Park in the South. It has an adverse impacts on herders through several ways including i)communication failure, ii)cut off from market and social welfare services due to the lack of infrastructure, iii)over use of the limited source of pasture land by many households or livestock(as of 2005, 40 household had 8,287 livestock by head of sheep, and the number has been increasing since then). These factors also contribute to the increase of poverty in the region.

As of 2003, the main sources of income of herders were animal husbandry, small trade, pension and natural resources. Here, main income sources of animal husbandry include cashmere (28%), horse trade (24%), cattle trade (15%), milk (8%), sheep trade (7%), sour cream (6%), goats (5%), horse and cowhide (2%), cream (2%), sheep skin (1%), sheep wool (1%), and others(1%). As the number of livestock increases, their income increases. However, research results show that increasing numbers of livestock require more labor, and as herders are interested in raising the number of their livestock, getting their children out of school for this purpuse increases. When considering their education level, 55% have a 4th grade education, 39% have an 8th grade education, 3% have a 10th grade education and 3% don't attend to school. Climate change and pasture land degradation exert pressure on people's livelihoods of the region. The rise in air temperature, decline in precipitation, permafrost melting and the decrease of soil moisture lead to the change of forest ecosystem to steppe ecosystem or barren land, and influences the decrease of grazing capacity of livestock, which is the main income source of herders.Khuvsgul lake basin, which was previously considered as the least affected area by human activities, is changing rapidly due to climate change and the instability of land use. In such conditions, engaging in animal husbandry to improve their livelihood is like trying to turn an impossible task into work.

Source: Prof. Boldgiv B. (2010) Climate Change and Some Issues Related to Human Development in Mongolia.Source material for Mongolia Human Development Report – 2011.

In 2013, the human development index of Mongolia (hereinafter referred as to HDI) was 0.675, and the country ranked 108 out of 186 world countries (UNDP, 2013). According to statistics shown in Figure 3.79, the 0.66 constant HDI during 1999-2002 zud events is a case of huge loss of opportunity to develop (Chuluun T. et al, 2012).

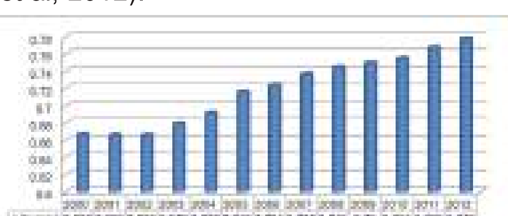


Figure 3.79 Dynamics of Human Development Index, 2000-2012. *Source: NSO, 2014*

Generally, climate change affects human development in various ways, and it's considered by five mechanisms that are mentioned below:

1. Climate change can impact the agriculture sector of the economy directly, and other sectors such as forestry, hunting, tourism, and fishing indirectly. In 2013, the agriculture sector constituted 14.4% of GDP and 29.8% of the total employment. Also, as of the same year, there were 209,993 households that have livestock and of which 285,691 are herders (NSO, 2014). Climate change induced weather variability, the changing pattern of precipitation and intensity

and frequency of natural disasters like drought, zud and thunder storms in short amounts of time affects the yield of pastures negatively. Simultaneously, the number of livestock is increasing constantly and the fact that there are 45,114,324 heads of livestock in 2013 is almost two times higher than that of 1990. However, the increased zuds and droughts in the future could lead to loss of up to 12% of animals in the medium-term and up to 18% of animals in the longer term (GoM, 2011). All of this might result in the reduction of incomes of the agriculture sector, consequently putting the livelihoods of one-third of the nation's population at risk. Further, it leads to a reduction in income i.e., "resources for a decent standard of living".

2. Water resources and its use are relevant to climate change. In other words, as temperature rises, water use increases. According to the future trends of climate change-water resources, summer rainfall decreases while the precipitation in the cold season is likely to increase, which influences the decline in the groundwater level in arid regions and the increase of spring flood dangers of local rivers in mountainous regions. Furthermore, air temperature rising in the warm season impact the decline or disappearance of water level of the open pools in the steppe or Gobi regions. On the other hand, intensification of summer rainfall exacerbates the risk of flooding in most of the territory. Thus, it could pose a risk to local citizens and livestock, and the spread of contagious diseases due to the use of unsafe water, and it further aggravates the vulnerability of the poor and may stifle their basic rights and freedom.

3. Increase in intensity and frequency of natural disasters induced by climate change has not only been an impact on livelihood of rural population but also it poses a greater threat to the society and economy of the country. For instance, the 2009-2010 zud events can be taken as an example. Rainfall at the end of November became a sheet of ice, and in late December most of the province recorded below -40°C; this was followed by heavy and continuous snowfall in January and February. Thus, over 50% of all the county herders' households and their livestock were affected by the zud. By April, 75,000 herder families had lost all or more than half of their livestock (Murray et al.,2012). In general, income of herders is fully dependent on their livestock and its productions, and it's unstable due to the fluctuations in market prices. It is especially a heavy burden for affected households, or in other words it directly influenced food security and household income. Further they are not able to store up dairy products for winter, and face the prospect of slaughtering their few remaining livestock (Maria Fernandez-Gimenez et al., 2011). In addition, human food items such as garlic and millet were procured from local markets to feed their livestock, which increased household expenses tremendously; hence, herder's purchasing power dropped.

4. Due to the changing climate, quality of wildlife habitat or areal changes and ecosystem borders shift from the south to north by desertification. This desertification trend impacts the wildlife habitat by destroying the habitat, and such negative consequences become an arising challenge for protection of biodiversity. There are 135 species

of mammals, 476 species of birds, 16 species of reptiles, 6 species of amphibians, 75 species of fish and about 13,000 species of insects that have been registered that are adapted to various ecosystems of the country. Out of these species, 28 endangered species and 72 rare species were recorded in the list (MEGD, 2013). A significant increase in livestock can create competition for the same ecological niches in terms of types of plants and grass eaten by different herbivores. As wild animals and domesticated livestock share common areas of pasture, there is an increased risk of spreading of infectious diseases from one population to another. Due to the use and pressure on wildlife habitat, 16% of mammals are at risk of being destroyed in the region, 2% is already endangered, 3% are vulnerable or at high risk of loss and the number of 4% of birds decreased as well as 11% of rare and endangered plant species is being lost, 26% might become lost and 37% are vulnerable or at high risk of loss and 15% might become endangered (MEGD, 2013).

5. Climate change has direct and indirect impacts on human health. In general, it directly impacts the increase in heart-disease due to increased warming, and increase in risk of the spread of certain vector-borne diseases as climate change opens up new areas for the spread of disease vectors. On the other hand, due to changes in water resources, water availability and lack of adequate sanitation, spread of water-borne diseases might occur (GoM, 2011). In addition, due to the consequences of drought and zud, people might be exposed to a certain risk of malnutrition. For instance, according to a study on “Resilience in Mongolian Pastoral Social-ecological System” conducted by Colorado State University and the Center for Nomadic Pastoralism Studies after the 2009-2010 zud events, herders told that “Annually we consumed about 10 goats and sheep during summer and fall, but this year we consumed only 5 (Bayantsagaan soum, Bayankhongor aimag), also during summer we normally eat a lot of fresh dairy products, but this summer we drank black tea and don’t eat urum and aaruul.” This means, herders might not get enough nutrition and thus pregnant women, children and elderly people might fall into nutritional deficiency.

In summary, according to the study report conducted by German watch, Mongolia ranks at 8 out of 10 countries in which the climate risk index is highest in the world by 1993-2012 data. Therefore, it can be concluded that climate change has an adverse impact on the society and economy of the country, and in particular, the poor with income below poverty level and the herder households are affected mostly. Taking response measures is in urgent need.

3.2.4 Infrastructure

In Mongolia, comprehensive science-based studies and assessments of climate change impacts on the infrastructure of the country have not yet been conducted. However, this subject was analyzed in the Preliminary Risk Assessment of Climate Change Impacts on the Environment and Socio-economy of Mongolia, which was completed under UNDP’s Strengthening Environmental Governance in Mongolia-2 Project. Moreover, it is supported with the

Asian Development Bank's (ADB) "The Economics of Climate Change in East Asia" study which examined the costs of adaptation to climate change in the infrastructure sector during 2011-2050. Below, hard infrastructure is considered in general, and the report was written by integrating key results and data from the previous studies.

Having an adverse impact on all infrastructure sectors, the increase in the intensity and frequency of extreme events induced by climate change in Mongolia has caused a great amount of losses to the society and economy of the country, and there is a potential risk for further increases in loss and damage. For instance, due to the occurrence of the heavy rainfall and hailstorm in Tushig soum of Selenge aimag on 3rd July 2013, 4,310.3 m^2 of the timber and metal roofs of budget organizations including the Governor's Office, health center, general education school, dormitory, kindergarten, culture center and police office collapsed; 291 windows were broken, and the windows of 204 households were also broken, 13,550.6 $m^2$of roofing from 183 households were detached, gers or yurts of 15 households collapsed and 24 people were injured. In addition, 74 car windows were broken, two pillars of 10 kW electricity transmission lines and four pillars of 4.022 transmission lines fell down, 71 pillars were deviated, two transformers were damaged and 449 ha of wheat fields, 490 ha of fields with chemical fallow, 292 ha of oats from three entities and potatoes and vegetable fields of 65 households were affected. According to the evaluations of professional organizations, damage worth 3,010,644,087 MNT was occurred in total (DEMoS, 2013).

Box 3.6 Consequences and Impacts of extreme events on the infrastructure sector

Due to climate change and ecological imbalance, the frequency of natural disasters has been increasing in recent years,which has resulted in a large amount of losses to the society and the economy of the country, along with the loss of normal operations of infrastructure. For instance:

In 2011, a disastrous event of sleet and ice sheet was observed in the territory of Darkhan-Uul and Selenge aimags. Consequently, the disaster resulted in the disruption of pillars of power lines of the Central Regional Electricity Transmission Grid Company, and a loss worth MNT 2 billion 414 million resulted from ice cover of 14-15 cm diameter on the high-voltage power lines and line load.

Furthermore, due to heavy rainfall (86 mm) in Erdenet on the night of 13th-14th July 2012, a flash flood, in which 1,201 livestock died and the road was damaged, resulted in a total loss equivalent to MNT 8 billion 300 million.

Source: MEGD (2013) Mongolian Environmental Outlook Report: 2011-2012,pp.13

Eleven climatic factors that might have an impact on the infrastructure sector were listed in the Preliminary Risk Assessment of Climate Change Impacts on the Environment and Socio-economy of Mongolia. Among climatic factors listed, flash floods due to the intensity of summer precipitation, snow blocks of mountains due to the increase of winter snowfall and increases of snow and ice pressures on electricity and high-voltage power lines and other construction facilities due to the spring/fall sleet and ice sheet were ranked high (Table 3.23).

Table 3.23 Vulnerability assessment of infrastructure

Climate change	Impact	Consequences	Losses (risk)									Probability	Need of urgent response measures	Total score	Rank
			Economy		Environment		Society								
			Asset, infrastructure	Business marketing activities	Biodiversity	Ecosystem services	Health and livelihood	Unemployment	Vulnerable groups	Social services	Human migration				
Increase in intensity and frequency of rainfall in warm seasons	Rainwater floods without sinking to the soil	Urban areas and paved roads are likely be flooded	8	4	0	4	16	16	8	4	16	8	8	92	**I**
Increase of precipitation in cold seasons	Thick snow cover	Mountains and roads are likely to be covered by snow	0	0	0	0	8	0	0	4	0	0	0	12	**IV**
Increase in intensity of the precipitation in transitional seasons	Thick snow cover and ice sheet	Snow and ice pressure on construction facilities are likely to increase	8	4	0	0	16	16	0	4	0	0	8	56	**II**
Increase of air temperature	Melting of permafrost soil from the top	Construction accidents are likely to occur in the sites where permafrost exists	8	4	8	4	0	0	8	0	0	0	8	40	**III**

Source: UNDP (2012) Preliminary risk assessment of climate change impact on environment and socio-economy of Mongolia

In addition, increasing mean temperatures and drought results in a decrease in water availability or the level of rivers and lakes, and furthermore, many rivers and lakes are drying up, which might affect the normal operation of existing or planned hydropower stations. On the other hand, flooding caused by the increasing intensity of summer rainfall may cause damage to dams, turbines and by-pass channels. Also, in spite of having a low risk of damage to construction facilities, it's undeniable that urban road networks and planned paved roads might be exposed to a certain degree risks due to the melting of permafrost (UNDP, 2012).

Box 3.6 Heat loss in buildings and Energy efficiency

The "Heating techniques of buildings. Building Code.02.01.03.92" standard of heat loss in buildings is pursued in Mongolia; however, its requirements are not implementedproperly and the monitoring is lacking. It was identified by the study that the heat loss in a majority of the buildings is 2-3 times lower than the standard value. For example, annual energy consumption of buildings that wereerected between 1960 and 2000 is 550kW.h/m^2 (MUST, 2004). In general, approximately 40 percent of buildings found in big cities including Ulaanbaatar, Darkhan and Erdenet are pre-cast panel buildings, and it is necessary to insulate the buildings with thermal insulation materials to save energy consumed for heating and to mitigate GHG emissions (UNDP, 2012 unpublished).If the building insulation can meet the existing contemporary standards, the heating capacity of Ulaanbaatar will increase by400-500 Gcal/h, and the buildings new source won't be required, (MUST, 2004) and GHG emissions will be potentially reduced from the current level.

Below, the pilot project on "Thermo-technical retrofitting of pre-cast panel buildings" implemented by GIZ Integrated Urban Development Program during July-September 2007, is shown as a case. Within the framework of the project, thermo- and technical rehabilitation of House no.8 of 5^{th}khoroo, 6^{th}khoroolol of Chingeltei district was implemented with the funds of 250.0 million Tugrugs from the GIZ Program and the Office of City Mayor, and the building was compared with buildings from the same block. The result of rehabilitation showed that energy-consumption during autumn and winter decreased by up to 60%, and the living conditions improved (average room temperature is above +22^0C). Due to the rise of surface temperature on insulated walls, the risk of mold growth could be reduced and the hygienic situation was improved, as well as the value of the apartment building increased. *(The thermo-graphic picture below shows the comparison of the before and after situation of the building)*

Building	Total energy-consumption (kW.h/year)	Heating area(m^2)	Area per m^2(kW.h/m^2)
Retrofitted building	282,217.0	1435.0	196
Unretrofitted building	397,490.38	1435.0	277
Saving	29%		

Source: UNDP (2012): Preliminary risk assessment of climate change impacts on environment, socio-economy of Mongolia, http://prezi.com/io6icalmrad2/copy-of/: Presentation-Options for improving energy efficiency, MUST(2004): Results of the study conducted by Department of Heating Supply and Transformation, UNDP MON/99/G35 project study

The length of the heating season is likely to be reduced by 6-7 days in the first three decades of this century and by 10 days by the mid of this Century (UNDP, 2012 unpublished). Even though it might save the energy consumed for heating, the energy demand for cooling in the residential and commercial sector might increase (IPCC WGII, 2014). The total cost of climate proofing infrastructure during 2011-2050 is estimated to be $150 million per year in Mongolia, and the relative cost of adaptation in the worst climate scenario for the country is 8.5% of baseline expenditure (ADB, 2013). Considering the road sector, the adaptation cost for roads are likely to increase due to the cost of resurfacing paved roads and/or using expensive pavement binders to cope with higher pavement temperatures, and the additional cost of building and maintaining all roads and sewerage because of changes in flood risks caused by the changes in patterns of precipitation. In general, economically both the temperature and the precipitation have an adverse impact on climate proofing infrastructure.

When a discount rate of 5% is considered for each infrastructure category, the net benefit of adaptation is negative for roads but positive for social and urban infrastructure (ADB, 2013). Therefore, climate proofing the road and housing sector or taking adaptation measures will ensure normal operation of the given sectors, and will decrease future operation and maintenance costs, whereas the adaptation of health and schools facilities and urban infrastructure (rain water drainage and municipal building) can be postponed until 2040. The uncertainty about future climate outcomes strengthens the case for caution before embarking on significant investments in adaptation; however, for Mongolia, the risk of climate change is large and the economy is less diversified, so giving more weight to the worst outcomes of climate scenarios in the development and implementation of adaptation measures or strategies is essential for risk aversion.

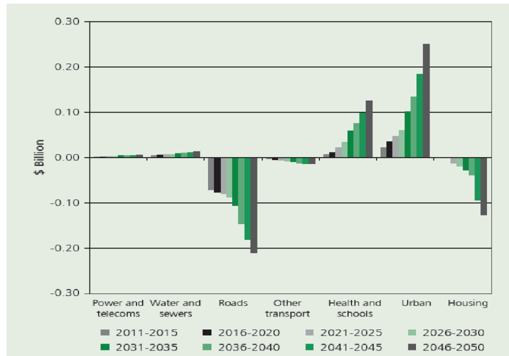


Figure 3.80 Net benefits of climate proofing by infrastructure category (power and telecoms, water and sewers, roads, other transport, health and schools, urban, and housing) in Mongolia. *Note: at 2005 prices with 5% discount rate average over all climate scenarios. Source: ADB project team*

In summary, the increasing tendency of the intensity and frequency of extreme events caused by climate change have an adverse impact on all infrastructure sectors. This is demonstrated with the fact that the roads are flooded out and destroyed in the warm season, normal operations of infrastructure facilities are lost, power transmission lines are broken in the spring or fall, the roads and tracks are covered with snow, which means herders and rural people living in remote areas cannot have an access to simple aid or services like medical service. Due to the change of precipitation and temperature, the length of the heating duration might be shortened and the energy consumed for heating might be saved; however, the energy demand for air-conditioning or cooling may rise. Generally, the annual cost of climate proofing infrastructure is estimated around $150 million. For Mongolia, a country whose economy is less diversified and is vulnerable to climate change, considering the worst outcomes of various climate scenarios is necessary for the avoidance of risk.

3.2.5 Human health

Climate change will affect, in profoundly adverse ways, some of the most fundamental pre-requisites for good health: clean air and water, sufficient food, adequate shelter and freedom from disease. The global climate is now changing faster than at any point in human civilization, and many of the effects on health will be acutely felt. The most severe risks are to developing countries, with negative implications for the achievement of the health-related Millennium Development Goals and for health equity (WHO, 2010).

It is possible direct and indirect influence will affect the health of the population, with risk factors in relation to climate change such as heat waves, air pollution, floods, drought, contaminated water and the negative impact to agriculture. Due to climate change it is possible for increasing frequencies of cardiovascular diseases, respiratory diseases such as asthma, diarrheal diseases, as well as people suffering from malnutrition. Also, climate change can increase vector borne diseases and other infections, especially infections among young children. It is possible for increased prevalence of emerging and re-emerging diseases. The increase of the frequency of natural disasters such as flooding, zud, storm, and extreme wind can cause death, distress, homelessness and disrupt the supply of essential medical and health services. In regards to the risks of climate change, and in order to reveal the negative impact to the health of the population and health care system and to assist the member countries, the 61st World Health Assembly (WHA) approved the resolution No. 61.19, which is dedicated to prepare action plan in adaptation to climate change. In order to support the decision of the WHA, the Western Pacific Region started the Climate Change and Health study in 2009, and developed a national adaptation strategy and plan of action within the region.

The Climate Change and Health study (2009) in Mongolia has a goal to establish the trends of morbidity of some diseases and reveal the relationship between climate change and health parameters reached. The study shows decreased morbidity of respiratory diseases (Figure 3.81) and increased circulatory diseases in the last 34 years (Figure 3.82) (GoM, 2009; Burmaajav B., 2010).

Figure 3.81 Morbidity of Respiratory Diseases, Mongolia, 1974-2008 years

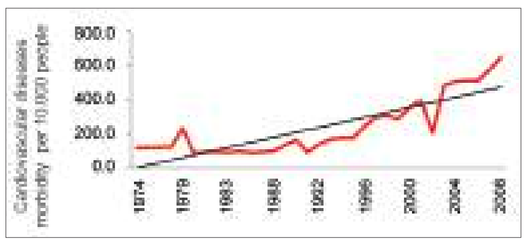


Figure 3.82 Cardiovascular diseases morbidity, per 10000 populations, 1974-2008

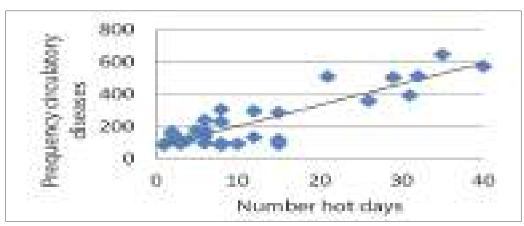


Figure 3.83 Relationship between the prequency of circulatory diseases in Ulaanbaatar (per 10 000 populations) and temperature above 30.0^{0}C. Risk assessment report, 2012

The study revealed the direct correlation between circulatory morbidity in the population and the number of hot days with temperatures above 30^0C in Ulaanbaatar (r=088). On the other hand, the study shows that, when it is hot in the capital city, the frequency of circulatory morbidity is high (L.Natsagdorj, 2012) (MNET, 2009). It is a possible reason for having no reduction of circulatory diseases in the last few years.

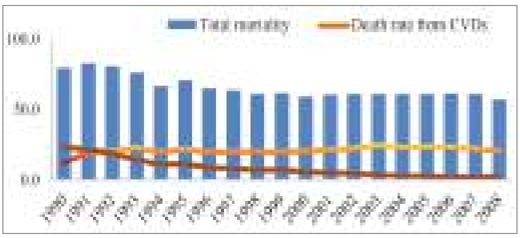


Figure 3.84 Mortality of population, (per 100000 population, 1990-2008 years)

While there is a decreasing mortality rate from respiratory diseases, there is a trend of increased mortality rate of cardiovascular diseases, and the mortality rate has stayed at the same level in the past few years (Figure 3.85) (GoM, 2009; Burmaajav B., 2010). By correlation analysis, air temperature has weak correlation with mineralization, sulfate, ammonia, nitrate and total coli forms, out of all water parameters. There was observed a slight increasing tendency of these water parameters with the increase in air temperature (Figure 3.85, 3.86) (GoM, 2009; Burmaajav B., 2010)

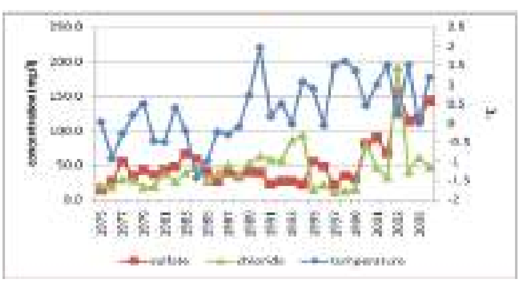


Figure 3.85 Sulfate, chloride and air temperature

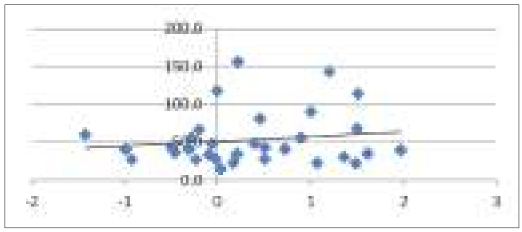


Figure 3.86 Correlation between sulfate and air temperature.

The study results from 1969 to 2008 used archive material and data from databases, and also the study reports of the NCCD and NCIDNF on infectious diseases including ILI, meningococcal infection, TB, typhoid, viral hepatitis A, dysentery, plague, tick borne encephalitis, anthrax etc. The study showed that most of the above mentioned infectious diseases have a relationship with climate parameters such as air temperature and precipitation (GoM, 2009; Burmaajav B., 2010; Clara Tammy et.al, 2013).

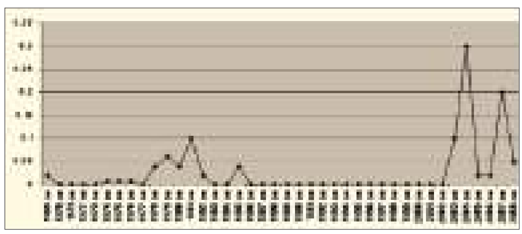


Figure 3.87 Morbidity dynamics of tick borne encephalitis

The morbidity of tick borne encephalitis has re-emerged since 2002 (Figure 3.98) (GoM, 2009; Burmaajav B., 2010).

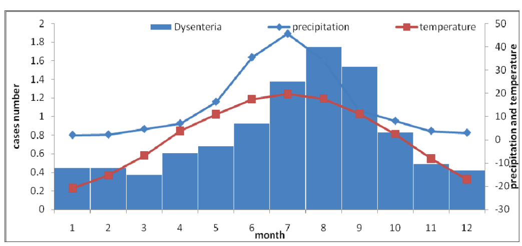


Figure 3.88 Correlation between dysentery and air temperature and Precipitation

Negative moderate correlation (r=-0,41 p=0.05) between conjunctivitis and water consumption was observed (MoH, 2013). Kidney and urinary tract stone disease is not correlated with water consumption (r=-0.26 p=0.22) and mineralization (r=0.33 p=0.27) of water. With increased mineralization in drinking water, gallstone and kidney stone diseases are increased, and it was also observed that with decreased water consumption gallstone and stone diseases of the urinary tracts increased (Figure 3.89 and 90) (MoH, 2013).

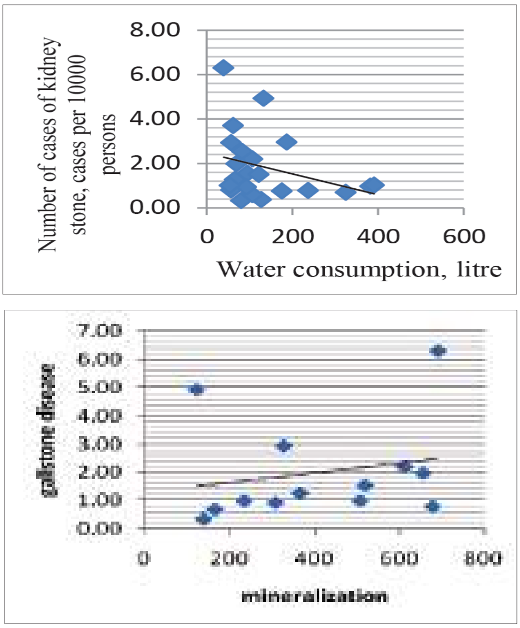


Figure 3.89 Correlation between gallstone disease and water consumption and mineralization of water

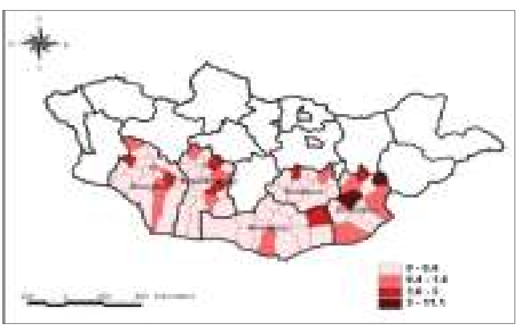


Figure 3.90 Gallstone disease per 10000 population, by soums of Gobi aimags (MoH, 2013)

These results show that the local and state organizations need to consider the supply of drinking water for the population in the gobi area and in areas of desertification in the future. The Climate Change and Health Study was conducted in 2010-2012 with state financial support, had reached some results. In the survey, some aimags and soums that represent four climate zones of Mongolia were selected and an attempt to determine positive and negative impacts on human health in the given regions was made. Zavkhan was selected to represent the wet and very cool zone; Selenge was selected to represent the wet and cool zone, as well as Sukhbaatar and Khan-Uul districts of the city of Ulaanbaatar; Dornod represented the dry and cool zone; and Umnugovi represented the very dry and warm zone (GoM, 2012). The number of days and the number of consecutive days where the absolute minimum temperature is below -30ºC are many in the winter months around Ulaanbaatar and Zavkhan, and it poses a risk of increased respiratory and cardiovascular diseases and stroke deaths caused by the absolute minimum temperature. On the other hand, there are many days and consecutive days where the absolute maximum temperature is above +30ºC. As temperature rises, air pressure drops, and during that period, people having cardiovascular and respiratory diseases are exposed to great risk (GoM, 2012). Research studies have already been started to study the prevalence, early-detection and diagnosis of marmot plague, and tick-borne and mosquito-borne diseases as well as Crimean-Congo fever that might spread among the population due to climate change; and also, further research studies are underway to determine their epicenters, environmental factors of transmission, and growth and development patterns as well as identifying changes caused by the changing climate.

The research study, conducted through the project on improving monitoring of climate change and vector-borne communicable diseases (2012), revealed that ticks, of which 94.25% carry *I.persulcatus,* are widely spread in the territory of Selenge aimag, and it was determined that *Anaplasma phagocytophilium* is transmitted by this tick at 26.14%, infection of *Anaplasmaplatys* is transmitted at 11.75%, and rickettsia infection is transmitted at 70.9%. When the number of ticks are studied with micro-climatic indicators, there was observed an inverse weak correlation with air and soil temperature (KOICA, 2012; Dolgorkhand A. et.al, 2012; Uyanga B. et.al, 2012; Burmaajav B., et.al, 2012; Bolor B. et.al, 2012).

Out of the participants of the survey, women are exposed to forest acarus risks when they go to the forest for collecting pine nuts, fruits and herb plants as well as for picnics, while men are exposed to forest acarus risks when they go to the forest for logging, haymaking, herding and gold exploring purposes (Dolgorkhand A., et.al, 2012). It was determined by the research study that new occurrences and the spread of the infection from tick rickettsia and tick-associated diseases are high in Khuder and Altanbulag soums of Selenge aimag, and thus the clinical symptoms (headache, joint pain and muscle aches) that occur during tick-borne infections were detected. Also, the level of Q fever and anaplasmosis was defined, and ehrlichiosis infection was detected for the first time in Khuder and Altanbulag soums of Selenge aimag (Dolgorkhand A., et.al, 2012).

From the surveillance conducted in Selenge aimag, the adult mosquitoes *Anopheles*, *Mansonia*, *Culex*, pupa *Anopheles*, and three types of larvae were identified around four soums (2012) [8], while by the surveillance of the spread of mosquitoes, health risks and climate change conducted in Bukhmurun soum of Uvs aimag (2013) [15], it was determined that 82.4% of identified mosquitoes were *Aedes*. The biological activity of mosquitoes increases in suitable warm and humid environments; therefore, climate change (warming) creates favorable conditions for the life and reproduction of mosquitoes.

According to the survey conducted in Bukhmurun soum of Uvs aimag, after being bitten by mosquitoes, specific clinical symptoms including headache, eye socket pain, vomit, chilblains, anorexia, fatigue, muscle pain, roseola, nodule, insomnia, occipital pain and joint and back pain were shown in 68% of total participants. Therefore, people are exposed to a high risk of mosquito-borne diseases, and a detailed study should be carried out (Uyanga B. et.al, 2013). During the study-intervention of social and psychological assistance during zud events, some people expressed thoughts and attempts to commit suicide because of zud, and three people committed suicide. Hence, it was recommended to give psychological advice to the population, particularly to the herders, and to conduct training to overcome zud during harsh winter events (Tuya Nai., 2010).

Box 3.7 Climate change and communicable diseases

Based on the data from a research study conducted in Ugalz mountain range of Tokhil soum, Govi-Altai aimag between1987-1990, a comparative study [13-14] was carried out under the project name “Improving monitoring of climate change and communicable diseases of which pathogens are transmitted by vectors,” and the following conclusions were made:

- Due to climate change, vegetation cover has changed, and vegetation cover indicating desert-steppe characteristics went up approximately by 100 meters along the vertical zone compared to that of 1987-1990.
- Due to warming, the area of desert-steppe increased and it has impacted the vegetation cover. Further, it has created favorable living conditions for rodents including the gobi suslik (S.erythrogenus) and шар ов (E.luteuse), and it has expanded their area.
- Due to adverse changes in the living conditions of marmots, their living areas were de-escalated, and along with the impacts of hunting, it has influenced the decline in number of the marmot population.
- According to the results of research studies conducted in the Ugalz mountains during 1987-1989, there were 32 species of marmot lice, 7 species of mites and 2 species of fleas that were registered, while in 2011, 6 species of marmot lice were recorded.
- Comparing the dynamics of parasites in marmot fur, and the edge of the marmot lair to the average temperature of 4-9 months during 1987-2011, which is the active period of the plague epidemic, the air temperature increased while the number of parasites in marmot fur and the marmot population decreased. The average temperature between 4-9 months and marmot density per ha r=-0.9 are direct-inversely proportional, and the number of parasites in the fur r=-0.4 is weak-inversely proportional and the number of parasites around marmot lairs r=-0.59 is mid-inversely proportional.
- As temperature rises, moisture decreases and aridity increases, during that period, the number of parasites apart from the host declines significantly.

Box 3.8

Promotion

- Climate Change - Health (Promotion material: lecture-2, messages-3, CD-1), 2011
- Lecture and seminars 2011 (Khovd, Dornod, Umnugovi (Tsogt-Ovoo, Bulgan), Bayankhongor (Shine Jinst, Bayangovi), Govi-Altai (Tugrug, Bayan-Uul))
- Articles and presentations (in foreign and domestic)- over 20
- Books and handouts-4

Research study

- Research study on climate change and human health, 2009
- Public health survey – intervention during zud, 2010
- Research study on climate change and human health, 2010-2012
- Survey on citizens’ knowledge and attitudes, 2011
- Surveillance on climate change and vector-borne diseases (2011-2012)
- Assessment on climate change – water quality, scarcity – human health (2011-2012)

Capacity building and adaptation

- Climate change – health I (2009), II (2010), III (2011), IY (2012) symposium
- Ministerial order no. 160 on healthy green environment, since 2011
- Climate change adaptation strategy, 2011, Ministerial order no. 404

3.3 Vulnerability and risk assessment

In the global climate risk index prepared by the organization "Germanwatch" for assessing climate related natural disaster risks since the 1990's, Mongolia has always ranked high among the countries listed according to their vulnerability. According to the average data between 1993 and 2012, Mongolia was ranked 8th among over 100 countries (Global Climate Risk Index 2014). This is a very high ranking for a landlocked country without typhoons and tsunami. That's why we are saying Mongolia is extremely vulnerable to climate change because of its geographic location, vulnerable ecosystem, people's lifestyle and economic system.

With future climate change, the most negative impacts for Mongolia could arise from the intensification of drought and aridity, increasing amount of snow in winter, rapid melting of permafrost and glaciers, the fact that the rate of evapotranspiration will far exceed the slight increase of precipitation in some areas and the increase in the frequency and magnitude of climate related natural disasters. The summarized outputs and results of assessments of vulnerabilities to, and risks associated with the changes and variability of weather and climate systems are as follows:

- According to the assessment conducted with HADCM3 model on the results of the IPCC AR4, globally the frequency of atmosphere related natural disasters could increase by 23-60% with intense, or slow or any rate of climate change (medium confidence).
- Due to the intensification of droughts in summer and zud (harsh weather conditions in winter and early spring), by 2011-2030 and 2046-2065, 5-10% of the livestock at the beginning of the year could die prematurely (high confidence). This is twice as much premature mortality rate of large livestock compared to the average of 1991-2010 period when climate change was occurred intensively.
- By the mid-21st century, due to pasture degradation and increase in number of days not suitable for grazing, the weight of an adult female Mongolian sheep in summer and autumn could decrease by 10-27% in forest-steppe and steppe regions in 2011-2039, by 24-38% in 2040-2069 compared to the level of 1961-1990 (medium confidence). The loss of weight in livestock means less livestock products such as meat, wool, cashmere and milk from each individual animal, thus having negative impact on the overall productivity of the animal husbandry sector. The meat production which has the most and direct relation to the weight of livestock could experience substantial loss as can be seen in the following, with 50 billion Tugrugs in 2020, 160 billion in 2030 which is a 3-fold loss and if no adequate measures are taken, with 280 billion Tugrugs in 2050, the animal husbandry production could decrease by 5.4%. Here, only the impact on meat production is calculated, if other livestock products and the snow-zud mortality are included, this number would increase several fold. The amount of snow is predicted to increase considerably, therefore, it is obvious that livestock grazing in winter will be hindered often due to the thick snow cover. It should be noted however, that the estimation did not include the livestock weight loss in winter and spring.
- Using DSSAT 4.0 model with medium

greenhouse gas emission scenario (A1B), it was found that the average summer wheat yield per hectare could decrease by 13% in 2011-2030 compared to the multi-year average. This decline could be 24-33% in the western arable farming region (Baruunturuun) and in the southern part of the central region (Ugtaal) (medium confidence). When statistical assessment is used where heat pressure is included, the decrease could be 35-62.5% when climate change is most or least intensive (low confidence). Generally, the probability is high that by the mid-century, wheat yield in non-irrigated fields would decrease by 10-15% compared to the current level. If a crop yield per hectare decreases by 13% as mentioned above, there would be product loss of about 40 billion Tugrugs in 2020 and by 2030-2040, at least 70 billion Tugrigs every year. This number could increase if following issues are taken into account: damage caused by phenomena such as drought and hail, negative impacts on other parts of the arable farming sector and the fact that in some regions (Baruunturuun, Ugtaal etc.) the crop yield may decrease more than others.

- Attention should be given to following risks that arise due to climate change: the production of sectors such as animal husbandry and arable farming would decrease, which would have negative impact on food supply and safety; livelihood, the work and living condition of the rural population would deteriorate, thus increasing poverty, urban migration and exacerbating the challenges faced by large cities (high confidence).
- It is probable that the relative recurrence of cardiovascular disease per 10,000 persons could increase 1.4-1.9 times in Ulaanbaatar by the mid-century compared to the average of 1974-2008 (relatively confident).
- The water balance assessment that was conducted with the results of climate models show decline in river discharge in most regions of the country by 2 mm. There could be an increase (up to 10 mm) in the higher parts of the Khenti mountains and 2-5 mm in other mountains (high confidence). Another important change of water resources is due to climate warming, the water surface evaporation would be almost 10 times higher than the slight increase in precipitation amount (high confidence). With the A2 greenhouse gas emission scenario, the total area of Mongolian lakes would lose annually 0.99 cubic km in the period from 2010 to 2039, 1.09 cubic km during 2040-2069 and with B2 scenario, the loss through evaporation in the above mentioned periods would be 0.60 and 0.75 cubic km respectively. In terms of ecological and economic assessment of water, this means with A2 scenario, an annual loss of 1.49 trillion Tugrugs around 2011-2030, 1.64 trillion by 2050 and with B2 scenario, in the periods mentioned above, 0.89 trillion and 1.13 trillion respectively. However, due to the melting of glaciers and ice sheets in the high mountains, the water level of the lakes and rivers of this region (Altai and Khuvsgul mountainous area) could continue to rise in the near future.
- The assessment on soil bio-matter circulation using Century 4.5. model shows in the first half of the 21st century, the organic nitrogen and carbon content of soil in 0-20 cm layer will decrease by 22-26% in the desert-steppe and desert regions, 4-15% in the

steppe region compared to the average of 1960-2000 (medium confidence). By the mid-century, the pasture yield is expected to decrease everywhere, with highest decline of 40-60% in the forest-steppe and eastern part of the steppe region, 20-40% in the transition zone between steppe and forest-steppe region and 2-20% decrease in the Gobi region respectively compared to the 1961-2008 average (high confidence). The economic assessment of pasture yield decline is yet to be conducted but it shows clearly that the ecosystem services for the society will decrease significantly. It is also apparent that due to climate change, ecological zones will shift and desertification will intensify (high confidence), however, it is still early to say exact numbers

- Because of drought and aridity, the forest area affected by pests is increasing from year to year. By the mid-century, the forest area affected by pests could increase by 2.5-14% compared to the average of 1981-2010 (medium confidence).
- Due to the increased amount of snow in winter, the fire risk in spring could be potentially reduced. However, due to early warming of summer combined with decreased summer precipitation, the frequency of forest and steppe fires could increase in early summer (medium confidence). The probability for fire in mid-summer could also increase (low confidence).
- The growth of trees in the Altai mountainous region and Khuvsgul basin area could improve and the upper forest tree line could advance further upwards due to the thawing of permafrost and increasing heat supply (medium confidence). In the rest of the country, however, the condition for forest growth could deteriorate (medium confidence). Nevertheless, the forest ecosystem conditions are not expected to deteriorate significantly before the 50-70's of this century.
- With increasing heat supply, the distribution of pasture pests could expand (medium confidence).
- The distribution of Brandt's vole could also increase due to climate change and pasture degradation (relatively high confidence).
- The thawing permafrost could cause damage to building structures, especially to the railway that is to be built and to paved roads which are located in high-mountain areas with permafrost (medium confidence).
- Due to the increase of snow in winter, transportation and communication related challenges could increase from roads and passes that are blocked by snow (high confidence).

The negative impacts of climate change are not yet expressed in monetary terms. However, intensive climate change of the present and the near future can pose serious challenge for the country's sustainable development. Especially, the probability is high that traditional pasture based animal husbandry practices can become extremely difficult thus threatening the semi-nomadic culture and civilization. This in combination with the decreasing crop yield in non-irrigated arable farming sector related to the climate aridification and increasing frequency of heat wave, could aggravate general food safety and the livelihood of rural communities.

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4 Climate change adaptation strategy and measures

4. Climate change adaptation strategy and measures

- Justification for climate change adaptation — Natsagdorj L.
- Possible adaptation options for vulnerable sectors
- Standing against climate change and achieving green development
- Adaptation means

CLIMATE CHANGE ADAPTATION STRATEGY AND MEASURES

4.1 Justification for climate change adaptation

Climate change is one of the main risks and challenges for Mongolia's future development. Mongolia is characterized by fragile ecosystems, vulnerable socio-economic sectors. The lifestyle and livelihood of a large part of the population is dependent on nature and climate conditions. Thus, climate change could have a serious impact not only on the natural environment but also on the socio-economic development. The "Millennium Development Goals-based Comprehensive National Development Strategy" of 2008, as well as the "National security concept of Mongolia" of 2010 reflect the issue of development and implementation of climate change adaption policy to a certain degree. The Mongolian "National action program on climate change" (NAPCC) was first elaborated in 2000 and was updated in 2011. The NAPCC includes general climate change adaptation strategy, policy and measures.

Climate change impacts are visible in Mongolia with the change in water resources and regimes, the drying up of lakes and springs in areas without permafrost, the dropping of ground water tables, pasture and soil degradation due to aridity and extreme heat in the summer and thus, a loss of biodiversity, intensified desertification, the change of wildlife habitat, and the increasing frequency of forest and steppe fires, with overall environmental degradation. High-mountain glaciers and permafrost which covers about 60% of the country are already melting. This development is currently having a positive effect on the regional water resources and partly on the high-mountain ecosystem. However, in a few decades, it could have unforeseen negative impacts. Due to climate change, the frequency and intensity of natural disasters including drought and zud are increasing, leading to loss of livestock and diminishing livelihood. Thus, climate change has become one of the causes for increasing poverty of the rural population which comprises almost 40% of the total population.

The global community is facing numerous challenges related to climate change and as for Mongolia, it is of utmost urgency to minimize the negative impacts of climate change and to adapt socio-economic life to the already changing environmental conditions and thus, to ensure the implementation of green development strategies. Since the mid-1990s, research has been conducted at a latest scientific level to repeatedly assess how climate would change in Mongolia in the future or this Century against the backdrop of global climate change and how it could affect environment and socio-economic development. The general results are becoming clearer and it more or less provides the basis to develop a long-term adaptation policy.

Mongolia has relatively small population, but growth rate is high and the prognosis suggests the population of Mongolia will reach 3.5 million in 2030, 3.82 million in 2040 and 4.1 million in 2050. As of 2010, 63% of the total population lives in urban areas. This number has increased by 10 points in the last 20 years. With growing population, the question of healthy and secure food becomes a serious issue. Currently, the urban population is consuming 1.5 times less meat, 3.9 times less milk than the rural population, whereas the rural population consumes 2 times less vegetables and 9.5 times less eggs than the urban population. Main indicators of nutrition such as underweight newborns, slow development in children under 5 years of age, malnourishment, rachitis and anemia are not decreasing.

4.2. Adaptation Options for Vulnerable Sectors

In order to ensure the country's sustainable development, policy and measures for climate change mitigation and adaptation should be implemented without delay. The fight against climate change is a large endeavor that requires time and resources that would, to a certain extent, require lifestyle changes. Therefore, we have to seriously consider this issue for the benefit of future generations. With all of our predictions, assumptions and knowledge, we have no right to postpone making decisions and put future generations at risk. Numerous researchers prove that postponing action against climate change will increase the damage and cost enormously. For development of a climate change adaptation policy, the economic assessment of positive and negative climate change impacts and how this would in the future affect the environment and socio-economic development is yet to be conducted. The climate change adaptation concept can be understood as reducing possible future risks for the country's vulnerable socio-economic sectors and building the foundation for green development that is well adapted to the environment.

Presented below are adaptation strategies and measures for certain vulnerable sectors.

4.2.1 Animal Husbandry

Strategic goal: To ensure food security, sustainable supply of raw materials for the food and light industries and to expand the production of clean and ecological products by developing an animal husbandry sector that is resilient and adapted to climate change.

Strategic objective 1. Improve the management of animal husbandry production and increase the output, quality and productivity. The following measures are to be taken to achieve this objective:

- establish and develop a legal and economic framework for promoting herder groups, communities, and cooperatives which are based on herders' economic interests;
- establish and implement the legal framework for providing incentives to herders who are practicing climate compatible production;
- develop training programs to adapt production of herder families to climate change, and conduct local and distance training jointly with international and national projects and programs;
- supply herders with suitable warm clothes in case of natural disasters and support national production of such products;
- improve the quality of livestock in selected regions by establishing breeding and trading farms of livestock with high productivity at aimag and

soum level based on public-private partnership principles;

- create policy framework for promoting the breeding of livestock with high productivity complying with pasture carrying capacity by providing incentives and taxes where appropriate;
- retain the weight of female reproducing stock at certain scientifically founded levels and maintain appropriate herd structure balance;
- promote intensive farming of productive stock close to highly populated urban areas and support the establishment/ strengthening of such facilities and capacities by providing incentives such as credits with favorable conditions; and
- increase investment for, and strengthen the capacity of, professional facilities mandated to reduce risk of climate-related animal diseases.

Strategic objective 2. Decrease vulnerability of pasture to climate change and improve its adaptive capacity:

- establish a clear boundary between regions for pastoral animal husbandry and intensive farming;
- formulate regulations and standards for rehabilitating pasture damaged by mining, exploitation, roads and infrastructure with payment from mining and a certain percentage of the revenue;
- ensure ecosystem balance by validating the right to use, restore and conserve pasture;
- improve pasture use and decrease pressure on summer pasture by providing the possibility to carry out biological and other forms of investment by herders;
- set up a “pasture risk fund” by establishing a payment system for pasture use and use the fund for improving pasture, irrigation, increasing fodder reserve and improving ecological education of herders;
- improve ecological education of herders and local government staff among others on traditional pasture management methods and modern best practices;
- introduce pasture resting and rotation methods in warm seasons, monitor and evaluate the effectiveness of the methods and the areas where resting and rotation occurred;
- conduct research and experimentation on improving pasture in major ecological zones and expand activities to restore degraded pasture and hay fields;
- in certain ecological zones experiment with summer and winter cropssuch as rye, barley, winter wheat and oatswith and without irrigation,and establish cultivated pasture that can be used in early spring and late autumn;
- conduct experiments with different sorts of crops, for instance, winter grains that are suitable for green forage such as rye, oats, peas, barley and annual plants with high yield that are suitable for silage such as sunflowers, corn and other legumes and develop and introduce agro-technology that is suitable for Mongolia;
- introduce green forage and silage, and production technology for milk cows;
- in order to prevent the malnourishment of livestock, segregate areas with high grass yields in mountain-steppe, meadow, steppe, desert-steppe regions and use it in winter and spring when there is lack of forage;
- prevent surge of pasture pests, rodents

and insects such as Brandt's vole and locusts, retain a balanced number, use environmentally un-harmful methods to fight them in order to ensure a balanced pasture ecosystem;

- learn and introduce best practices and advanced technology in using and conserving pasture from other countries;
- establish an express information network based on a geographic information system and pasture information in a central and branch database;
- establish a framework for protecting livestock from the risk of decline in pasture and fodder. In order to do this, each soum and bagh should assess the state of its pastures based on satellite and land measurement data and develop pasture use management plans;
- update the pasture map of 1:1.0 million and use it as a basis for pasture use and plan;
- disperse livestock concentration by exploring unutilized areas due to lack of water and build advanced wells, thus, restoring and preserving the state of the pastures;
- protect river and spring sources, build ponds for catching water from rain and melting snow, encourage use of simple wells by herders and support the activities with international and national projects; and
- decrease greenhouse gas emission from traditional pastoral animal husbandry, develop an integrated inventory method and trade emissions at the international market, thus providing incentive for herders.

Strategic objective 3. Produce nutritious forage appropriate for the productivity of pastoral and intensive animal husbandry and improve the food supply for people:

- increase per unit productivity by using mineral and biological fertilizer in hayfields located in the mountain-steppe, meadow and steppe regions where there is adequate moisture supply;
- ensure sustainability of hayfield structure and productivity by introducing rotation;
- in regions with abundant water resources, use freshets and overflow water for watering hayfields along rivers to increase the yield;
- protect moisture in soil and thus, increase the yield by building fences on the hayfields for collecting snow;
- develop agro-technology for cultivating annual fodder crops with high yields that are suitable for silage such as sunflowers, corn and other legumes and implement it into production;
- develop recipes and norms for producing fodder with mixed, granule and hardy ingredients, and conduct industrial experimentation;
- build small-scale local fodder production factories for mixed and mineral fodder based on the raw materials available in a given region;
- establish a recipe for hand fodder with plant, animal and mineral sources,anda recipe for substituting milk, and start production;
- experiment with high yield sorts suitable for green forage in irrigated and non-irrigated conditions and cultivate green forage with seeds from the seed bank or imported seeds;

- cultivate intensive fodder crops in the Gobi with irrigation, thus, producing the fodder close to consumers;
- enrich the genetic database of fodder crops and perform ecological and biological assessments; establish collection of selected sortsin primary and selective arenas and conduct biological and economic assessments;
- cultivate home-grown and well-established fodder crop seeds;
- compensate for the lack of protein in livestock fodder with the help of fodder biotechnology;
- take measures to produce fodder supplement products of microbiological origin, conduct research and experiments for establishing technology for producing new products; and
- establish and develop models for an adequate combination of animal husbandry and arable farming in regions close to markets, where fodder can be produced and prepared.

Strategic objective 4. Build capacity to overcomerisks related to animal husbandry:

- improve the livestock insurance system and establish new double insurance;
- assess fodder size and location accurately, and build a fodder reserve at the soum and aimag level in case of natural disaster and improve fodder storage and quality;
- prepare architectural plans for warm shelter for livestock, introduce techniques to build shelters with locally available raw materials and implement science-technology projects in this field; and
- set up an early warning system for drought and zud.

4.2.2 Arable farming

*Strategic goal:*Supply the domestic demand for food from arable farming sources and for livestock fodder by exploiting beneficial opportunities of climate change and mitigating risks that could arise from the negative impacts.

Strategic objective 1. Explore possibilities to cultivate winter crops:

- conduct experiments with winter wheat crops such as rye, barley and oat sorts in the main arable farming regions, develop cultivation agro-technology and import 300 tons of seeds from the selected elite sorts.

Strategic objective 2. Increase the soil moisture supply by retaining snow on the arable farming fields:

- conduct research with a science-technology project in main arable farming regions on retaining snow and meltwater for the soil moisture (digging, cutting, piling to increase density to slow down melting) and import and supply the necessary technology to the scientific organizations in Darkhan, Khalkh gol and Uvs; and
- establish forest buffer strips and cover crops that retain snow on the arable farming fields and prevent soil erosion.

Strategic objective 3. Exploit opportunities to cultivate crop sorts with medium to medium-late maturity periods and high yield:

- conduct experiments with wheat, potato and vegetable sorts with medium to medium-late maturity periods and cultivate seeds of selected sorts.

Strategic objective 4. Sustainably use irrigable farm land resources for irrigated arable farming:

- summarize the study conducted by the Ministry of Industry and Agriculture on location and size of land that can be used for irrigated arable farming and develop an action plan for its utilization jointly with the MEGD and inform the public; and
- conduct a feasibility study on possible irrigable land with the state budget for fields with an area above 500 hectares and with the aimag, soum budget for fields with an area of 200-500 hectares.

Strategic objective 5. Protect and sustainably use water resources from glaciers and ice sheets:

- conduct research on rivers and streams fed by glaciers and snow sheets that are being used or could potentially be used for arable farming; and
- establish water reservoirs by rivers fed with glacier and snow sheet sources that are rapidly melting.

Strategic objective 6. Employ irrigation methods and technology that employ the least amount of water resources and labor for irrigated agriculture:

- import and supply drip irrigation technology to farmers for cultivation of fruits, perennial trees, bushes and potatoes;
- reduce loss of water by lining the inner wall of all irrigation ditches and canals (with plastic sheet, cement or stone);
- support national production and importation of black and transparent plastic sheets; and
- include in the irrigated fields the shift cultivation of legumes such as soybeans, peas lentils, and forage legumes such as alfalfa and clover.

Strategic objective 7. Introduce methods to increase moisture accumulation and to decrease evaporation in the non-irrigated arable farming:

- introduce technology to reduce mechanic tillage (reduce number of tillages, decrease its depth);
- introduce no-tillage systems (by using Round-up herbicides); and
- reduce evaporation of the farm land with straw mulch.

Strategic objective 8. Select and cultivate drought and heat resistant crop sorts:

- test, select and cultivate heat resistant summer wheat sorts.

4.2.3 Water resource

Strategic goal: Reduce climate change related risks for water resources, ensure water resource quality and sustainability of water supply for the population, industry and agriculture and prevent flooding.

Strategic objective 1. Hoard winter snow and use it for improving soil moisture, reforestation, pasture water supply and irrigated arable farming:

- conduct research and experiments to increase soil moisture by hoarding snow, for instance, in strips or creating snowdrift in forest, pasture and farmland, and introduce it into practice; implement “science-industry” partnerships in the Orkhon, Tuul, Sharin gol, Baruunturuun, Khovd and Khalkh river basins; and

- build a water reservoir for spring flood water runoff, use it for irrigation of arable farming and pasture, water supply and urban development; conduct research and experiments for groundwater recharge from the water reservoir seepage.

Strategic objective 2. Exploit the opportunity from improving heat-moisture conditions and increasing ecosystem productivity in the taiga, high-mountain and mountain steppe regions and implement activities to support the natural capacity to regulate the water regime of rivers by increasing forest resources:

- 70% of Mongolia's water resources have their source in the Altai, Khangai,and Khentii ranges, Khuvsgul mountains, and the higher part of Ikh Khyngan range, which covers 30% of the Mongolian territory. Included in this area in the protected area network and protect ecosystems where river basins have their source; and
- establish stations for long term monitoring of ecosystems, forest climate and hydrology.

Strategic objective 3. Support water ecosystem resilience by developing farms based on the endemic fish of rivers and lakes, beneficial aquatic plants and animals in higher elevated regions where due to climate change, water temperature will rise, and the aquatic environment is going to change;

- develop farms in higher elevated regions based on the endemic fish of rivers and lakes, beneficial aquatic plants and animals to conserve and use the river/lake resources; and
- implement climate change adaptation projects that support ecosystem resilience in vulnerable places like; rivers with a source on the southern side of the Altai, Khangai range, sources of the Tuul and Orkhon rivers and the Kherlen river basins and improve the wetlands and shallow lakes ecosystem by building canals.

Strategic objective 4. Meet adequate demands for water resources, establish and utilize early warning systems and build capacities to prevent floods, water shortage and ecosystem degradation:

- introduce modern technology and advanced systems for monitoring-modeling-forecasting including modeling, satellite data, monitoring of hydrology, meteorology and environment; provide the conditions for using the resources for socio-economic sectors, nature conservation and ensure the sustainable operation of this system;
- estimate the runoff amount that supports the ecosystem in each river basin, based on this and further research, estimate and implement the resource use amount and regime for each water basin, river and groundwater;
- monitor water consumption and save water, for instance by introducing modern technology for water recycling; and
- decrease water consumption and drastically reduce water loss in pipes.

Strategic objective 5. Build the water resource reserve and increase groundwater and lake water reserves:

- use water resources in regions with high mountains and ice sheets for supply of water for energy, pasture and arable farming, conduct research on water regimes to build water reserves;

- build water reservoirs by rivers and lakes that are fed by glaciers and ice sheets; and
- conduct research on groundwater, water circulation in wetlands and how evaporation affects these.

Strategic objective 6. Introduce adequate use of water, increase efficiency in water use and supply, introduce methods and technology for saving water, adequate use and climate change adaptation:

- build and use efficient system for water reservoir and water supply, determine area and volume of small scale water reservoirs according to the geographic locations in order to reduce the amount of water loss from evaporation; increase water reserve of wetlands;
- introduce drip and soaker irrigation technology for arable farming, reduce water loss from irrigation ditches and canals by lining the inner wall with plastic sheets and cement; and
- promote hydropower use and build water reservoirs with multi-year run-off regulation.

Strategic objective 7. Regularly update and implement the "Program on integrated water resource management" for climate change adaptation including measures to reduce negative impacts of climate change on water regimes and resources, exploit beneficial opportunities and to enhance ecosystem resilience:

- implement strategies, programs and plans of Integrated water resource management (IWRM) in 29 river basins of Mongolia;
- enhance river basin (rivers, lakes, wetlands) resilience and integrate adaptation measures into the IWRM program and implement them; and
- introduce payment for ecosystem services (PES) system in animal husbandry, arable farming and economic sectors.

Strategic objective 8. Increase density of surface and ground water monitoring network, build capacity to provide prompt advanced information based on modern mathematic models and technology to public and government organizations:

- expand and automate surface and ground water and soil moisture monitoring network and improve capacity; and
- build integrated system for water information, calculation and supply including satellite data, precipitation radar network, geographic information system, water-energy rotation database, mathematic models and provide instantaneous information.

4.2.4 Forest resource

Strategic goal: Build and strengthen the forestry sector's adaptive capacities by mitigating negative impacts and maximizing positive impacts of climate change on forest ecosystems.

Strategic objective 1. Assess climate change impacts on the forestry sector, forest ecosystem vulnerability and adaptation options based on scientific research:

- conduct research on the negative and positive climate change impacts on the forestry sector and assess forest ecosystem vulnerability, sensitivity and adaptation options;

- for forest inventory, use satellite images with high resolution and introduce advanced techniques using evenly (systematically) positioned permanent circular sampling plots;
- develop and implement a management plan for the forestry sector including species diversity indicators and forest adaptation measures based on forest inventory and management; and
- develop and adopt improved remote sensing techniques for mapping of forest area change and for analyzing the carbon sequestration potential of plants and soil;

Strategic objective 2. Carry out reforestation/afforestation and forest cultivation activities with genetically good quality tree seeds, seedlings and planting materials that have the ability to adapt to climate warming and aridification and restore deforested areas by fostering natural regeneration and, thus, expand the size of forested areas:

- select and produceplanting materials that are well adapted to the continental climate and dry conditions of Mongolia by using crossbreeding and other methods;
- improve genetic qualities of diverse species of trees in order to increase greenhouse gas sequestration capacity and biomass productivity;
- designate permanent seed harvesting areas in selected forest stands and establish forest seed plantation by using seedlings produced with genetically good quality seeds harvested from the selected forest stands and from micro-breeding cloning;
- introduce advanced technologies and techniques in tree cultivation to produce planting materials, such as seedlings adapted to climate change and unfavourable conditions (such as drought and aridity) and that have good growth capacity, and cultivate seedlings in containers;
- develop reforestation methods and techniques adapted to dry climate and adopt reforestation techniques using container seedlings; and
- expand activities related to reforestation/afforestation, tree nurseries, forest buffer strips and establishment of other green areas and increase planting capacity up to 15,000 hectares per year.

Strategic objective 3. Protect forest ecosystems, biodiversity and forest resources from negative impacts of forest fires, diseases, pests and harmful human activities and reduce the rate of forest loss:

- increase the protection of state forest land by promoting contractual ownership of communities, companies and organizations;
- organize public awareness raising activities on media aboutfire damage and prevention; take measures to prevent fires from spreading, for instance by establishing strips of earth and deciduous forest, forest roads and cleared areas;
- establish mechanisms to provide financial incentives for volunteer groups formed to detect and extinguish forest fires immediately when it starts, increase public participation in fire prevention and fighting efforts, organize seasonal fire patrol groups with financial rewards;
- establish forest and steppe fire fighting stations in regions with extremely high fire risks and provide state funding;

improve material resources for forest fire fighting facilities by supplying aircraft, vehicles, fire extinguishing equipment and substances;

- conduct regular monitoring on pest distribution and take measures to fight against pests as soon as its numbers start to increase;
- establish the legal framework for aimag, soum and inter-soum Forest units to take action against illegal use of forest resources; improve funding andtheir technical supplies (e.g. vehicles); and
- establish an incentive system to encourage local communities, forest user group, organizations to take active part in combating illegal timber harvesting and use of non-timber forest products.

Strategic objective 4. Conduct regular cleaning, thinning and sustainable management in natural and planted forests in order to regulate forest composition and density, to increase productivity so that a climate change adapted forest is established:

- define basic parameters of thinning (e.g. selection of trees, cutting intensity, intervals etc.)for each of the dominant tree types based on experiments and research and develop thinning techniques and guidance;
- provide the economic and management conditions for performing regular thinning at certain intervals starting from the saplings to mature trees; and
- perform thinning in forests in consistency with a given region's specific conditions in order to ensure a healthy forest environment and to promote growth and productivity.

Strategic objective 5. Promote sustainable management and use of forest resources adhering to methods and techniques that are suited to the unique characteristics of Mongolian forests and land that are environmentally friendly and preserve ecological balance; and that improve timber product management and improve the utilization rate of timber raw materials:

- use forest resources with environmentally friendly and ecologically balanced techniques and technologies, develop scientific justification and practical guidance for the sustainable management of Mongolian forests and put them into practice;
- promote and develop solar and wind energy use, production of bio-fuel and briquettes with less smoke in order to reduce overall national fuel wood consumption;
- adopt techniques to produce bio-energy with forest products that substitutes fossil fuel; and
- improve efficiency of timber use and processing by introducing to timber enterprises modern techniques and technologies to process wood materials thoroughly; process waste timber, increase production of new products and improve the utilization rate up to 80% per one cubic meter of harvested timber.

Box 4.1 Case Study on Climate Change Adaptation measures in the Northern Mongolian forest conducted by the GIZ "Biodiversity and adaptation of key forest ecosystem to climate change" program, *Source: Klaus Schmidt -Corsitto*

The Northern Mongolian forest resources are the most threatened compared to the other regions in Mongolia because of its biodiversity, geographic variation and water resources. Northern Mongolian forest resources are estimated to be 12.9 million hectares and of these, 2.3 million hectaresare Southern mono species of Saxaul forest. Northern, pseudo and alpine Taigais estimated to be 10.6 million hectares (see http://forestry.gov.mn/mn/#tab1-tab). The impact of climate change is expected to reduce the natural forested areas in Mongolia. With increased temperature and evapotranspiration, Mongolian forests are expected to shift to the Northern regions. Increase in forest fire, fire intensity and forest pests will be the main reasons for future forest loss and forest shifts. The Dark Taiga will lose forested areas due to the shifting of the Light Taiga forests. Adaptation of forest ecosystems to climate change means that there is a need to make the forests more resistant to the main forest loss factors (such as forest fire and pests) through sustainable forest management and improved silvicultural measures. Anthropogenic mismanagement contributes to the increase in negative effects of climate change to forest ecosystems (for example: extensive amount of logging, overgrazing, unsustainable forest management, and unsustainable collection of non-timber forest products, man-made wild fire, and inefficient harvesting methods). Two of the main forest adaptation options are: at a Forest policy level and at an Implementation level. Few of the most efficient adaptation options for each level are cited below:

Adaptation options at a Policy level:

Since the early 1990s, forest policy in Mongolia was driven by mainly strict protection and less sustainable management. In the late 1990s, the strong relation between sustainable forestry and its impact on reducing climate change effects on forest stands was still not well known among the decision makers and the public. However, now it has been proven that sustainable and clean forestry have its impact on reducing fire and pest risks.

Adaptation options:

- Improving forest taxation inventory guidelines with new management planning options.

It means to extend the forest taxation inventory guidelines with more silvicultural management options on clean forestry implementation, afforestation with site adapted tree species, artificial and natural regeneration methods, thinning and logging methods, planning of fire breaks, circulation period, determination of optimal / final diameter, limitation to livestock management in forested areas, determination of biodiversity hotspots and identification of protection zones or tree habitats and more.

- Increasing the number of forest units and qualified experts at all levels (forest engineers, foresters and forest workers)

The number of forestry intellectuals at an academic level is high; however, the number of qualified forest workers decreased since the early 1990s. At least 6.000 forest workers are needed in Mongolia to manage the non-protected forest areas in a sustainable way.

- Improving the framework for forest companies and forest user groups that are working in the field of clean, sustainable and climate change adapted forestry

Following support measures can contribute to the promotion and development of the forestry sector: the subvention, tax-free import and incentives for sales. These activities can increase the participation of those acting in the field of clean, sustainable and climate change adapted forestry.

- Prevent and protect forest ecosystems and forest resources from negative climate change impacts that are increased by improper human activities such as human induced forest fires, diseases, and destructive pests and insects; and mitigate forest degradation rates.

Negative climate change impacts on natural resources are widely increased by improper human activities. Especially the fire outbreaks are caused mainly by human carelessness. Extensively organized public awareness and education for sustainable development (ESD) on natural resources management, fire prevention, pest prevention, and prevention of forest degradation should be addressed to the public by formalized public awareness raising actions and through implementation of ESD (education for sustainable development) school curricula. Rapid detection of disasters and immediate actions should be formalized and budgeted by centralized and decentralized government administration.

- Increase the knowledge about forest resources in Mongolia and its changes

The permanent observation by satellite images and ground verification (permanent circular sampling areas) has already started in Mongolia and should be continued including interpretation with political adaptation conclusions.

Adaptation options on a Silvicultural level:

In Mongolia, the context of Silviculture is driven by the need-oriented logging activities which were implemented until the 1990s, predominantly by clear-cutting. However even with the restriction in logging activities, the forest loss trend continued. Forest loss is mainly caused by forest fire and forest pests. The intensity of forest fire and pests have been increasing for the last 20 years due to climate change related increase in air temperature and reduced evapotranspiration and weather extremes (drought, flood and storm). Anthropogenic non-sustainable forest management is also increasing the negative impacts of climate change related forest loss (overgrazing in forested areas, local overuse of forest resources, illegal logging). Following the cycle of forest management from forest regeneration to final use of wooden products, following main adaptation options are summarized. The adaptation options concentrate on the different "Light Taiga" forest types, whereas the "Dark Taiga" forest types and wetland forest types are not as much disturbed by the midterm climate change impacts as Light Taiga forest stands. A strict conservation policy or a restriction of an extensive logging of only some matured trees should be the best adaptation option for "Dark Taiga". Because these forest stands are not intensely threatened by forest fire and pests.

- Seed collection and tree nursery management

Following adaptation options should be considered:

- Improving seed quality and provenances:

The genetic variety of tree seeds in Mongolia is important due to landscape variations, different climate zones and altitude variations. Afforestation activities should only be realized by site adapted tree species of site adapted provenances. Main adaptation options are:

- Implementation of a new Law on Forest Seed or Principles with detailed regulations on seed traffic, seed provenances, and high quality seed stands.

Law on Forest Seed and its implementation will diminish the risks imposed by foreign seeds. With the genetic improvement of seed stands, the drought resistance could be improved.

- Using natural regeneration as the main option for forest regeneration: At least 100 million seedlings growing and surviving its first critical year, annually and this is the main reason why natural regeneration is the most important regeneration system. Natural regeneration implies that the seeds are site adapted and of high quality genetic sources. Collection of a seedling from highly dense regeneration area and planting them in the neighboring non-natural regeneration areas is one of the many adaptation options; especially, when this activity is ensuring the optimal plant space and facilitating the growth of healthy elite seedlings.
- Site adapted seedling production for afforestation and reforestation: The only one remaining option for rehabilitation of deforested and destroyed areas is the site adapted seedling production –built by approved or tested seed stands and the seedlings are planted. The valorization and systematic collection of seeds in selected forest stands is an important adaptation option. It should focus on identification of seed stands on dryer landscapes (southern direction where there is less soil moisture).
- Tree nursery management for seedling production in consideration of climate change aspects: One main objective of future tree nursery management is to produce seedlings with higher drought resistance and favoring tree species with natural drought resistance (for example: Pinus silvestris). Reforestation by planting bigger sized saplings under drought, fire and pest affected forests' remaining canopy is a very successful rehabilitation measure. However at a tree nursery, these saplings should be raisedin coverage / in shadows (small sized tree nurseries surrounded by adult trees).

Climate Change compatible Silvicultural options

Adopting a Climate change compatible silvicultural measure is one of the many challenges faced in this sector. The results of the National Forest Inventory and research trials on silvicultural measures will permit the realization of the adaptation options to climate change impacts. Based on observations, it was proven that the natural and artificial forests that have multi-level and mixed forests tend to have less frequent and less intense fire occurrences and pest damages. Comparatively, forests with natural dead wood tend to burn less than the forests with large amount of dead wood that are mainly left after logging activities. "Dark Taiga" and "Wetland Forests" are of higher stability against the risks of drought, fire and pests. The following silvicultural adaptation options are considered as primary actions that need to be undertaken:

- Implementation of Clean forestry measures in logged forest areas: Mongolian government decided to adopt and implement the “Clean forestry” program recently, which is an important adaptation option. Clean forestry was one of the main measures taken to fight against bark beetle calamity in Central Europe from1940 until1960, during the last century. However in Mongolia, the aim of the Program is different. Its aim is to reduce the risks of forest fire and pests. Clean forestry comprises of two important activities: 1. Use of timber wood down until a diameter of about 10 centimeters and 2. Collection of remaining timber woods after logging activities. The uses of standing dead wood after forest fire or pest damages are not the central context of clean forestry. In general, this dead wood has to remain in the forest because of its positive impact on the micro-climate, soil hydrology, soil texture stability and shade / cover for natural regeneration. Even when the little details of the implementation of the Clean forestry techniques should be tested, evaluated or explained in the future, it is projected to be the most efficient adaptation option for Mongolia and it should already be implemented at all logged forests.
- Optimal forest use time / avoiding the over-aging of trees: 76.4% of Mongolian forests are over-aged, only 11.98% are forests with important commercial timber stands, 11.14% are middle aged and only 0.48% are young stands and plantations. Over-aged forests cause economic loss but more importantly it increases fire risks. One important adaptation option is to use over-aged forests and enhance natural regeneration of these forests for a timeframe of about 20 to 30 years. The mid-term adaptation objective should be to balance the disturbed age difference. The set diameter for logging of particular tree species should be determined and the optimal age for the tree to be cut should be set and agreed upon for Mongolia’s commercial tree rotation period.
- “Sustainable forest management in commercial forests” as an adaptation option: Sustainable forest use is an adaptation option for commercial forests. Sustainability means production in conformity to the carrying capacity. Modern forest management plans include a description of the actual status of forest stands (forest stand description including tree species and its association and age, the aim of production and the aim of protection, the forest infrastructure (logging and transportation roads, wood storage sites)) and methods to achieve the production and aim of protection. Regarding the diversity of forest stands in Mongolia, the methodologies to use the forests are completely different at each particular region. “Light Taiga”, “Dark Taiga”, “Wet Forest”, “Alpine Taiga” forests and “Pseudo Taiga” forests require different sivicultural methods. Forests with dominating or exclusively Larch trees (63% of tree species growing in Mongolian forests are Larch trees) could be used in a very efficient way in shelter wood compartment system for stabilization.
- Shelter wood compartment system

Shelter wood compartment system is a sivilicutural method to raise tree species with one or more light demanding trees in one stand or shade tolerant trees in one forest stand. Following illustration shows the shelter wood compartment system in a simple way:

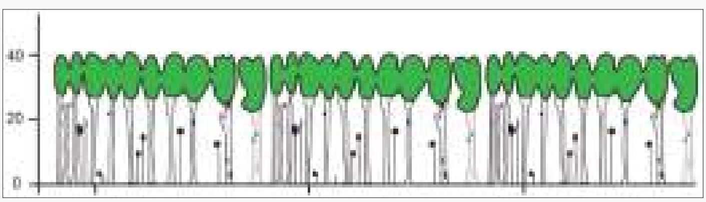

Figure 4.1 Unique species of over-aged forest stands without natural regeneration and dead wood content. The forest has no economic growth and no successful regeneration. The application of the shelter wood compartment system could result to an Open forest as illustrated below:

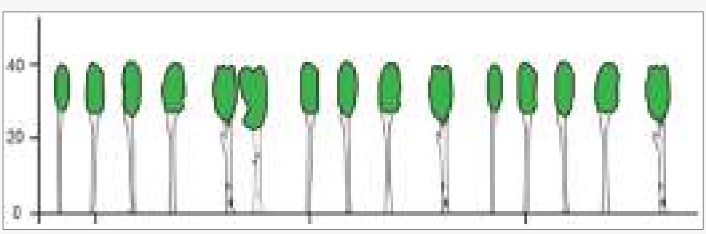

Figure 4.2 Forest stand after 2 to 4 thinning operations (shelter wood compartment system) with improved soil condition (reduced organic layer because of light incidences), fire resistance (reduced organic layer and dead wood) and improved condition for regeneration (because of partly bare soil caused by reduced organic layer and logging activities).

The result of the regeneration (mostly through natural regeneration) is illustrated below:

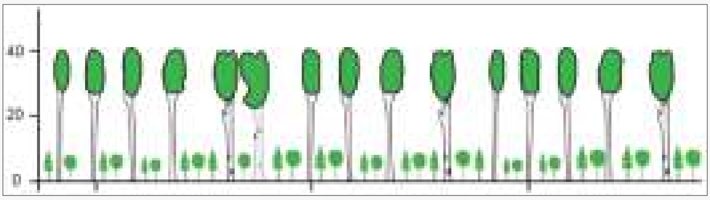

Figure 4.3 Shelter wood compartment system after thinning and regeneration activities.
In a favorable environment, a mixed regeneration should be implemented for improved stability against the risks of fire and pests.

The shelter wood compartment system is a simple adaptation option for centraland large scale "Light Taiga" stands, "Pseudo Taiga" stands and "Alpine Taiga" stands. It is recommended to be implemented through"light ground thinning".

- Selection system as an adaptation option

Naturally on mountains of 1700 m altitudeandin valleys of high altitude,Dark Taiga forests and partialWetland forestscomprise of multi-level forest stands (PinusSibicrica, PiceasObovata, Abiessibirica and others). Wetland forest stands should be excluded from all of the use and logging activities. However, "Dark Taiga" forests could be extensively used by selective cutting and stabilized against climate change effects. The outcome of the Selection system could be very similar to natural multi-level and multi-species forest stands.

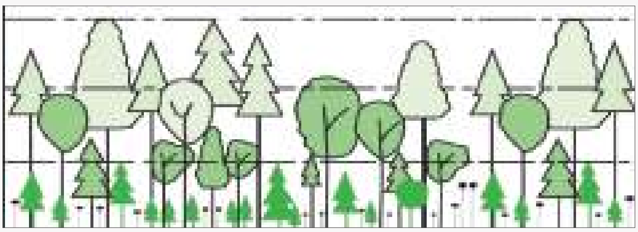

Figure 4.4 Multi-level and multi-species forest stand.

In general,these forests are the most resistant against all calamities (fire, pestsand drought) and should be considered as a silvicultural option in the upper "Light Taiga", especially in Khentiiand partly in Bulgan region. The selective cutting system by final diameter selection criteria ensures the existence of aresilientforest stand management. Hence, this option should be considered as one of the key adaptation options.

- Artificial and natural regeneration as anadaptation option: Afforestation and reforestation for successful adaptation to climate change is the most crucial and less recognized challenge.
- Afforestation as an adaptation option: Forest fire and pest resistant and site adapted seedlings of approved or even selected tree stands is the precondition for successful afforestation activities. Afforestation of sites (Afforestation at non-forested areas; for example in Steppe regions) should only be considered withlight resistant pioneer species with the aim of having short rotation period and for fuel wood production purposes. Another option for afforestation could be the establishment of wind breaks near the main roads or human settlements or for erosion control or stabilization of river beds. In more difficult sites (damaged soil structure, erosion), pioneering crop options should be considered. However, afforestation should not be considered as the main option for forestry activities because of its great need for reforestation.
- Reforestation as an adaptation option: The reforestation of degraded forests due to fire, pests or over use of forested sites is important for the long-term assurance of forest ecosystem functions. The degradation of forests is widespread in Mongolia. Decision on which reforestation measures to undertake is based on the intensity of the degradation.
- Reforestation with site adapted tree species in tide planting distances (1,5 X 0,5 to 2X 1): Full scale reforestation is carried out when destroyed / degraded forest sites are not regenerated naturally for the preceding 10 years after the disaster. A period of at least 10 years should be planned before the artificial reforestation is carried out. After 10 years period, chances for natural regeneration decreases.
- Plantation under canopy: Plantation under canopy is an efficient reforestation option in partly destroyed forest ecosystems with weak natural regeneration under destroyed or heavily damaged forest or under over-aged forests with no natural regeneration. The reforestation under canopy takes advantage of the still favorable micro-climate (humidity and light) of the former or partially existing forest stands. The planting distance could be chosen at a broader scale, for example >= 8X2 m equidistance.

- Natural regeneration and enrichment plantation: Natural regeneration is the most important. Enrichment plantation to complete natural regeneration with different tree species to grow mixed and more resistant forested sites are a significant adaptation option for partly destroyed or damaged forests and for open mono-species forest sites. The planting system could be implemented through regular broad scale planting distances (for example 10X4) or plantation in hurts, groups or clumps of trees. Growing mixed forests is the most efficient way to fight against the negative impacts of climate change and reduce risks of fire and beetle pests.
- Mixed seed sawing: In some cases, especially under climate change impacts, the best site adapted tree species are unknown. Mixed seed sawing (for example Pinus Silvestris, Pinus Sibirica, Betual sp.,Picea obovata) could help avoid the selection of unfit species selection. The best site adapted species will come out on top of all the species.
- Propagation by cuttings: In many tree nurseries, propagation by cuttings is used in order to raise saplings. Use of cuttings for direct reforestation in wet and under stocked forested sites are very cost efficient. The use of Populus sp. and Salix sp. is common and proven to be successful.

4.3 Standing against climate change and achieving green development goals

Scientific research shows climate change trends will be even more intensive in the future (IPCC AR5). Due to its geographic location and characteristics, climate is changing more rapidly in Mongolia compared to the global average and the probability is high that this trend will continue in the future. Therefore, it is of utmost importance to consider climate change when planning the sustainable development of the country in the mid to long-term. This means mitigating negative impacts of climate change on the environment and socio-economic sectors that are already visible and those that can occur in the future and exploiting positive opportunities effectively. This issue was clearly reflected in the National security concept of Mongolia (2010), but not sufficiently in the sector strategies.

Future climate change has implications for the essential national interests of Mongolia including:

- safe and healthy environment of a Mongolian person;
- food security;
- economic security;
- culture and civilization security; and
- environmental security.

Natural disasters, including the increasing frequency of untimely disasters (e.g. extreme warming in winter, large amounts of snow in early or late summer, wet snow in spring and autumn that causes icing on the electric wires and paved roads etc.) could have the most negative impact on human security. Increased precipitation intensity and the percentage of heavy rain in the overall summer precipitation total, also increases the risk of floods. Due to the increasing amount of snow in winter, mountain passes are covered in snow and roads are more slippery, which could lead to more traffic accidents. Lack of surface and groundwater could deteriorate the water quality and supply for public consumption and agricultural purposes thus leading to increase in diseases related to water quality and supply. Due to climate change, different kinds of disease transmitters could come (especially from the south) and the type and frequency of zoonotic diseases among the livestock and wildlife could increase. All of this requires strengthening the disaster management framework, taking measures at the national level to reduce vulnerability, provide the possibility for national and local government organizations, professional organizations, private sector and the public to participate and to improve capacity. Here, the establishment of disaster risk management framework based on communities, deserves special attention (UNDP, 2010).

Climate change has the worst impact on food security. The “National security concept of Mongolia” aims to take technical and economic measures to sustainably supply no less than 70% of the most essential food products for Mongolian people with domestic production. In order to achieve this goal, priority has to be given to the sustainable growth of agricultural production.

In order to ensure economic security, adequate economic structure with multiple pillars has to be built in the first place. Especially, in order to reduce poverty, special attention should be given to the diversification of income sources for herders.

Nomadic civilization is a unique culture that relies on ecosystem services and is adapted to the natural environment. Considering the general trend of human development, a culture that is adapted to the changing environment deserves to be promoted. Ensuring ecological balance, protecting water resources, mitigating negative impacts of climate change and land degradation, preventing loss of biodiversity and reducing risks of environmental pollution, natural hazards and disasters are all part of the foundation for human life in a safe and healthy environment and, thus, for ensuring environmental security.

Up until now, the national and regional development planning followed the tradition of establishing the economic model first and then adding some ideas on how to deal with the environmental issues. This is one of the root causes for environmental degradation in Mongolia. According to the green development concept, on the other hand, national mid to long-term development planning includes developing predictions on environmental issues including future climate change trends, and what kind of positive and negative impacts this would have on the socio-economic sectors. All of this is considered under the umbrella of national and international circumstances and future trends of technology.

4.4 Adaptation means

Article 4.1. of the United Nations Framework Convention on Climate Change states, “All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall formulate, implement, publish and regularly update national and, where appropriate, regional programs containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and measures to facilitate adequate adaptation to climate change.”

Climate change adaptation has been reflected in a number of policy documents of

Mongolia's socio-economic development. In 2014, the "Green Development Policy of Mongolia" was approved by the State Great Khural. This document includes climate change adaptation issues in a relatively extensive form.

4.4.1. Adaptation strategy

Green development is based on an intricate interrelation of environment and economic activities with a human in the centre of the development. Mongolian economy is largely dependent on natural resources such as water and pasture and natural resource intensive sectors such as animal husbandry and arable farming. Currently, Mongolia is facing climate change related challenges that other developing countries are also facing but there are also some challenges that are unique to Mongolia, due to the country's geographic and climatic characteristics. For instance, the thawing of permafrost that covers about 60% of the whole territory will have significant impacts on agricultural production, water resources and infrastructure developments such as roads and buildings. In addition, climate change will have serious impacts on ecosystems, natural pastures, arable farming, animal husbandry, water resources and soil quality. Therefore, climate change adaptation is more significant for Mongolia than the issue of reducing greenhouse gas emissions. However, considering long-term goals to tackle climate change issues, the strategies for adaptation and mitigation should be balanced.

Historically, Mongolian agriculture, including animal husbandry and arable farming, were adapted to the risks deriving from climate change and variability. However, current climate change will require governments to make efforts to increase the cultivation of crops and develop new methods and technologies to tackle issues rising from climate change. Due to the shifting of geographic zones, which is the basis for agricultural production, pasture availability and arable farming developments will change. This could mean, for some people in certain regions, improvement of crop yield, but for most people, climate change adaptation will require considerable investment and potential loss. In addition, climate change could exacerbate the conflict for water in water resource poor regions and this could affect people's livelihoods. Therefore, the government adaptation strategy for agriculture and water sectors should pay attention to the following issues:

- organize extensive information and awareness raising activities among decision makers, local herders/farmers and the general public;
- provide information and technology to herders and farmers and introduce it in practice;
- promote research and technological advancement in order to ensure agricultural development that can meet the diverse environmental challenges in the 21st century; and
- improve the coordination of research and monitoring activities and take management measures.

There are numerous uncertainties as to what direct and indirect impacts climate change could have on natural resources and agriculture and to the development and assessment of possible adaptation options. Adaptation technology normally requires a large initial investment. In addition, the results of an adaptation measure are not immediately visible. Therefore, effective adaptation requires considerable time and effort.

The adaptation options mentioned above are beneficial even if the climate does not change as predicted. These measures that need to be taken in different sectors present complicated, multifaceted and absolutely necessary issues for decision and policy makers. Thus, the screening matrix method was employed in order to prioritize adaptation options according to their significance. The selected adaption measures were evaluated with the help of criteria and indicators. Adaptation options were given non-numeric evaluation of high, medium and low based on necessity to implement, significance and urgency. Measures that cost little and have fewer hurdles, can be implemented easily. However, this evaluation is based neither on the issues at hand, integrated and economic model nor assessment of the benefit of adaptation measures.

Measures such as controlling and regulating the number of livestock according to pasture availability and changing river course are costly and have less social acceptance, thus are harder to implement. Long term research is needed to ensure sustainability of the economy, society, technology and environment, to alleviate uncertainties and to develop future adaptation strategies. Extensive and detailed scientific research on understanding climate characteristics will play an important role in supporting effective decision making on climate change issues.

4.4.2 Possible challenges and constraints in implementing climate change adaptation measures and activities

It is necessary to evaluate possible challenges when implementing adaptation measures. It is clear that numerous challenges can arise when implementing adaptation measures depending on the country's socio-economic development, geographic location and characteristics. In the following, those challenges that have high probability of occurrence are listed together with ways to meet those challenges.

At the institutional level: Challenges in some socio-economic sectors have been analyzed and the implementation of measures to meet those challenges has begun. In 2012, MEGD has been reorganized as one of the line ministries of the government which presents an important step to coordinate climate change policy at the national level. Nevertheless, due to a lack of coordination and information, conflicts occur among different ministries and agencies. Some measures and activities are ineffective and inefficient because of unclear mandates and responsibilities for climate change adaptation. Coordination and cooperation among diverse stakeholders are very important in implementing adaptation measures. The right and responsibility to make decisions and implement activities related to climate change lie with the ministries for agriculture, environment, energy and local government organizations and thus, they are responsible for the final result. Therefore, climate change is not the responsibility of one sector or organization. Instead, it relies on cooperation among all stakeholders, mutual assistance and distribution of responsibility. During the implementation of the planned activities, it is important to take measures such as improving the coordination of government organizations, monitoring their effectiveness and efficiency, determining adaptation measures for the present and future, and increasing the efficiency of the funding.

At the funding level: It is obvious if the funding for adaptation measures is insufficient, the results would be ineffective. The difference between planning and implementation, for instance the high cost of adaptation measures will put pressure on the implementation process. The effectiveness and success of activities will depend on reliable sources of funding. Thus, it would be effective to devote international sources of funding and investment for adaptation measures as the possibilities to build a sufficient reserve in the national budget, which is limited due to current economy situation of Mongolia. It will be necessary to extend international cooperation with different countries and financial organizations in order to attract foreign investment and promote transfer of technology.

At the social level: Lack of knowledge and information, misconceptions, an old-fashioned mentality of individuals and the public will pose challenges for the implementation of adaptation measures; therefore, these challenges need to be addressed. The adaptation measures implemented by herders and others in the agricultural sector should be compatible with the tradition and culture and they should be based on concrete life experience. Since the end beneficiaries actor of adaptation policy is the public, their participation should be ensured already at the adaptation policy formulation and planning stages so that the public becomes aware of their benefits and responsibilities. It is impossible to implement all adaptation measures at the same time at any given time. Therefore, by meeting challenges that occur during certain implementation period, the opportunity could arise for evaluation and mitigation of potential challenges that could occur for other activities. It is thus important to identify ways to meet challenges so that it will allow to save time and resources.

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5 Greenhouse gas monitoring and inventory

5. Greenhouse gas monitoring and inventory

- Greenhouse gas monitoring	Oyunchimeg D.
- GHG Inventory: Energy and Industrial sector	Tegshjargal B.
- GHG Inventory: Agricultural and waste sector	Sanaa E.

GREENHOUSE GAS MONITORING AND INVENTORY

5.1 Greenhouse gas monitoring

The Global Greenhouse Gas Reference Network measures the atmospheric concentration, distribution and trends of the three main long-term drivers of climate change, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as carbon monoxide (CO) which is an important indicator of air pollution. The Reference Network is a part of NOAA's Earth System Research Laboratory (ESRL) in Boulder, Colorado, USA. The measurement programme includes around the clock measurements at 4 baseline observatories and 8 tall towers, air samples collected by volunteers at more than 50 sites, and air samples collected regularly from small aircraft mostly in North America. The air samples are returned to Boulder for analysis. All measurements of up to 55 trace gases are subject to stringent quality control procedures, and are directly traceable to internationally accepted calibration scales where possible. In fact, NOAA's Global Greenhouse Gas Reference Network maintains the World Meteorological Organization international calibration scales for CO_2, CH_4, CO, N_2O, and SF_6 in air. The NOAA/ESRL/GMD CCGG cooperative air sampling network effort began in 1967 at Niwot Ridge, Colorado. Today, the network is an international effort which includes regular discrete samples from the NOAA ESRL/GMD baseline observatories, cooperative fixed sites, and commercial ships. Air samples are collected approximately weekly from a globally distributed network of sites. Samples are analyzed for CO_2, CH_4, CO, H_2, N_2O, and SF_6. Measurement data are used to identify long-term trends, seasonal variability, and spatial distribution of carbon cycle gases.(http://www.esrl.noaa.gov/gmd/ccgg/). CO_2 concentration is steady increasing globally (Figure 5.1). Global CO_2 increased by an average of 1.70 ppm/yr from 1981-2012, with a minimum of 0.67 ppm/yr and a maximum of 2.84 ppm/yr. Since 2000, CO_2 has increased by 1.96 ppm/yr (http://www.esrl.noaa.gov/gmd/ccgg/newsletters/newsletter_2013.pdf). The first daily average above 400 ppm observed at Mauna loa, Hawaii, USA since spring 2013 (http://co2now.org/). *Source: GMD-NOAA, USA*

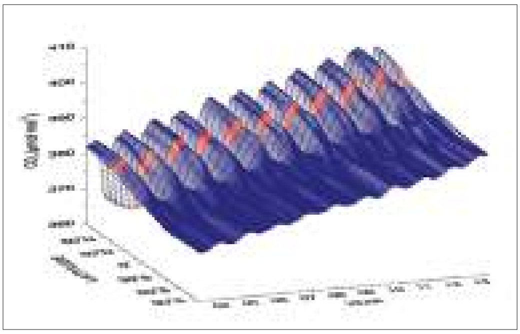

Figure 5.1. Long-term trend and spatial distribution of atmospheric CO_2. *Note: Red line indicated data of UUM site, Mongolia*

Since 1992, GHG sampling has been conducting by GMD, NOAA, USA jointly with Institute of Meteorology Hydrology and Environment of Mongolia at UUM site (Latitude: 44.4516° N, Longitude: 111.0956° E, Elevation: 1007.00 masl) in Erdene soum, Dornogovi aimag of Mongolia. The site is located in the dessert -steppe region of east south side of Mongolia far from any anthropogenic sources. It is a site of cooperative sampling network. Air samples are collected approximately weekly and analyzed for CO_2, CH_4, CO, N_2O, and SF_6 and other CO_2 isotopes in NOAA ESRL/*GMD* of USA. The mean concentration of main GHG is increasing constantly at the site of Mongolia. Concentration of CO_2 has increased by more than 11.4 percent /40.7 ppm/ (Figure 5.2) and CH_4 3.3 percent /60 ppbv/ (Figure 5.3) for a period 1992-2013. The 2012 average annual concentration of GHGs are CO_2 378.8 ppm, CH_4 1887.3 ppbv and SF_6 7.8 ppt at UUM site.

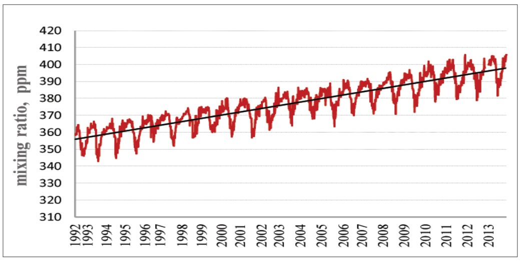

Figure 5.2 Atmospheric CO_2 at UUM site, Mongolia /Erdene soum, Dornogovi aimag/

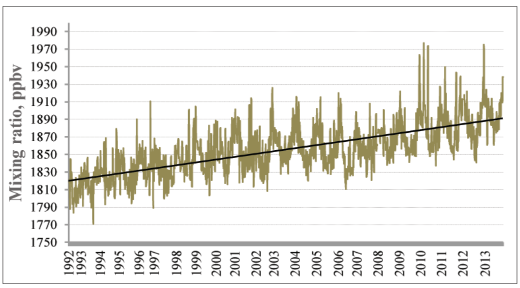

Figure 5.3 CH_4 concentration at UUM site, Mongolia /Erdene soum, Dornogovi aimag/

SF_6's has small atmospheric concentration and high global warming potentials. SF_6 concentration has increased by 2 times (Figure 5.4) for a period 1998-2013 at UUM site. (D.Oyunchimeg 2013).

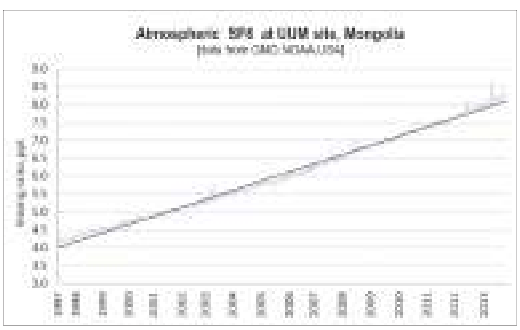

Figure 5.4 Atmospheric SF_6 at UUM site, Mongolia /Erdene soum, Dornogovi aimag/.

At the UUM site of Mongolia, CO_2 increased by an average of 1.96 ppm/yr during the period 1992-2012, with a minimum of 0.54 ppm/yr and a maximum of 3.89 ppm/yr. Since 2000, It has high variability (Figure 5.5). CH_4 increased by an average of 3.6 ppbv/yr from 1992-2012, with a minimum of (-4.2) ppbv/yr and a maximum of 14.8 ppbv/yr (Figure 5.6).

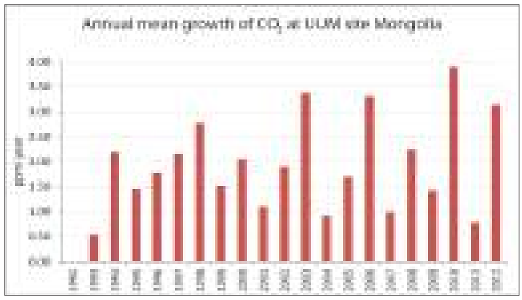

Figure 5.5 Annual mean growth rate of CO_2 at UUM site, Mongolia

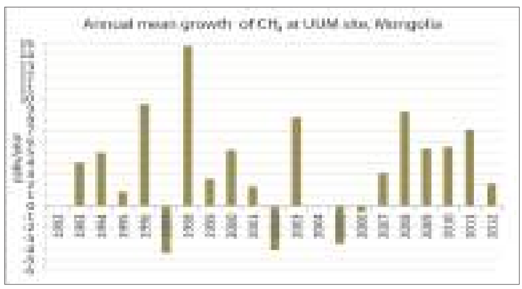

Figure 5.6 Annual mean growth rate of CH_4 at UUM site, Mongolia

SF_6 increased by an average of 0.24 ppt/yr from 1998-2012, with a minimum of 0.16 ppt/yr and a maximum of 0.3 ppt/yr (Figure 5.7).

Figure 5.7 Annual mean growth rate of SF_6 at UUM site, Mongolia

The study based on CO_2 data from the Ulaan-Uul Station, Mongolia (UUM), results are shown that comparing atmospheric CO_2 values between subsequent weekly flask samples that differed by greater than 3 ppm and the associated synoptical conditions. Standard deviation of the differences 2 weeks CO_2 was 2 ppm at UUM site. We have selected extrem values of CO_2 which were higher than 3 ppm subsequent weekly flask samples that diffred by greater than 3ppm.

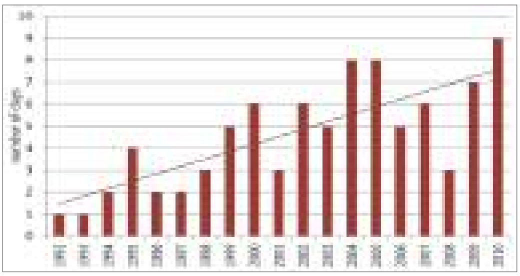

Figure 5.8. Occurrence of subsequent weeks when CO_2 values were greater than 3 ppm. *Source: annual_meetings/2012/abstracts/47-120406,GMD* NOAA.

The trend in the number of subsequent weeks with elevated CO_2 differences has been increasing over the 18 years until 2010 (Figure 5.8). The weekly differences were greater than 3 ppm when air masses were transported from industrial regions of Russia and China to Mongolia (Oyunchimeg D., 2012)

5.2 Greenhouse Gas Inventory

5.2.1 Energy Sector

Most Greenhouse Gas (GHG) emissions in Mongolia are from fossil fuel combustion as the analysis of GHG emissions shows. The experts have noted that the GHG emission mitigation policy should be focused on the reduction of coal use through coal substitution, namely, replacing fossil fuels with renewable energy resources. The GHG inventory for the energy sector has been prepared for the period 1990 to 2012. Three main gases were considered, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and the indirect gases like carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC) and sulfur oxide (SO_2) as well. The GHG inventory took into account the emissions resulting from fossil fuel combustion as well as fugitive emissions resulting from the extraction of solid fossil fuels. Activity data was taken from the coal balances and data on imports of liquid fuels, which are annually issued by the National Statistical Office. The energy balances and consumption data were taken from country statistics of the International Energy Agency (IEA) and other relevant Ministries and organizations of Mongolia.

CO_2 emissions from solid fuel combustion for the period 1990-2012 are presented in Table 5.1, and were calculated using the sectorial approach. The table shows that most of the solid fuel or coal was used in the energy industry for the electricity and heat generation in power plants and heating boilers.

The energy sector is the most significant source of CO_2 emissions in Mongolia. In 1990, CO_2 emissions from solid fuel combustion were 8,135.04 Gg; the emissions from the following sectors were energy industries 63.22%, manufacturing industries 17.02%, transport 1.57%, commercial 4.16%, residential 9.17% and agricultural 2.19%. But in 2012, CO_2 emissions from solid fuel combustion were 8,771.49 Gg totally, of which the energy industries emitted 76.97%, manufacturing industries 7.12%, transport 0.54%, commercial 0.14%, residential 8.01%, agricultural 0.05% and other sectors 7.17% emitted (see Table 5.1).

CO_2 emissions from liquid fuel combustion are resulting mainly from imported liquid fuels such as gasoline, diesel oil, fuel oil, jet kerosene and LPG. In 1990, CO_2 emissions from liquid fuels were

2,518.17 Gg which accounted for 18.82% of the total fuel combustion. But 2012 CO_2 emissions from liquid fuel combustion were 3,523.08 Gg, which is 21.23% of the total (see Table 5.2). CO_2 emissions from fossil fuel combustion are rising due to its consumption.

Table 5.1 CO_2 emissions from Solid fuel combustion, Gg and %

Years	Sectorial Approach							
	Energy Industries	Manufacturing Industries	Transport	Commercial	Residential	Agriculture	Other	TOTAL
1990	5,143.28 63.22%	1,387.31 17.02%	127.87 1.57%	338.75 4.16%	746.36 9.17%	178.35 2.19%	213.12 2.62%	8,135.04 100.00%
1995	4,599.77 73.12%	850.56 13.52%	108.8 1.73%	265.79 4.23%	176.5 2.81%	31.41 0.50%	257.99 4.10%	6,290.82 100.00%
2000	5,079.94 83.78%	267.04 4.40%	81.88 1.35%	262.09 4.32%	256.78 4.24%	3.37 0.06%	112.17 1.85%	6,063.27 100.00%
2005	5,254.11 83.24%	132.56 2.10%	112.5 1.78%	216.74 3.43%	443.15 7.02%	20.53 0.33%	132.12 2.09%	6,311.71 100.00%
2006	5,252.07 78.94%	253.88 3.82%	135.61 2.04%	179.54 2.70%	611.07 9.18%	9.2 0.14%	211.63 3.18%	6,652.99 100.00%
2007	5,849.64 81.55%	460.48 6.42%	136.85 1.91%	89.73 1.25%	420.63 5.86%	3.37 0.05%	212 2.96%	7,172.7 100.00%
2008	5,756.34 81.00%	448.25 6.31%	45.99 0.65%	195.17 2.75%	456.53 6.42%	7.85 0.11%	196.29 2.76%	7,106.43 100.00%
2009	5,891.73 78.04%	399.62 5.29%	46.21 0.61%	2.24 0.03%	669.64 8.87%	15.7 0.21%	524.95 6.95%	7,550.1 100.00%
2010	6,457.17 78.91%	387.66 4.74%	56.08 0.69%	3.37 0.04%	686.47 8.39%	11.22 0.14%	581.03 7.10%	8,183 100.00%
2011	6,302.89 78.26%	423.01 5.25%	59.45 0.74%	2.24 0.03%	717.88 8.91%	10.1 0.13%	538.41 6.69%	8,053.97 100.00%
2012	6,751.67 76.97%	624.9 7.12%	47.11 0.54%	12.34 0.14%	702.17 8.01%	4.15 0.05%	629.15 7.17%	8,771.49 100.00%

Table 5.2 CO_2emissions from Liquid, Solid and Biomass Fuel combustion

Years	Liquid Fossil		Solid Fossil		Biomass		TOTAL	
	Gg	%	Gg	%	Gg	%	Gg	%
1990	2,518.17	18.82	8,135.04	60.79	2,728.9	20.39	13,382.11	100.00
1995	1,011.05	9.63	6,290.82	59.94	3,193.51	30.43	10,495.38	100.00
2000	1,308.22	12.47	6,063.27	57.80	3,119.41	29.73	10,490.9	100.00
2005	1,687.96	15.35	6,311.71	57.39	2,998.17	27.26	10,997.84	100.00
2006	1,888.07	16.30	6,652.99	57.44	3,040.65	26.25	11,581.71	100.00
2007	2,365.12	17.62	7,172.7	53.45	3,881.54	28.92	13,419.36	100.00
2008	2,539.74	18.62	7,106.43	52.11	3,991.78	29.27	13,637.95	100.00
2009	2,336.44	16.40	7,550.1	53.01	4,356.25	30.59	14,242.79	100.00
2010	2,488.26	16.64	8,183	54.74	4,278.37	28.62	14,949.63	100.00
2011	3,070.62	18.73	8,053.97	49.13	5,268.49	32.14	16,393.08	100.00
2012	3,523.08	21.23	8,771.49	52.86	4,298.66	25.91	16,593.23	100.00

Figure 5.9 shows the CO_2 emissions by fuel type for the period of 1990-2012. The largest percentage of CO_2 emissions from fuel combustion is from solid fuel, approximately 49-61%, liquid fuel approximately 10-21%, and 20-32% from biomass. The CO_2 emissions from biomass are relatively constant, but emissions from liquid fuel are tending to increase.

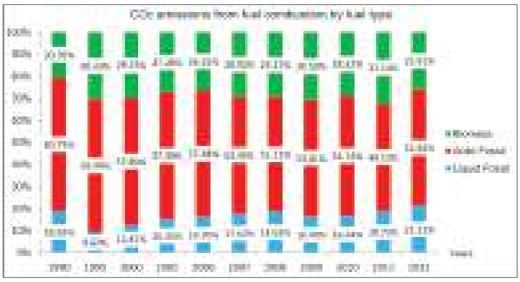

Figure 5.9 CO_2 emissions from fuel combustion in energy sector, by fuel type. *Source: experts calculations*

CH_4 and N_2O emissions. The sources of methane emissions in the energy sector arise from fuel combustion activities and fugitive emissions from coal mining. The main sources of N_2O emissions are fuel combustion activities in the energy industry and the residential sector. In 1990, CH_4 emissions from the energy sector were 494 Gg CO_2-eq. (23,520 tonnes) and decreased to 363 Gg CO_2-eq. (17,270 tonnes) in 2000. CH_4 emissions have been increasing since 2001 and reached 997 Gg CO_2-eq. (47,460 tonnes) in 2012.

To estimate fugitive emissions from coal mining it should be divided into surface and underground mines. Underground mines are emitting more CH_4 emissions than surface mines and it depends on the high gas concentration in the deep ground. In Mongolia there are no underground mines. Since the closure of the underground mine in Nalaikh district of the capital city has increased the number of artisanal miners. In 2013 there were around 1,500 artisanal miners in 200 underground mines in Nalaikh district and 28 of them had operating licenses. Artisanal coal mining is not officially considered a mining activity since artisanal miners act contrary and do not carry out their responsibilities according to the existing laws. For example, their activities have never been the subject of any environmental evaluation and such miners act without any feasibility study. But in the calculation of CH_4 emissions from coal mining, underground mines were considered from 1990 to 2006, and from 2007 to 2012 only surface mines were considered.

Fugitive emissions or CH_4 emissions from coal mining in the energy sector accounted for 50% in 1990, decreased to 40% in 2000, but increased to 61% in 2012. N_2O emissions from the energy sector are very low and were on average 0.27 Gg during the period 1990-2012.

Total CO_2, CH_4 and N_2O emissions in Gg CO_2-eq. Table 5.3 shows the total GHG emissions in Gg CO_2-eq. unit by using the Global Warming Potential (GWP) provided by IPCC. The GWP of a gas refers to the total contribution to global warming resulting from the emission of one unit of that gas relative to one unit of the reference gas, CO_2, which is assigned a value of 1. According to the IPCC Second Assessment Report ("1995 IPCC GWP Values") based on the effects of GHGs over a 100-year time horizon, the CH_4, the N_2O and HFCs emissions were converted into equivalents of CO_2. For example, if CH_4 has a GWP of 21, it means that 1 kg of CH_4 has the same impaction on climate change as 21 kg of CO_2 and thus 1 kg of methane would count as 21 kg of CO_2 equivalent (eq.). As a result, the total emissions of GHGs from the energy sector were estimated at 13,661 Gg CO_2-eq. in 2012, of which CO_2, CH_4 and N_2O accounted for 91.7%, 7.3% and 0.01% respectively.

It shows that the value of CH_4 and N_2O emissions are very low and the predominant emission is CO_2 from the energy sector.

Table 5.3 Total CO_2, CH_4 and N_2O emissions in Gg CO_2-eq.

Gases / Sources	1990	1995	2000	2005	2010	2011	2012
CO_2	10,653.21	7,301.87	7,371.49	7,999.67	10,671.26	11,124.59	12,530.81
A – Fuel Combustion	10,653.21	7,301.87	7,371.49	7,999.67	10,671.26	11,124.59	12,530.81
Energy Industries	5,620.01	4,728.51	5,157.04	5,297.98	6,649.13	6,551.45	7,009.61
Manufacturing Industries	1,607.14	886.23	314	196.97	1,230.74	1,502.04	1,753.71
Transport	1,728.77	867.15	1,176.50	1,593.86	1,380.03	1,641.67	1,978.50
Commercial / Residential / Agriculture	1,484.17	561.98	611.79	779.04	830.33	891.02	923.61
Other	213.12	257.99	112.17	132.12	581.03	538.41	629.15
CO_2* from Biomass	2,728.90	3,193.51	3,119.41	2,998.17	4,278.37	5,268.49	4,298.66
CH_4	493.92	373.17	362.67	414.96	906.78	1141.56	996.66
A – Fuel Combustion	493.92	277.83	268.8	280.14	462	579.39	470.4
Energy Industries	1.68	1.26	1.47	1.47	1.89	1.89	2.1
Manufacturing Industries	3.78	2.31	0.63	0.42	0.42	0.63	0.63
Transport	7.35	3.78	5.04	6.09	60.9	6.93	8.4
Commercial / Residential / Agriculture	290.85	270.27	261.45	272.37	453.6	569.94	459.48
A – Fugitive emissions from Fuels	190.26	95.34	93.87	134.82	444.57	561.96	526.26
Solid Fuels	190.26	95.34	93.87	134.82	444.57	561.96	526.26
N_2O	93	86.8	83.7	83.7	127.1	148.8	133.3
B – Fuel Combustion	93	86.8	83.7	83.7	127.1	148.8	133.3
Energy Industries	31	24.8	27.9	27.9	37.2	34.1	37.2
Manufacturing Industries	9.3	6.2	3.1	0.93	3.1	6.2	6.2
Transport	6.2	3.1	3.1	6.2	3.1	6.2	6.2
Commercial / Residential / Agriculture	49.6	52.7	49.6	49.6	83.7	105.4	83.7
TOTAL	11,240.13	7,761.84	7,817.86	8,498.33	11,705.14	12,414.95	13,660.77

*These values are presented for informational purposes only and are not included in the total emissions.

Indirect GHGs (NO_x, CO, NMVOC) and SO_2 emissions from fuel combustion activities. In addition to the main GHGs, many energy-related activities generate emissions of indirect GHGs. Total emissions of NO_x, CO, NMVOC and SO_2 from energy-related activities for the period 1990-2012 are presented in Table 5.4. From fuel combustion activities were emitted about 62 Gg NO_x, 491 Gg CO, 69 Gg NMVOC and 70 Gg SO_2 in 2012. The largest percentage accounted for CO from fugitive emissions in the energy sector.

emissions from fuel combustion in 2012. The sum of these sectors accounted for 98% of the total NMVOC emissions.

SO_2 is not a "greenhouse gas," but its presence in the atmosphere may influence the climate. SO_2 emissions are directly related to the sulfur content of fuel. The most significant source of SO_2 emissions in Mongolia is coal. But the sulfur content of the coal in Mongolia is relatively low. In 2012, almost 83% (57.77 Gg) of the total SO_2 emissions were emitted from coal combustion.

Table 5.4 NO_x, CO, NMVOC and SO_2 emissions from the energy sector, Gg

Gases/Years	1990	1995	2000	2005	2010	2012
NO_x	52.33	35.13	37.87	43.11	51.90	62.06
CO	338.27	282.77	294.60	306.16	444.29	490.58
NMVOC	49.17	38.47	41.36	43.53	60.67	69.12
SO_2	72.77	54.12	47.72	48.48	61.19	69.66

The most significant sources of NO_x are energy industries and mobile sources. In 2012, the energy industries and transport sectors accounted for 43% and 31% of the NO_x emissions from fuel combustion activities in Mongolia. The major part of CO emissions from fuel combustion activities come from motor vehicles. In 2012, the transport sector emitted about 30% of the total CO emissions. Another large contributor to the CO emissions is the residential sector with small combustion equipment. The residential sector emitted 69% of the total CO emissions from the fuel combustion.

The most significant sources of NMVOC from fuel combustion activities are mobile sources and residential combustion (especially biomass combustion). The road transportation accounted for 40% and the residential combustion 58% of the NMVOC

Figure 5.10 shows the total GHG emissions from the energy sector in Gg CO_2-eq. units for the period 1990-2012. The direct and indirect emissions from the energy sector decreased from 1990 to 1998 and from 1999 on they are tending to increase.

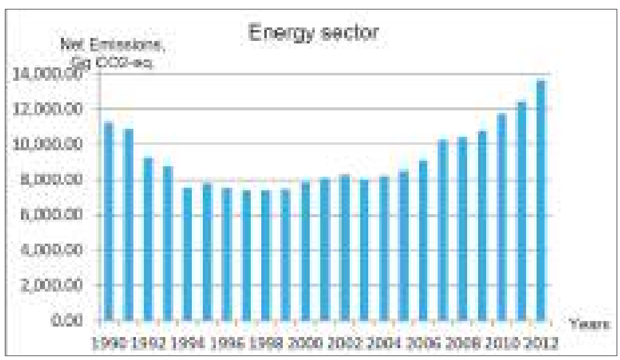

Figure 5.10 Total GHG emissions from the energy sector for the period 1990-2012, Gg CO_2-eq.,
Source: experts calculation

5.2.2 Industrial Sector

The Industrial Sector includes GHG emissions which are produced from a variety of industrial activities which are not related to energy. The main emission sources are industrial production processes which chemically or physically transform materials. During these processes, many different GHGs, including CO_2, CH_4, N_2O and HFCs, can be released. GHG emissions inventory in the industrial sector includes CO_2 and SO_2 emissions from cement manufacturing, CO_2 emissions from lime manufacturing, NMVOC emissions from food and drink production, and different halocarbons that are also consumed in industrial processes or used as alternatives to ozone depleting substances (ODS) in various applications such as air conditions and refrigerators. Cement production is a notable example of an industrial process that releases significant amounts of CO_2 (IPCC, 1997 p. 2.1). In addition, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) have very high GWP.

GHG emissions from Cement production. The cement production process, during the combustion of milled limestone in a kiln at a temperature of 1400-1450°C emits CO_2 from the lime. This process is the next significant source of CO_2 emissions after fossil fuel combustion. Currently, there are three cement industries - in Darkhan, Khutul and Nalaikh. The capacity of Darkhan and Khutul cement industries are larger than the Nalaikh cement industry, and the cement industries in Khutul and Nalaikh have new dry method technology. The advantage of this technology is the energy savings.

Activity data for cement production is available in the Statistical Yearbooks of Mongolia. The emission factor for cement production is the default value of IPCC guidelines. The CO_2 and SO_2 emissions from the cement production are shown in the Table 5.5. In 1990, CO_2 emissions accounted for 219.74 Gg and decreased to 30.86 Gg in 2004, but increased to 174.18 Gg in 2012. The SO_2 emissions from the cement production decreased from 1990 to 2004 and increased in the period 2005-2012.

Table 5.5 GHG emissions from Cement production, Gg

Gases/ Years	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
CO_2	219.74	54.24	45.71	55.78	70.19	89.63	134.25	117.05	160.77	212.26	174.18
SO_2	0.13	0.03	0.03	0.03	0.04	0.05	0.08	0.07	0.10	0.13	0.10

GHG emissions from Lime production. The CO_2 emissions from lime manufacturing for the period 1990-2012 are shown in the Table 5.6. The CO_2 emissions from lime manufacturing in 1990 were 93.73 Gg and reduced to 27.30 Gg in 2004, but increased to 62.06 Gg in 2012. Cement production accounted for 66% on average and the remaining 34% accounted for lime manufacturing of the total CO_2 emissions in the industrial sector in 2012. Figure 5.11 shows the total CO_2 emissions in 1990 and 2012 by the cement and lime production ratio. non-methane volatile organic compounds (NMVOC). NMVOCs are produced during the processing of cereals and fruits in preparation for the fermentation processes. The activity rate is the total annual production. Emissions are included from all processes in the food chain which occur after the slaughtering of animals or harvesting of crops (IPCC, 1997 p. 2.41). Activity data for food and beverage production were taken from the Statistical Yearbooks of Mongolia. The estimates of emissions from food and beverages were made for the annual production of spirit,

Table 5.6 CO_2 emissions from Lime Production, Gg

Gases/ Years	1990	1995	2000	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO_2	93.73	46.77	33.67	27.30	73.89	54.92	39.40	49.87	39.22	45.68	41.22	62.06

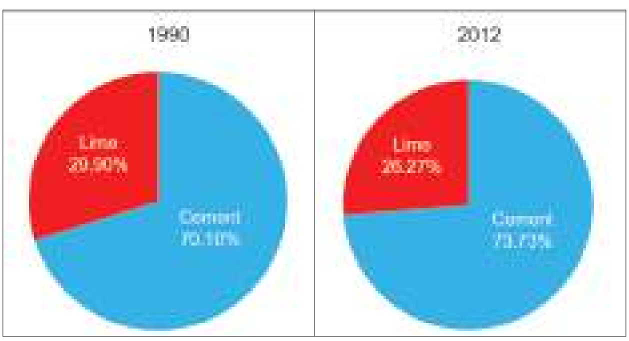

Figure 5.11 Total CO_2 emissions of the industrial sector in 1990 and 2012. *Source: experts calculation*

beer, wine, meat and meat products, bread, cakes and animal feeds. The activity data of beer production was not available from 1990 to 1994. Therefore it was not possible to estimate NMVOC emissions from the beer production in this period. The NMVOC total emissions in 1990 were 1.208 Gg and reduced to 0.802 Gg in 2012. Table 5.7 shows the total NMVOC emissions by food and beverages categories for the period 1990-2012.

GHG emissions from Food and Drink production. The relevant precursor gas emitted during food production is

Table 5.7 Total NMVOC emissions from food and beverages production in industrial sector, Gg

Products/Years	1990	1995	2000	2005	2010	2012
Beer	-	0.0005	0.001	0.003	0.016	0.023
Spirit	0.521	0.318	0.569	0.464	0.541	0.496
Alcohol, wine	0.005	0.003	0.005	0.006	0.016	0.022
Meat, fish and poultry	0.019	0.004	0.002	0.002	0.004	0.005
Cakes, biscuits	0.038	0.009	0.007	0.009	0.013	0.015
Bread	0.506	0.294	0.162	0.181	0.174	0.203
Animal feed	0.119	0.047	0.011	0.016	0.066	0.038
TOTAL	1.208	0.675	0.747	0.681	0.830	0.802

Emissions related to consumption of Halocarbons (HFCs, PFCs) and Sulfur Hexafluoride (SF_6). Partially fluorinated hydrocarbons (HFCs), perfluorinated hydrocarbons (PFCs), and sulfur hexafluoride (SF_6) are serving as alternatives to ozone depleting substances (ODS) being phased out under the Montreal Protocol. Current and expected application areas of HFCs and PFCs include:

- Refrigeration and air conditioning
- Fire suppression and explosion protection
- Aerosols
- Solvent cleaning
- Foam blowing
- Other applications

Primary uses of SF_6 include:

- Gas insulated switch gear and circuit breakers
- Fire suppression and explosion protection
- Other applications

Partially and fully fluorinated hydrocarbons (HFCs and PFCs) are not controlled by the Montreal Protocol because they do not contribute to depletion of the stratospheric ozone layer. HFCs are chemicals containing only hydrogen, carbon and fluorine. There are a variety of HFCs which are now being produced, and HFC-134a entered production in 1991. The 100-year GWP of HFC-134a is 1300.

SF_6 is a particularly potent GHG with a 100-year GWP of 23,900 and an estimated lifetime of about 3200 years. The chemicals (HFCs, PFCs, SF_6) are of concern, however, because they have high GWP and long atmospheric residence times (IPCC, 1997 pp. 2.43, 2.44).

For Mongolian conditions, it was calculated potential product halocarbon emissions (HFCs) contained in various products such as refrigeration and air conditioning, which are imported, using Tier 1b methodology of IPCC guidelines. The number of refrigerators and cars with air conditioners are available in the Statistical Yearbooks of Mongolia. The quantity of material per unit (emission factor) selected from default factors in Revised 1996 IPCC Guidelines for National GHG Inventories. Table 5.8 shows total emissions related to consumption of halocarbons.

Table 5.8 Total emissions related to consumption of halocarbons, Gg

Gases/Years	1990	1995	2000	2005	2010	2012
HFCs	0.01	0.03	0.15	0.56	1.36	1.92
PFCs	0	0	0	0	0	0

Figure 5.12 shows total emissions from the industrial sector for the period 1990-2012. The total emissions from the industrial sector increased dramatically in 2004, 2008, 2011 and decreased sharply in 2009. This shows how the 2008 global economic crisis influenced the industrial sector of our country in 2009. At that time the total production of the industrial sector in 2009 decreased to 3.3% from the previous year and the main reason of this decline was the collapse of 14.2% in the manufacturing sector and 6.2% in the metal ore mining sub-sector (Ch. Narantuya, 2010).

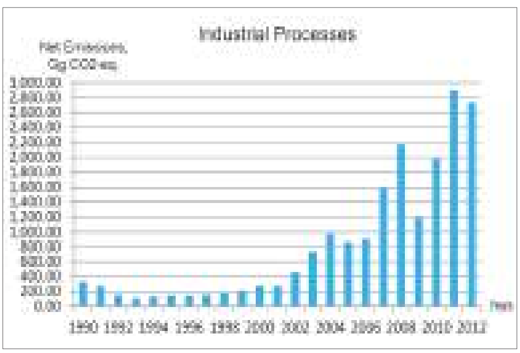

Figure 5.12 Total GHG emissions from industrial sector, Gg CO_2-eq., *Source: experts calculation*

5.2.3 Agricultural Sector

Agricultural activities contribute directly to emissions of GHG through a variety of different processes. This part discusses three GHG-emitting activities and excludes methane emissions from rice cultivation, because of it is not occurring in the country.

CH_4 and N_20 emissions from domestic livestock (enteric fermentation and manure management). Methane and nitrous oxide emissions from livestock are directly affected by the number of livestock and the type of manure management practices. The amount of CH_4 that is released depends on the type, age, weight of the animal, the quality and quantity of the feed, and the energy expenditure of the animal. Whereas, most Mongolian livestock are indigenous breeds that graze throughout the year on natural pastures with low productivity and small size as compared to other breeds of animals in the world. Moreover, the climate in Mongolia influences the type of forage and the amount digested by livestock annually. Therefore emission factors of methane for enteric fermentation and manure management have been developed for Mongolian specific conditions using a Tier 2 approach by the local experts (Namkhainyam et al., 2014) and values are shown in Table 5.8 – 5.11.

Table 5.9 Country Specific Emission Factors for Cattle

Main categories of cattle	Fresh bred dairy cattle	Mature local dairy cattle	Mature non-dairy cattle (female)	Other non-dairy cattle	Calves
Emission Factor (EF)	65.6	44.53*	40.42	29.8*	13.4

*value chosen for this inventory

Table 5.10 Country Specific Emission Factors for Livestock except Cattle

Livestock type	Sheep	Goats	Camels	Horses
Emission Factor (EF)	6.51*	5.17*	46.69*	14.17*

*value chosen for this inventory

Table 5.11 Country Specific Emission Factors for Manure Management for Livestock

Livestock type	Fresh bred dairy cattle	Mature local dairy cattle	Other cattle	Sheep	Goats	Camels	Horses
Emission Factor (EF)	5.5	0.9*	0.7*	0.08	0.09	1.2	1.1

*value chosen for this inventory

Emissions of N_2O related to manure handling before the manure is added to soils are included in N_2O emissions from manure management category. According to IPCC guidelines (1996, 2006) on manure management system categorization and definition, only pasture/range/paddock and daily spread systems occur in Mongolia. Therefore N_2O emissions during storage and treatment of these two systems are assumed to be zero and N_2O emissions from the land application of Mongolian livestock are covered under the agricultural soil category.

The number of livestock is changing due to natural disasters, such as zud and droughts in some years from 1990 to 2012, and social and economic shifts of country within studied periods. As a result, methane and nitrous oxide emissions from domestic livestock fluctuate following those long and short term results (Figure 5.13 – 5.15).

CH_4, CO, N_2O, and NO_X emissions from the burning of agricultural residues. Agriculture residues were calculated for wheat and potatoes as these are the most common crops in Mongolia. However, GHG emissions from the field burning of agriculture residues were very small compared to other emissions from agriculture.

N_2O emissions from agricultural soils. Emissions of N_2O from agricultural soils are primarily due to the microbial processes of nitrification and denitrification in the soil. Direct soil emissions of N_2O from animal production include those induced by grazing animals. Cultivation of organic soils may increase soil organic matter mineralization and, in effect, N_2O emissions.

Results of the calculation of GHG emissions from the agricultural sector are shown in Table 5.12. Due to some changes in emission factors and activity data, the GHG inventory of the agricultural sector is re-estimated from 1990 to 2012.

Table 5.12 GHG Emissions from the Agricultural Sector, Gg

Years	Methane Emissions from Domestic Livestock			Field Burning of Agricultural Residues				Agricultural Soils
	Enteric Fermentation	Manure Management	Total					
	CH_4	CH_4		CH_4	N_2O	NOx	CO	N_2O
1990	274.89	7.04	281.93	0.22	0.0044	0.16	4.71	11.22
1995	296.93	7.73	304.66	0.08	0.0016	0.06	1.72	6.05
2000	296.69	7.64	304.33	0.05	0.0009	0.03	0.97	3.57
2005	257.50	6.24	263.74	0.03	0.0005	0.02	0.57	3.14
2006	286.84	6.81	293.65	0.05	0.0009	0.03	1.00	2.84
2007	326.14	7.58	333.72	0.04	0.0008	0.03	0.85	2.77
2008	344.73	7.83	352.56	0.07	0.0014	0.05	1.50	3.60
2009	356.39	8.04	364.42	0.13	0.0025	0.09	2.65	5.05
2010	276.29	6.47	282.76	0.12	0.0023	0.08	2.44	5.41
2011	301.58	7.08	308.66	0.15	0.0029	0.10	3.05	6.56
2012	340.99	7.92	348.91	0.16	0.0031	0.11	3.31	7.39

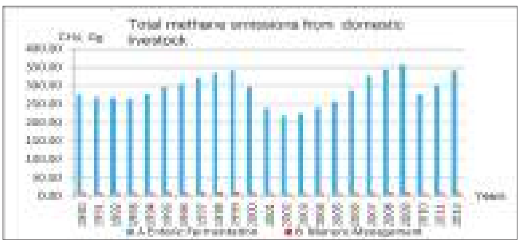

Figure 5.13 Total methane emissions from domestic livestock

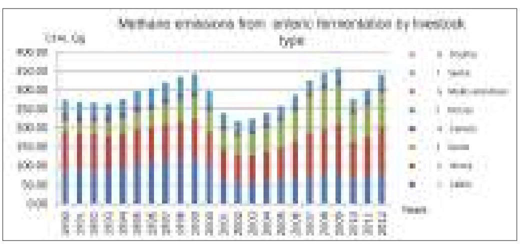

Figure 5.14 Methane emissions from enteric fermentation by livestock type

Figure 5.15 Methane emissions from manure management by livestock type

5.2.4 Waste sector

The GHG inventory of the waste sector is based on estimating emissions of methane (CH_4) from solid waste disposal sites, CH_4 emissions from wastewater handling, and N_2O from human sewage. Due to some changes in emission factors and activity data, the GHG inventory of the waste sector is re-estimated from 1990 to 2012. Urban population is used for the waste sector calculation since waste in rural areas is typically scattered on the land rather than in solid waste disposal sites (SWDSs).

CH_4 emissions from solid waste disposal sites. Mongolia has experienced trends towards increasing solid waste output, mainly due to a concentration of the population in urban areas, increased consumption and changes in the economic structure. In 2012, Mongolia has a total population of 2,867,744 people and 45.96% of the total population lives in Ulaanbaatar, the capital city (Mongolian statistical website: www.1212.mn). About 50% of total solid waste is generating only from Ulaanbaatar city, and detailed information of the solid waste management system

is given in the technology assessment chapter of this book.

In the previous (1990-2006) inventory, the value for municipal solid waste (MSW) generation rate was chosen as 0.334 kg/capita/day which is based on household waste estimation from JICA's survey in 2007 (The study on a solid waste management plan for Ulaanbaatar, Mongolia, final report, 2007). However, an updated value of 0.84 kg/capita/day (Namkhainyam et al., 2014) which was calculated from not only household waste but also from commercial/institutional waste, is used for MSW generation rate in current inventory. The fraction of the MSW disposed to solid waste disposal site (SWDS) was assumed as 0.65 by local experts (Namkhainyam et al., 2014). Other country specific parameters of solid waste are shown in the Table 5.13.

Methane emissions from wastewater handling. The calculations are for two basic types of wastewater treatment systems:

- Domestic and commercial wastewater
- Industrial wastewater

In Mongolia, about one-third of domestic and commercial wastewater is treated by sewer systems with aerobic treatment. Table 5.14 summarizes fractions of the housing category and wastewater handling method based on population and housing census of Mongolia, 2010. These values are used as the main parameters for calculation of GHG emissions from wastewater handling. Additional information on the wastewater handling system is provided in the technology assessment chapter of this book.

Table 5.13 Household waste in Ulaanbaatar

Parameters	Values
Percentage of MSW disposed to SWDS, %	65.0
Composition of waste with moisture, %	22.0
Paper and textiles	
Garden and park waste and other (non-food) organic putrescible	5.0
Food waste	24.0
Wood and straw waste	2.0

Source: Namkhainyam et al., 2014

Solid waste disposal sites in Mongolia fall into the unmanaged shallow type according to IPCC guidelines, and the methane correction factor is taken as a default value (0.4). Methane emissions from solid waste disposal sites are shown in the Table 5.16.

According to Mongolian standards, Biological oxygen demand (BOD) is 75 g/cap/day (27,375 kg/1000 persons/yr). However, compliance of this standard is unclear and much higher than the IPCC default for all regions. Therefore, the IPCC default value as 14,600 kg/1000 persons/yr for Asia, the Middle East, and Latin America is used for BOD.

Table 5.14 Percentage of housing category and wastewater handling method in Mongolia (2010)

Housing category	%	Wastewater handling method	%
Population lives in apartment connected with central sewer systems	30%	Sewer systems with aerobic treatment	30%
Population lives in houses, gers using latrine in bigger cities and province centers	35%	Latrine	45%
Population lives in houses, gers using latrine in soum (sub province) centers	10%		
Herders	25%	None	25%

Industrial wastewater contains degradable organic matter that has the potential to emit methane. In Mongolia, major industrial wastewater sources with high CH_4 gas production potential are identified as follows:

- meat processing (slaughterhouses),
- alcohol production,
- beer production,
- dairy products

The main meat processing factory uses a septic tank + lagoon system for its wastewater treatment while the alcohol, beer and dairy production industry directly discharges into the central sewer systems with aerobic treatment. Namkhainyam B. et al., 2014 estimated degradable organic component and wastewater produced for per tonne production of those industries as a country specific value and the results are shown in Table 5.15. The calculation results for methane emissions from wastewater handling are shown in Table 5.16.

Nitrous oxide from human sewage. Thirty percent of the population lives in apartments connected with central sewer systems, and the annual per capita protein intake is used for the nitrous oxide emission calculation and the results are shown in Table 5.16.

GHG emissions from the waste sector. Total methane emissions from waste were estimated at 7.51 Gg (157.71 CO_2-eq.) in 1990, and this amount increased to 11.27 Gg (236.67 CO_2-eq.) in 2012. During the period of estimations, about 95% of CH_4 emissions came from solid waste disposal sites, about 1.7% came from industrial wastewater, and the leftover came from domestic wastewater.

Total nitrous oxide from human sewage was estimated at 0.05 Gg (15.5 CO_2-eq.) in 1990 and this amount increased to 0.08 Gg (24.8 CO_2-eq.) in 2012.

GHG emissions from the waste sector between 1990 and 2012 are summarized as CO_2-eq and shown in Table 5.17.

Table 5.15 Degradable organic component and wastewater production of per tonne product

Industry	Wastewater produced W, (m^3/tonne product)	Degradable organic component (kg COD/m^3 wastewater)
Alcohol	24	11
Beer	6.3	2.9
Dairy products	7	2.7
Meat processing (slaughterhouses)	13	4.1

The trend in emissions shows that the annual emissions of CH_4, N_2O from solid waste disposal sites, and wastewater handling have increased continuously year after year in relation to the population increase, especially in urban areas. Meanwhile, the emission trend of CH_4 from industrial wastewater was fluctuating due to the certain year's economic condition, which directly influences the food industries production in the country (Figure 5.17).

5.2.5 Net GHG emissions in Mongolia

The total GHG emissions in Mongolia excluding the Land Use Change and Forestry (LUCF) sector and including Energy, Industrial Processes, Agriculture and Waste sectors in Gg CO_2-eq. unit for the period 1990-2012 are presented in Figure 5.17. In 1990, the net GHG emissions were 21,146 Gg CO_2-eq. and reduced to 14,827 Gg CO_2-eq. in 2001. The reduction is mostly due to a socio-economic slowdown during the transition period from centrally planned to a market economy.

Table 5.16 GHG emissions from the waste sector, Gg

Year	Methane emissions from solid waste disposal sites	Wastewater handling				Total methane emission	Total nitrous oxide emission
		Industrial wastewater	Domestic and commercial wastewater	Sub-total	Human sewage		
	CH_4 (Gg)	CH_4 (Gg)	CH_4 (Gg)	CH_4 (Gg)	N_2O (Gg)	CH_4 (Gg)	N_2O (Gg)
1990	6.94	0.31	0.25	0.56	0.05	7.51	0.05
1995	7.03	0.08	0.27	0.34	0.06	7.37	0.06
2000	7.80	0.10	0.28	0.38	0.07	8.19	0.07
2005	8.75	0.10	0.30	0.40	0.07	9.14	0.07
2006	8.95	0.12	0.31	0.43	0.07	9.38	0.07
2007	8.96	0.17	0.31	0.48	0.07	9.44	0.07
2008	9.43	0.22	0.32	0.53	0.08	9.96	0.08
2009	9.77	0.20	0.32	0.52	0.08	10.29	0.08
2010	9.98	0.21	0.33	0.54	0.08	10.52	0.08
2011	10.31	0.24	0.33	0.57	0.08	10.89	0.08
2012	10.66	0.26	0.34	0.60	0.08	11.27	0.08

Table 5.17 GHG emissions from the waste sector, CO_2-eq.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	174.5	175.7	175.2	170.5	169.6	173.0	175.7	181.3	186.1	193.1	193.5	194.2
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	200.5	204.8	208.0	215.1	219.9	221.3	232.4	241.1	245.7	254.3	262.8	

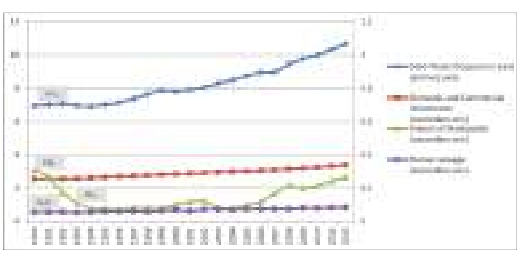

Figure 5.16 GHG emissions from the waste sector, Gg

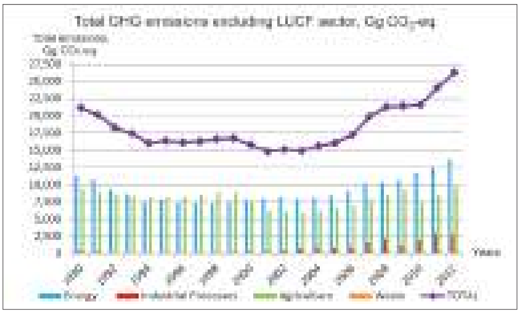

Figure 5.17 The total GHG emissions excluding LUCF sector, Gg CO_2-eq. *Source: experts calculation*

During this period the methane emissions increased due to an increase in livestock population. In 1998, the methane emissions increased to 7,752 Gg CO_2-eq. and in 2002, it was reduced to 5,259 Gg CO_2-eq.; since 2003 it has been gradually increasing (see Figure 5.18). According to total GHG emissions by gas type, CO_2 and CH_4 are the most significant gases. Figure 5.19 shows the comparison of the total GHG emissions in 1990 and 2012. In 2012, the total N_2O and CO_2 emissions decreased, but HFCs and CH_4 emissions increased. CO_2 emissions were 51.86% in 1990, but in 2012 reduced to 48.59%.

In addition to the main GHG emissions, many activities generate indirect GHG emissions. Total emissions of nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulfur dioxide (SO_2) from 1990 to 2012 are presented in Figure 5.20. The main indirect GHG is carbon monoxide which is emitted mostly from fuel combustion. In 2012, 62.17 Gg NO_x, 493.89 Gg CO, 69.92 Gg NMVOC and 69.77 Gg SO_2 were emitted from overall activities in Mongolia. Emissions of SO_2 are directly related to the sulfur content of fuel.

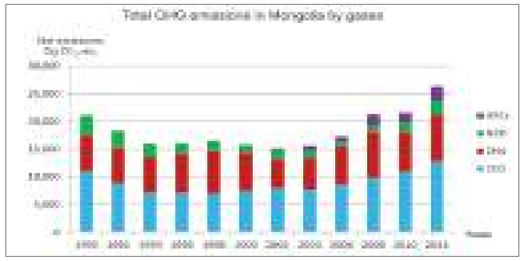

Figure 5.18 Mongolia's total GHG emissions by gases, Gg CO_2-eq., *Source: expertscalculation*

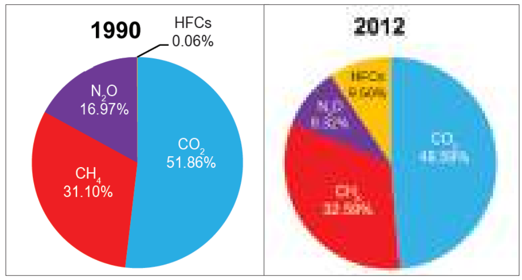

Figure 5.19 Mongolia's total GHG emissions by gases in 1990 and 2012. *Source: experts calculation*

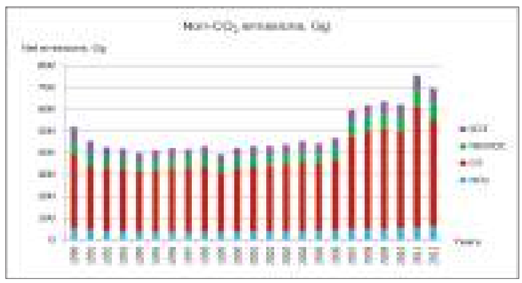

Figure 5.20 Non-CO_2 emissions, Gg, *Source: experts calculation*

Sectorial GHG emissions in Mongolia. The national GHG Inventory in Mongolia was prepared and excluded the Land Use Change and Forestry (LUCF) sector. According to total GHG emissions by categories, the energy sector accounted for 53.16% of total GHG emissions in 1990, but 51.99% in 2012. The second largest source of GHG emissions is the agricultural sector. Because of a reduction in newly cultivated land from 1990, the share of the agricultural sector in total GHG emissions was 44.47% in 1990, but reduced to

36.61% in 2012. GHG emissions from industrial and waste sectors accounted for 2.38% in 1990, but increased to 11.40% in 2012 (see Figure 5.21). This is almost seven-fold growth of the GHG emissions from the industrial sector which is related to the construction boom in our country and follows an increase in cement and lime production.

Table 5.18 shows that the single largest emitter of CO_2 is the energy sector. In 2012, 98% of CO_2 emissions were from the energy sector which includes all types of fuel combustion activities. The main contributor to the CH_4 emissions is the agricultural sector contributing about 86% of the total CH_4 emissions. The second biggest contribution comes from the energy sector with about 12%, while the waste sector contributes about 2-3% of the total.

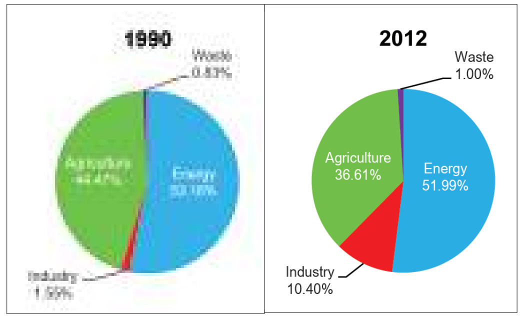

Figure 5.21 Total GHG emissions by categories in 1990 and 2012, *Source: experts calculation*

The total GHG emissions in Mongolia are comparatively low, but the per capita rate of GHG emissions is relatively high compared to other developing countries because of the cold continental climate, the use of fossil fuels for energy, and the low efficiency of fuel and energy. Mongolia's total GHG emissions (excluding LUCF sector) are presented in Gg CO_2-eq. unit in Table 5.19.

Table 5.18 GHG emissions by categories in 1990, 2000 and 2012

GHG source and sinks	CO_2 emissions	CH_4	N_2O	HFCs	TOTAL
	Gg				Gg CO_2-eq.
1990					
Energy	10,653.21	23.52	0.30		11,240.13
Industrial Processes	313.47			0.01	326.99
Agriculture		282.15	11.22		9,403.35
Waste		7.51	0.05		173.21
Total (excluding LUCF sector)	10,966.68	313.18	11.57	0.01	21,130.16
2000					
Energy	7,371.49	17.27	0.27		7,817.86
Industrial Processes	79.38			0.15	274.38
Agriculture		304.38	3.57		7,498.68
Waste		8.19	0.07		193.69
Total (excluding LUCF sector)	7,450.87	329.84	3.91	0.15	15,589.61
2012					
Energy	12,530.81	47.46	0.43		13,660.77
Industrial Processes	236.24			1.92	2,732.24
Agriculture		349.07	7.39		9,621.37
Waste		11.27	0.08		261.47
Total (excluding LUCF sector)	12,767.05	407.80	7.90	1.92	23,779.85

Table 5.19 Mongolia's total GHG emissions (excl. LUCF) for the period 1990-2012, Gg CO_2-eq.

Years/Categories	Energy	Industrial Processes	Agriculture	Waste	TOTAL
1990	11,240.166	326.937	9,403.910	174.490	21,145.503
1995	7,760.925	139.298	8,275.052	173.045	16,348.320
2000	7,818.111	275.958	7,498.817	193.546	15,786.432
2005	8,499.933	857.674	6,511.293	215.110	16,084.010
2010	11,705.140	1,974.450	7,618.505	245.679	21,543.774
2011	12,414.950	2,892.480	8,518.617	254.311	24,080.357
2012	13,660.770	2,732.240	9,621.112	262.817	26,276.939

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6 Climate change mitigation strategy and measures

6. Climate change mitigation strategy and measures

-Projections of GHG emissions	Dorjpurev J
- Mitigating GHG emissions in mid-term period	
- Policies and measures to reduce GHG emissions	
- International mechanism and opportunities to implement GHG mitigation measures	
- Green development and GHG emission reduction	
- Nationally appropriate mitigation action (NAMA)	Saruul D.
- Enhanced carbon sequestration by land ecosystems	Sanaa E.

CLIMATE CHANGE MITIGATION STRATEGY AND MEASURES

6.1 Projections of GHG Emissions in the Near Future

Projections of GHG emissions between 2006 and 2030 in Mongolia have been estimated within the project for preparation of Mongolia Second National Communication in 2010 (MNET 2010). For the forecasting of emissions from energy sectors which accounts for most of the GHG emissions, calculation results from LEAP modeling of Mongolian Long term Energy planning are used. The LEAP is a scenario-based energy-environment modeling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region under a range of alternative assumptions on population, economic development and technology and so on. Projection of emissions from agriculture, land-use change and forestry (LUCF), and waste sectors were calculated up to 2030 on the basis of previous trends, taking into account social and economic changes and currently implemented or adopted policies and measures.

The aggregated projections of GHG emissions are shown in Table 6.1.

The total GHG emissions are expected to increase 3.25 times from 2006 to 2030 (Table 6.1). The energy consumption is expected to increase rapidly due to economic and population growth. The energy consumption in the industrial sector is rapidly increasing due to the development of the mining and quarry industry in mining sectors. GHG emissions in energy sectors from 2006 to 2030 are expected to increase 4 times.

According to the Mongolia National Livestock program, the livestock population will be 36 million in 2021, in order to comply with the actual pasture carrying capacity and to prevent desertification. Therefore GHG emissions are not expected to increase much. However, as of 2014, the total animal population is already reached to 50 million. Therefore, in reality GHG emissions, especially methane emission would be increased significantly in the future.

In the level of 2030, GHG emissions in the industry sector are expected to increase 2.5 times, and in the waste sector 2 times compared to 2006.GHG removals in LUCF will be reduced 3 times in the projection period (Figure 6.1 and Figure 6.2).

Table 6.1 *Aggregated projections of GHG emissions by sector*

Sectors	*GHG emissions in GgCO$_2$-eq*						*Average annual growth rate,%*			
	2006	*2010*	*2015*	*2020*	*2025*	*2030*	*2006-2015*	*2015-2020*	*2020-2030*	*2006-2030*
Energy	*10,220*	*14,033*	*20,233*	*25,930*	*32,796*	*41,815*	*10.89*	*5.63*	*6.13*	*12.88*
Industry	*891*	*1,354*	*1,602*	*1,836*	*2,065*	*2,318*	*8.87*	*2.92*	*2.63*	*6.67*
Agriculture	*6,462*	*6,405*	*6,573*	*6,657*	*6,762*	*6,867*	*0.19*	*0.26*	*0.32*	*0.26*
LUCF	*-2,083*	*-1,932*	*-1,785*	*-1,420*	*-1,000*	*-680*	*-1.59*	*-4.09*	*-5.21*	*-2.81*
Waste	*138*	*158*	*183*	*209*	*254*	*294*	*3.62*	*2.84*	*4.07*	*4.71*
Total	*15,628*	*20,018*	*26,806*	*33,212*	*40,877*	*50,614*	*7.95*	*4.78*	*5.24*	*9.33*

Source: MNET,UNEP: Mongolia Second National Communication, Under the United Nations Framework Convention on Climate Change, 2010.

Since GHG emission projections which were prepared for Second National Communication in 2010, there were several GHG emission projections in the energy sector such as the Energy sector GHG emission projections prepared in 2013 for Green Strategy Policy developed by MEGD. (Dorjpurev J. 2013) (In the Table 6.2 included as “Green Strategy”), and also the energy sector projections prepared by GGGI in 2014 (GGGI 2014). The comparison of those projections is shown in Table 6.2.

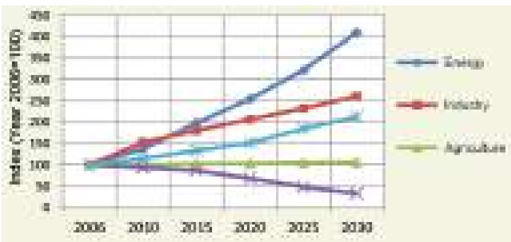

Figure 6.1 Projections of GHG emissions and removals (sector). *Source: MNET,UNEP: Mongolia Second National Communication, Under the United Nations Framework Convention on Climate Change, 2010*.

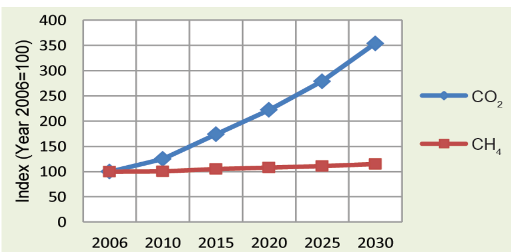

Figure 6.2 GHG emission projections (by gas types). *Source: MNET,UNEP: Mongolia Second National Communication, Under the United Nations Framework Convention on Climate Change, 2010.*

Figure 6.2 shows that those 3 different projections are rather similar. Average of those projections shows that energy sector GHG emissions will reach 20 million tons CO_2*-eq* in 2015, 36 million tons CO_2*-eq* in2025 and 43 million in 2030 *(Figure 6.3).*

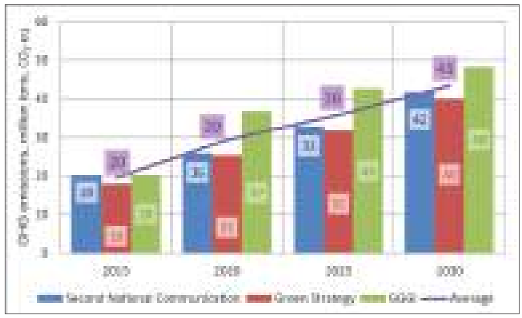

Figure 6.3 Comparison of GHG emission projection prepared in three different studies

6.2 Mitigating GHG emissions in mid-term period

Mitigation of GHG emissions shall be understood by countries in a relative sense. There are two concepts on it. Firstly, developed countries are obligated by the Kyoto protocol to reduce their GHG emissions by certain percentage comparing to that of 1990. Secondly, for the developing countries, there is no obligatory requirement to mitigate their current GHG emission level because their GHG emissions might increase in a certain period of time to meet their sustainable

Table 6.2 GHG Emission projections from Energy sector prepared in three different studies

		2015	2020	2025	2030	2035
SNC	Consumption	7,8	10,4	13,7	17,7	-
	Supply	12,5	15,6	19,2	24,1	-
	Total	20,2	25,9	32,8	41,8	-
Green Strategy	Consumption	6,9	8,9	11,3	14,0	-
	Supply	11,0	16,5	20,5	26,0	-
	Total	17,9	25,4	31,8	40,0	-
GGGI	Consumption	9,0	11,9	14,8	18,2	21,8
	Supply	11,4	24,8	27,8	30,1	33,8
	Total	20,4	36,8	42,6	48,3	55,6

development policies and goals. Therefore, these developing countries have proposed to reduce the emission that could normally be emitted at the certain level of the development by definite level through taking any appropriate actions. In other words, these countries work towards reaching relative targets.

The main source of GHG emissions in Mongolia is coal combustion. Hence, GHG's mitigation policy should be directed towards burning coal by environmentally friendly technologies and reducing coal consumption through substituting coal with different sources, as well as focusing on the efficient use of electrical and thermal energy produced from coal burning, and the use of energy efficient applicants is important. In addition, the significant reduction of the demand for fossil fuel through the use of renewable energy sources or other clean energy sources is potentially possible to achieve.

GHG emissions could possibly be mitigated through the use and establishment of large scale hydropower plants, wind farms and large scale solar power plants by using the abundant resources of sun, wind and water of Mongolia.

For Mongolia, the measures to be implemented in a near and mid-term future to reduce GHG emissions is more efficient use of traditional energy sources like coal. In the energy sector, there is a great opportunity to mitigate GHG emissions by using fossil fuel efficiently in power plants and heating boilers and by promoting the end-users' proper use of energy. During the long-lasting winter season in Mongolia, heating of offices and apartments is a main condition of maintaining sustainability of livelihoods and economic activities. The cold season in Mongolia lasts for almost for 8 months, and sometimes air temperature reaches to -30°C to -40°C. Also, through the improvement of centralized and decentralized heating supply systems and building insulation, the fossil fuel consumption is to be reduced, and that would potentially mitigate GHG emissions.

The list of appropriate measures to mitigate GHG emissions from the energy sector in the near and mid-term future are shown in Table 6.4.

Livestock is a main methane emission source in Mongolia. 90-93% of total methane emissions are from livestock. Potential options for methane emission reductions in livestock are as follows (Dagvadorj et al. 2010):

- to limit the increase of the total number of livestock; and
- to increase the productivity of each type of animal, especially cattle.

The forest is an economically, socially and environmentally multi-beneficial complex ecosystem. The Mongolian forest is economically beneficial, and it plays a main role in biodiversity conservation and maintenance of carbon balance in the region. Certain amounts of carbon temporarily captured in the forest; therefore, the emissions from the activities including forest fire, decomposition and logging, and the sequestration of its increase will both have an impact on accumulation of carbon in the atmosphere.

Mitigation options for GHGs mitigation and carbon sequestration in the forest sector (Dagvadorj et al. 2010) are:

- *Natural restoration;*
- *Tree planting;*
- *Afforestation and reforestation;*
- *Implementation of Green Belt program; and*
- *Use of bio-energy.*

In terms of land use and hygienic conditions, waste related issues area serious problem for the cities and settlements, particularly for Ulaanbaatar. The methane emission from waste is comparatively low; however, the following measures can be used in the waste sector:

- *Produce methane from the waste;*
- *Improve waste management; and*
- *Recycle the waste.*

In order to conduct GHG's mitigation assessment, making an analysis on various technologies and practical measures to reduce GHG emissions is necessary. In this regard, the methodology of developing several scenarios for the development trend of the given country and making a comparative analysis is used for such assessment. A Baseline scenario of the development is comparatively analyzed with GHGs mitigation scenario. The Baseline scenario of the development shows the future increase of GHG emissions under the business-as-usual scenario.

It has been conducted several studies of GHG emission projections and mitigation possibilities in the Mongolian energy sector with support from international organizations (GGGI 2014; Dorjpurev J. 2013; ADB 2013). The Global Green Growth Institute (GGGI) has prepared the report of "Strategies for Development of Green Energy Systems in Mongolia project". The goal of this project has been to explore several different "scenarios" of evolution of Mongolia's energy sector, with a focus on identifying green energy options-options for providing required energy services (heat, light, transport, and goods, for example) while reducing environmental impacts-for Mongolian policymakers. An energy scenario is an internally consistent "story" of how energy use, power and heat supply, and the underlying economy, may develop in the future. Scenarios for the project were developed with the input of, and with data collected by, an Advisory

Table 6.3 GHG emission reduction options in the near future

Sectors	Options	Mitigation technologies
Energy supply	Increase renewable energy options	Hydropower plants
		Wind farms
		PV
		Solar heating
	Improve the efficiency of heating boilers	Improve the efficiency of existing HOBs
		Install boilers with the new design and high efficiency
		Convert steam boilers into small capacity Combined Heat and Power plants
	Improve household stoves and boilers and change fuels	Modernize existing household stoves and boilers
		Change fuels for household stoves and boilers
	Improve coal quality	Coal benefication
		Apply effective mining technology including selective mining and dewatering system, coal handling plants
	Improve CHP plants	Improve efficiency
		Reduce internal use
Energy demand sector	Improve building insulation and heating systems	Improve building insulation
		Improve heating systemsin buildings
		Improve lighting efficiency
	Increase energy efficiency in Industry	Implement management in energy efficient use in industry
		Implement motor efficiency improvement
		Technology changes (e.g., dry processing for cement industry, etc.)

Source: Dagvadorj D., Dorjpurev J., Namkhainyam B. (2010) Mitigating climate change: Needs and opportunities to reduce GHG emissions. Ulaanbaatar

Committee of officials from the Ministry of Energy and several other organizations in Mongolia, as well as input from a local consultant team.

This study presents four broad scenarios of how energy supply and demand could evolve in Mongolia through the year 2035. The four scenarios were developed over the course of 2013 with input from a project Advisory Committee and others:

- The *reference* scenario reflects a continuation of a largely coal-based energy supply in an economy driven largely by mining exports, especially of coal and copper. This scenario assumes relatively few changes in energy supply or the intensity of demand other than gradual improvements in some technologies (e.g., vehicles, appliances) consistent with international trends likely to evolve regardless of changes in Mongolia's policies.
- The *recent plans* scenario begins to introduce a shift to renewable energy and increased energy efficiency based on recent plans and priorities of the Ministry of Energy and Ministry of Environment and Green Development: namely, large hydropower plants (e.g., Sheuren) and wind turbines, application of pulverized coal combustion technologies, and programs to implement efficient lighting and improved insulation of panel apartment buildings.
- The *expanded green energy* scenario describes a future where Mongolia makes an even stronger transition to renewable energy and implements extensive energy efficiency measures across its economy. This scenario also builds from work on renewable energy and energy efficiency potentials conducted in the country, including work bythe Ministry of Energy, the Ministry of Environment and Green Development.
- The *shifts in energy export* scenario builds from the *expanded green energy* scenario; In this scenario, Mongolia shifts the types of fuel and energy that it exports: rather than exporting an increasing amount of coal from Tavan Tolgoi and other deposits.The country instead exports renewable (wind and solar) electricity.

This study finds that, in the *reference* scenario, total energy demand in Mongolia may rise from less than 150 Petajoules (PJ) in 2010 to over 400 PJ in 2035. The *reference* scenario sees demand for electricity (especially from industry) and oil products (especially from cars and trucks, as diesel and gasoline) grow especially fast – both at over 5 times 2010 levels in 2035.

The *expanded green energy* scenario implements deep energy efficiency strategies in all sectors, from best-available technologies in industry, to highly efficient vehicles (including hybrids and, over time, electric vehicles) in the transport sector, to highly energy efficient building retrofits, including for gers. Together, these efforts reduce energy demand by 32% relative to the *reference* scenario in 2035, slowing the average rate of growth of energy use from 4.7% to 3.1% between 2010 and 2035. The *shift in energy export* scenario differs from the *expanded green energy* scenario only in what type of energy is exported.

The *recent plans* and *expanded green energy* scenarios also see progressively greater penetration of renewable electricity on the supply side. In the *reference* scenario, coal-fired power plants remain the dominant means of fulfilling new electricity demands, and the fraction of Mongolia's electricity generation supplied by renewable energy remains under 5% through 2035 (Figure 6.4).

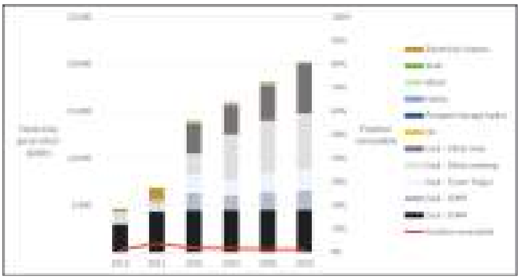

Figure 6.4 Electricity generation in the reference scenario. *Source: GGGI (2014) Strategies for Development of Green Energy Systems in Mongolia, Draft Final Report*

The *expanded green energy* scenario sees all currently proposed hydro (e.g., Shuren, Egiin, Orkhon Tuul), solar PV (Sainshand, Khurmen), and wind (e.g. Gobisumber, Umnogovi etc.) power projects realized. When combined with the reduction in electricity demand resulting from the extensive energy efficiency measures discussed above, this allows for the avoidance of significant new (and expanded) coal-fired power plants, and for some existing plants to be phased down. The fraction of electricity provided by renewable energy in this scenario exceeds 40% as early as 2030. And, though a complete assessment of costs was not possible, this study estimates that the expanded green energy could cost nearly 500 million dollars less than the reference scenario cumulatively through 2035 (on a “net present value”, NPV basis) due to the significant fuel savings associated with energy efficiency(GGGI 2014).

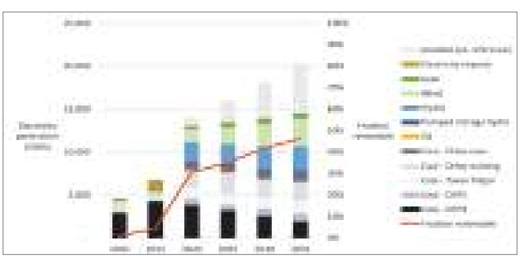

Figure 6.5 Electricity generation in the expanded green energy scenario. *Source: GGGI (2014) Strategies for Development of Green Energy Systems in Mongolia, Draft Final Report*

In the fourth, *shifts in energy export* scenario, Mongolia rapidly builds out solar PV and wind resources in the Gobi region, starting with 30 MW in 2017 and then growing installations at an average annual rate of about 60% (higher in early years, lower in later years), an average rate of renewables expansions that matches China’s over the past two decades. At this level, Mongolia could install nearly 12 GW of renewables in the South Gobi region by 2031, displacing a significant fraction (potentially even all) of the value of coal exports by that time, depending on the value of exported electricity and fossil fuels. Exporting this amount of power will require large investments in transmission and distribution facilities, probably with multiple connections to entry points on the Chinese grid as well as high-voltage direct current (HVDC) lines to other nations, such as Korea and Japan. Though highly ambitious, the shifts in the *energy export* scenario could give Mongolia a significant source of “green growth” and, by substituting exports of fossil fuels for exports of renewable electricity, increase the country’s “low-carbon competitiveness”, should global demand for fossil fuels begin to decline based on concerns by major economies (including China) regarding climate change.

This study also quantified the potential to reduce greenhouse gas (GHG) emissions in Mongolia. Implementing all measures studied, as in the *expanded green energy* scenario, could reduce GHG emissions by 28 million tones CO_2e in 2035, or nearly 50% compared to the *reference* scenario, and holding GHG emissions essentially constant after the 2020 case (Figure 6.6).

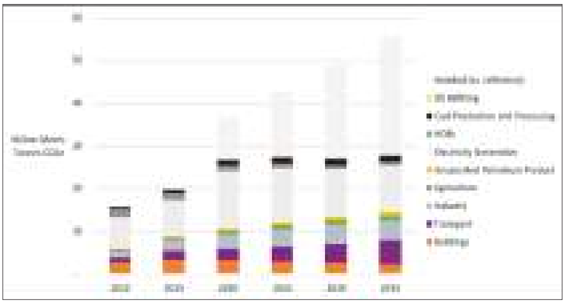

Figure 6.6 GHG emissions by sector, expanded green energy scenario. *Source: GGGI (2014) Strategies for Development of Green Energy Systems in Mongolia, Draft Final Report*

Figure 6.7 displays the GHG emissions abatement potential associated with each of the major measures analyzed in this study. The five measures with the greatest GHG abatement potential are (from higher to lower potential): energy efficiency improvement in the mining sector, wind power, hydropower, higher-efficiency new coal power plants, and transport mode shift to rail. The high potential for these first four measures is not surprising, given the rapid growth in the mining sector and the dominance of GHG emissions from power supplies. The high GHG abatement potential from mode shift in the transport sector is surprising and interesting, and derives in large part from the assumption that transport demand will grow rapidly in Mongolia (about 5% per year), and that most of that new demand will be in road transport. However, if transport activity does not grow that fast, overall energy use, GHG emissions, and emissions abatement potential may be less in the transport sector than indicated here.

This analysis suggests that several policy initiatives warrant further consideration in Mongolia. Each of these initiatives is associated with measures (as in the cost curve) that could reduce Mongolia's GHG emissions by at least one million tonnes in 2035 relative to the referenced case:

- Strengthening the 2007 Renewable Energy Law, and developing a new Renewable Energy Program, based on analysis such as that presented in this report;
- Reforming subsidies on coal and electricity to minimize support, via tariffs or otherwise, for inefficient consumption and high-carbon energy sources;
- Developing and enforcing more stringent building energy codes and appliance of efficiency standards, and continuing initiatives started in recent years;
- Expanding building retrofit programs from the existing programs focused on energy retrofits of existing apartment buildings;
- Developing guidelines for urban planning and transportation planning, including combined land use and transportation planning, as well as a national strategy for moving people and goods, particularly by rail etc.;
- Developing energy or emissions standards for widely used industrial technologies (e.g. those in the mining sector) or for primary industry sectors that produce particularly energy-intensive materials; and
- Enhancing vehicle efficiency or emissions standards

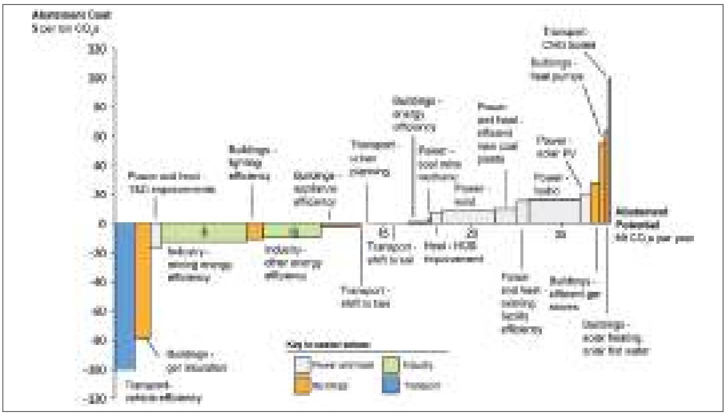

Figure 6.7 "Cost Curve" of GHG emission abatement opportunities and cost-effectiveness of CO_2e reduced in 2035. *Source: GGGI (2014) Strategies for Development of Green Energy Systems in Mongolia, Draft Final Report*

In addition, Mongolian ministries may wish to further explore formulations of national goals for GHG emissions reduction. In particular, in addition to goals on territorial GHG-intensity (per unit of GDP) that MEGD has considered, developing a supplemental goal based on extraction-based GHG-intensity may help Mongolia to more comprehensively track progress towards a green economy and away from "carbon entanglement", or the over-reliance on coal for economic growth.

Each of these policy initiatives could likely also benefit from further research, pilot programs, and program development.

In the study, "Economics of Climate Change in East Asia", which was conducted by Asian Development Bank in 2013, the future projection of GHG emissions in East Asia and the cost estimates were calculated respectively for each of the East Asian countries. Marginal abatement cost curves for Mongolia is shown in Figure 6.8.

According to the picture, the use of large-size trucks is a high-efficient option, while the use of gas is an option which is to reduce GHG emissions at maximum level or by 5-6 million tonnes. However, issues related to the gas supply or provision was not included in the study report. When conditions are in place to exploit natural gases domestically by 2030, to produce gas with coal gasification technology or to import natural gas from neighboring countries, this option can be implemented.

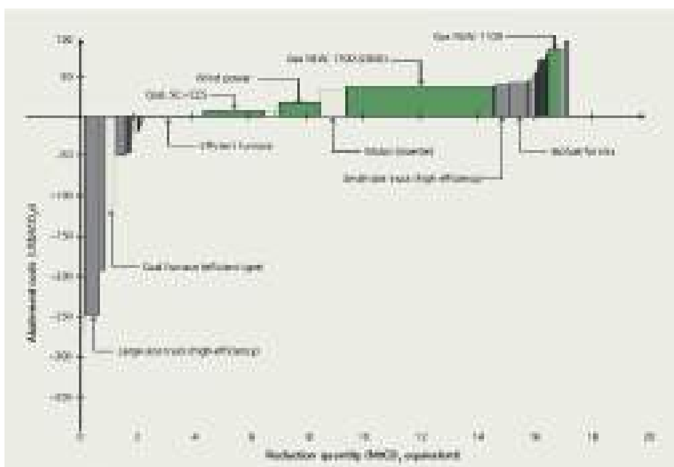

Figure 6.8 Marginal Abatement Cost Curve for Mongolia for the High Rate Scenario, 2030. *Source: ADB (2013) Economics of Climate Change in East Asia*

6.3 Policies and Measures to Reduce GHG Emissions

Countries develop nationally appropriate and specific mitigation policies, and implement a wide-range of measures in reducing GHG emissions. The implementation of those policies and measures depends on the specific characteristics of the given country and the level of cooperation, mutual understanding and relations between countries; however, any given approach has both advantages and disadvantages (Dagvadorj et al. 2010).

- In the evaluation of policies and measures 4 main criteria must be met; 1) no negative impact on environment, 2) low cost, 3) opportunity to disseminate (including funding), and 4) possibility to organize are used.
- Commonalities in GHG mitigation policy activities:
  - Implementing and linking climate change policies with other developmental policies would support in overcoming certain obstacles or constraints;
  - Rules and standards have an impact on determining GHG emission levels; however, these cannot improve or create a new and innovative technology;
  - Tax and levies cannot become an evaluation of GHG mitigation activities. Some press have defined that an efficient approach to the pricing of GHGs is a tax;
  - Financial incentives (subsidies and tax concession) are used by the Government in diffusion and promotion of new technology. Economic cost is generally higher than above mentioned instruments; therefore, these are crucial for overcoming the barriers;
  - Industrial and intergovernmental voluntary negotiations and cooperation are politically positive, and it increases the understanding between interested parties as well as plays an important role in developing national policies. Most of the negotiations are run under business principles; therefore, it cannot reduce the emissions. However, there are good examples where contracts signed in some countries have accelerated the use of best technologies, which has significantly reduced emissions.;
  - The means of communication or media (i.e. advertising company) can impact the quality of the environment positively by providing necessary information; however, it is difficult to assess its impact in a quantitative manner; and
  - Research studies, and processing and visual presentation activities can take the promotion of advanced technologies and sustainability decrease the expenditures to the next level.

Even though the total amount of greenhouse gas emissions of the country is relatively low, Mongolia has developed and is implementing GHG mitigation policies and strategies just like other countries. These policies and measures are not only directed at reducing GHG emissions, but also play an important role in increasing the efficient use of energy and heating, and introducing environmentally friendly technologies.

Mitigation policy is aimed at the following issues (MNET 2009):

(a) Set up institutional framework and ensure organizational cooperation: As previously mentioned, the energy sector isa main source of greenhouse gas emissions, and as energy issues are getting many-sided, mitigating policies require a special inter-sectorial coordination. Ministry of Energy (MoE) bears the main responsibility for implementing and making decisions on issues relevant to the energy sector, while Ministry of Environment and Green Development (MEGD) is a leading entity for organizing mitigation activities. Hence,

enhancing inter-organizational coordination for developing policies and implementing projects and measures directed at GHG mitigation is important.

(b) Set funding priority: GHG mitigation measures require a great amount of investment. Having limited economic resources or capacity, determination of spending priority or sequence of potential financing sources at a national level, and allocation of the sources by technical and economic criteria, is vital for Mongolia. Particularly, the funding should be directly transferred to the organization that performs an operation; and for cooperative organizations, funding should be allocated per organization.

(c) Set legal framework: As an organizer and supporter of climate change response measures, the Government is responsible for creating legal and institutional frameworks. Generally, mitigation projects require a huge amount of initial investment and modern technologies; hence, certain economic and policy mechanisms are important for the implementation of GHG mitigation measures. For instance, one of the economic mechanisms to overcome some investment barriers could be tax, tax concession and other compensations. In this case, more efficient technology, low carbon sources of energy and the best resource management should be implemented. Tax concession is especially important when buying energy-saving applicants by import and leasing. Moreover, certain incentives can be used for financing the below measures including:

- New technology research and development;
- Low interest loans;
- Introduction of energy-efficient applicants and equipment; and
- Public awareness activities and so on

Activities to establish coordination mechanisms are directed at the following:

- Develop new regulations and rules relevant to energy efficiency standards and natural resources management activities; and
- Improve the implementation of existing regulations and rules.

Technology diffusion initiatives are important for improving energy efficiency in the energy supply and its consumption. Public education and close cooperation between producers and consumers are important factors for the implementation of mitigation measures. In order to implement these initiatives, it is necessary to use a wide-range of education and information tools including efficient labeling of the applicants, promotional brochures for owners of buildings, and radio and TV broadcasts. In addition, measures including the expansion of energy networks, development of hydropower plants and the use of solar and wind power systems play a significant role in reducing greenhouse gas emissions and are also important for enhancing sustainable development in rural areas.

There are several policy documents including laws and programs that are being implemented in regard to GHG mitigation activities.

National Action Program on Climate Change (NAPCC) (MNET 2011b).

The goals of the program are to ensure environmental sustainability, development of socio-economic sectors adapted to climate change, reduction of vulnerabilities and risks, and mitigation of GHG emissions as well as promoting economic effectiveness and efficiency and implementation of 'green growth' policies.

One of the strategic objectives of the program is to mitigate GHG emissions and establish a low carbon economy through the introduction of environmentally friendly technologies and improvement in energy effectiveness and efficiency.

In order to implement this strategic objective the following activities shall be implemented:

Table 6.4 GHG Emission reduction measures in two phases of NAPCC implementation

***In the first phase (2011-2016*)**	***In the second phase (2017-2021)***
Reduce internal fuel consumption of electric and heat power generations	Convert Ulaanbaatar Power Plant-3 and Darkhan Power Plant to high efficient technology withsupercritical parameters
Increase efficiency of energy transfer and distribution	Set up high efficiency and environmentally sound central heating systems in aimag centers
Establish a renewable energy fund	Supply by electricity all soum centers and settlements not able to be connected to the central grid using renewable energy sources
Develop wind and solar electricity generation systems	Use solar and geothermal energy and bio gas forheating and hot water suppliesof private houses
Supply soum centers (smallest administrative unit of Government in Mongolia) and settlements that are not connected to the central electricity network with electricity from renewable energy generators	Expand hydro power generation and increase construction of hydropower plants in appropriate places
Conduct a pilot study into, and introduce heat pump technologies	Explore possibilities to build large scale solar power plants
Conduct technological research and development into the utilization of methane gas from underground mining	Expand research on use of nuclear energy
Introduce and disseminate improved technology for coal processing and clean fuel processing in local areas	Set up integrated gasification combine cycle plants
Develop advanced technologies for, and increase the use of, organic waste processing and production of liquid and gas fuels	Build coalmine methane gas power plants for electricity generation
Introduce automatic heat regulators in building heating systems of Ulaanbaatar, Darkhan and Erdenet cities and implement the first stage of providing urban users with heat meters	Expand the liquid gas distribution network
Limit incandescent light bulb usage	Supply clean coal to households for consumption in urban Ger districts
Develop technologies for dry (lower emission) cement production	Continue the introduction of automatic heat regulators in building heating systems of Ulaanbaatar, Darkhan and Erdenet and complete the provision of heat meters to all urban users
Prioritize road construction projects that connect to the international road network	
Improve urban road traffic management and reduce traffic congestion	Limit incandescent light bulb usage
Expand the railway network in the Gobi desert and the eastern part of the ccountry and restrict the usage of haulage trucks	Begin initial research into building an underground metro in Ulaanbaatar
Increase hydrogen and hybrid fuel use in vehicles and encourage low consumption cars	Initiate a shift from diesel railways to electric rail
Extend the number of buses and trolleybuses used for public transport in cities	Innovate enhanced insulation materials for buildings using nanotechnology
Install insulation in buildings with high heat loss in Ulaanbaatar and take measures to reduce heat loss	Improve tree nurseries, restrict forest logging for household consumption, increase forestation and reforestation activities and increase green spaces in urban areas
Improve land use efficiency, increase re-use of abandoned crop lands, imf cultivation of wilderness and expand mining rehabilitation efforts	Introduce technologies for producing gas and other fuels using sewage mud from waste water treatment plants
Conduct forestation and reforestation activities, expand green compounds and increase carbon sequestration	
Protect forests from harmful insects, ban illegal logging and implement measures against forest resource depletion	
Build solid waste treatment and re-use plants	

Source: MNET (2011b) National Action Program on Climate Change. Ministry of Nature, Environment and Tourism of Mongolia (MNET) Ulaanbaatar

National Renewable Energy Programme

In June 2005, the Parliament of Mongolia approved the National Renewable Energy Program to promote the use of renewable energy in Mongolia. The program aims to create conditions necessary for ensuring ecological balance, unemployment and poverty reduction, and to sustain social and economic development by increasing the percentage of the renewable energy shares in the total energy supply of Mongolia, by improving the structure of the energy supply, and by widely applying renewable energy in rural areas.

The goal envisioned in the program is to increase the percentage of the renewable energy shares in the total generation to 3%-5% by 2010 and 20%-25% by 2020.

Renewable Energy Law

In order to prepare the legal environment for implementation of the goals in the National Renewable energy program, the Parliament of Mongolia passed the Renewable Energy Law in January, 2007.

The primary stipulation of this law provides a feed-in tariff for the grid and the independent power generation from renewable energy, as shown in Table 5.5. Any price difference of electricity generated by a renewable energy power source, which is connected to a transmission network, shall be absorbed into the selling price from other power plants connected to the transmission network.

According to this law, the Renewable energy fund shall be established and the fund will be disbursed to compensate for price differences of energy produced by an independent renewable energy power sources as specified in Table 5.5.

According to the renewable energy law, feed-in tariffs shall be stable for a minimum period of 10 years starting with the date this law was enforced.

Barriers for implementation of mitigation technologies in the energy industry sector (MEGD 2013a).

In general, barriers for implementation of mitigation technologies in the energy industry sector are similar but there are different circumstances depending on technologies. The common economic and financial barriers are inappropriate financial incentives; the high cost of capital; the high transaction cost; the lack or inadequate access to financial resources; and uncertain macro-economic environment.

Common barriers regarding the policy are the legal and regulatory aspects; the lack of long-term political commitment and uncertain government policies (political risks for investors); the lack of government control for implementation of laws and regulations; and the government or utility monopoly of the energy sector.

Table 6.5 Feed-in tariffs, USD/kWh

Type of renewable energy generation	***Connected to transmission grid***	Independent power generation		
		Up to 500 kW	501-2000 kW	2001-5000 kW
Hydropower station(up to 5000 kW)	0.045-0.06	0.08-0.10	0.05-0.06	0.045-0.050
Wind power source	0.08-0.095	0.10-0.15		
Solar power source	0.15-0.18	0.20-0.30		

Moreover, common barriers regarding the market and network aspects are under developed competition, and insufficient coordination between relevant ministries and other stakeholders.

For Hydro Power Plants, politics is the main barrier. Decision makers and experts in the energy sector understand the need for developing large scale hydropower plants in the current energy system of Mongolia. However, these kinds of projects have not materialized due to political reasons and special interests. The plans on building large scale hydro power plants are reflected in every policy document of the energy sector. The discussions on the required investment and projects have taken place a few times in parliament and cabinet meetings. Even so, it still has not moved forward due to political reasons.

Regarding the wind park, the highest priority barrier is system constraints (capacity limits of the grid system). Wind parks adversely affect the energy system stability as their operations and electricity supply depends on irregular wind availability, especially for a country like Mongolia whose energy system consists of small sized coal fired power plants. Connecting many high capacity wind power plants will destabilize the system.

The main difficulty hindering the implementation of large hydro power plant projects is the low electricity tariff. Even though in the renewable energy law, it is mentioned that feed-in tariff is to be provided for electricity supplied by renewable energy resources, the electricity generated by HPPs with capacity of more than 5MW is not covered under this feed-in tariff. The low tariff hinders investment in hydro power plant projects as the power purchase agreement doesn’t reflect feed-in tariffs mentioned in the Renewable Energy Law.

On the other hand, there are many companies who are interested in developing wind parks because the Renewable Energy Law has explicitly stated the feed-in tariffs are to be provided for electricity supplied by wind. As of 2012, there are five companies which have obtained special licenses to construct wind parks and the planned installed capacity of all these wind parks is 500 MW.

Enabling framework for overcoming the barriers in the Energy sector (MEGD 2013a).

- In order to encourage the development of climate technology in the energy industry subsector, the government should implement the concession law which was adopted by Parliament in 2010 for both public and private sectors. Climate technologies such as large scale HPP, Wind Park and Efficient coal fired power plant projects should be included in this list of concessions which is approved by the Mongolian Government.
- Another way to get financial investment sources in climate technologies is to use the Development Bank of Mongolia. According to the Development Bank Law, the Development Bank shall provide loans to finance large scale development projects and programs approved by Parliament.
- The government should introduce an environmental tax for conventional energy (coal fired power plants).
- The Energy Regulatory Committee should increase energy tariffs to a level which will allow the licensed energy companies to recover their costs and expenses.
- Development plans and programs of the energy sector should align with environmental and green development principles.

6.4 Nationally Appropriate Mitigation Action (NAMA)

High commitments and efforts to reduce GHG emission of developed countries is not sufficient to mitigate and limit the globally changing climate. In this regard, a new concept called Nationally Appropriate Mitigation Action(s) (NAMA) has emerged based on the idea that developing countries also need to take action towards to reduce GHG emission. NAMAs do not bind a legal obligation at the international level, however NAMAs are voluntary actions taken by developing countries to reduce GHG emissions to levels below those of “business as usual” (BAU). At the same time those NAMAs must be support and aligned with national development policy and actions. The concept of NAMAs had its origin in the Bali Action Plan through COP 13 which organized in Indonesia in 2007 under the framework of the UNFCCC. Since then certain decisions are has been made in the negotiations at COPs to modify NAMA concepts.

The goal has risen that the global average temperature should not exceed 2°C compared to preindustrial period (UNFCCC COP15, 2009). To reach that goal the concentration of GHG in the atmosphere most be fluctuate between 445 - 490 ppm. Therefore, it’s necessary to take actions toward to reduce GHG by 50-85% compared to level of 2000 in 2050 and those actions should start no later than 2015 (IPCC 2007). In this regard, not only developed countries but also developing countries need to make the commitment to reduce GHG to reach this ambitious goal. Developing countries are requiring to receive financial, technological and capacity support from developing countries to implement NAMAs and on the other hand developed countries are requiring that the supported NAMAs to the developing counties are able to measure, report and verify (MRV) the reduced GHG emission. Therefore, any actions taken in NAMA framework should be measurable, reportable and verifiable.

NAMA related policies and actions at national level.

The Conference of the Parties (COP) at its fifteenth session which held in Denmark adopted a decision that took note of the Copenhagen Accord in 2009. Mongolia had expressed its intention to be listed as agreeing to the Accord and submitted the list of NAMAs to the UNFCCC secretariat on January 2010. In the list of NAMAs, Mongolia has determined total of six sectors’ 11 actions towards to reduce GHG emission (Table 6.6).

Table 6.6 The list of NAMAs of Mongolia to the Copenhagen Accord

Sectors	Actions
Energy supply	Increase renewable options
	Improve coal quality Improve efficiency of heating boilers Improve household stoves and furnaces Improve CHP plants Increase use of electricity for local heating in cities
Building	Building Energy efficiency Improvement
Industry	Energy Efficiency Improvement in Industry
Transport	Use more fuel efficient vehicles
Agriculture	Limit the increase of the total number of livestock by increasing the productivity of each type of animal, especially cattle
Forestry	Improve forest management and reeduce emissions from deforestation and forest degradation, improve sustainable management of forests and enhance forest carbon stocks in forest sector

Source: http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php

Mongolia has limited possibilities to reduce GHG emission through reducing energy production and consumption to keep sustainable development of the country. As developing country, GHG emission is directly related to energy consumption and economic growth. Therefore, it need to take actions towards to increase the share of renewable energy in the energy production, increase the efficiency of production and consumption, and reduce inefficiency use of electricity, heat, fuel, and raw materials. This will create opportunities to implement actions from the list of NAMAs through to gaining international support, obtaining financing and attracting private investments. The main policy and action paper related to NAMA is "National Action Program on Climate Change" which ratified by Parliament in 2011 and its third strategic objective is directly linked to the implementation of NAMAs. It should also be noted that other existing Low Emission Development Strategies such as Green development policy (approved by Parliament 2014), National Renewable energy program (approved by Parliament in 2005), and New reconstruction midterm development program (approved by Parliament in 2010) have put forward following major objectives towards to mitigate GHG and these are:

- Reduce GHG emissions in the energy sector by 20% by 2030, through increased energy efficiency, and by ensuring that the share of renewable energy used in total energy production is at 20% by 2020, and at 30% 2030
- To increase share of renewable energy in total energy generation to 20-25% by 2020, and to reduce system loss by more than 10% (baseline yr. 2005) by 2020
- To decrease air pollution of UB city 30% by 2012, 50% by 2016 compared to 2010.

To achieve these objectives projects and actions on NAMAs have important role.

Mongolia's total GHG emission is quite low compared to the region. However, the energy intensity is far greater among East Asian countries due to coal based energy and heat production (Figure 6.9). Energy intensity has declined significantly in East Asia Energy intensity has decreased over time in Mongolia, Japan, Korea and China, although the rate of decrease has been far greater in Mongolia (50%) during 1990–2010. Mongolia is the most energy intensive (1.19 kg of CO_2 per unit of GDP), more than five times greater than Japan and 2.7 times greater than the world average (0.44 kg of CO_2 per unit of GDP). Many opportunities exist to deploy energy efficiency technologies through NAMA framework in Mongolia (Economics of Climate change in East Asia, ADB (2013)).

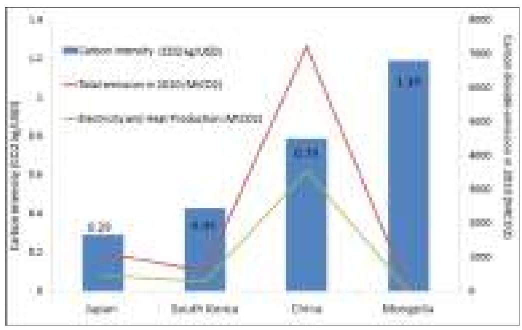

Figure 6.9 Carbon intensity of East Asia, *Source: Economics of Climate change in East Asia, ADB (2013)*

Mongolia works toward to implement actions in the list of NAMAs via approaching to international financing mechanisms and to developing projects proposals and design ideas.

Government of Mongolia take actions on following NAMA related activities into actual projects and actions. These are:

- *NAMA registry* – is emerged based on the desicion of COP 16 and COP 17 and its purpose is to increase opportunities for implementation of and recognition for Nationally Appropriate Mitigation Actions (NAMAs) in developing countries. COP considered that such cooperation will allows developing countries to stimulate best practices between the countries and also help to provide and share the information to international organizations that support NAMAs. Government has the responsibility to constitute the NAMA registry to the UNFCCC secretariat. In Mongolia, MEGD has this responsibility. For developing counties the primary issues to solve in the implementing NAMAs are gain international support for a NAMA such as obtain financial aid, get support on technology transfer and human capacity building. Currently, Mongolia has registered two NAMAs to the NAMA registry and these are a). "National Efficient Lighting Program in Mongolia" and b) "Transforming construction in Mongolia using Supplementary Cementitious Materials".

- *UN REDD+:* Mongolia has joined UN-REDD Programme in June 2011 in order to implement its obligation to UNFCCC and its Kyoto Protocol. The national REDD+ Readiness Roadmap is completed by support of UNDP. The National UN-REDD Programme is presented in the 12th UN-REDD Programme Policy Board meeting held in Lima, Peru on 7-9 July 2014 and approved for adoption. As becoming a partner country of the UN-REDD Programme, Mongolia has the obligation to report and make its forest inventory with method that is consistent with international requirements. The Programme "Biodiversity and Adaptation of Key Forest Ecosystems to Climate Change" supported by GIZ is providing technical assistances on to development of inventory methods, training the national professionals and capacity building, and tools and equipment supplies.
- *The Global Green Growth Institute (GGGI)* has been working in Mongolia since 2011 to support country's green growth policy implementation efforts by analyzing Mongolia's most energy intensive fields such as energy, transportation, building and mining sectors in its Strategies for Development of Green Energy Systems in Mongolia project. The project resulted in developing four major scenarios of for Mongolia's potential energy future and GHG emissions through 2035. According to Expanded Green Energy Scenario, one of four different scenarios, with extensive use of renewable and aggressive energy efficiency improvements could result 28 million tons of GHG emission reductions and about half of the GHG abatement options is available ate negative costs.
- *NAMA Facility:* As announced during the climate negotiations 2012 in Doha, Qatar, Germany and United Kingdom jointly established the NAMA Facility to reduce GHG emission and support substantial investment on development of NAMAs in developing countries. In 2013, contributed jointly an initial €70 million of funding to support developing countries and an additional €50 million to fund a second bidding round for NAMA support projects to be held in 2014. One of the main reasons is for developing countries accessing finance for implementation through existing commercial and public channels has been quite limited. NAMA Facility will create opportunities for developing

countries to receive financial support to implement real projects and programs towards to limit and reduce GHG emissions. Mongolia has submitted two projects as mentioned above: a). “National Efficient Lighting Program in Mongolia” and b) “Transforming construction in Mongolia using Supplementary Cementitious Materials” in the last year (2013).

- *Technology Needs Assessments (TNA)* is the small sized project funded by the GEF and implemented by the UNEP to assist understanding the needs for technology transfer in the developing countries. It provides an opportunity to realize the need for new techniques, equipment, knowledge and skills for mitigating GHG emissions and reducing vulnerability to climate change. Upon exercising the assessment, it will enable the counties to identify and determine technology priorities based on the circumstances of each countries. Mongolia has expressed its interest to implement the projects and signed the agreement with the UNEPRisoe Centre (URC) in 2011. The main output of the project is published in two volumes a). Volume 1 - Climate Change Adaptation in Mongolia and b). Volume 2 - Climate Change Mitigation in Mongolia. TNA Volume 1 describes key adaptation technologies in priority sectors for Mongolia such as animal husbandry, wheat production and pasture management. Technology Action Plan (TAP) is developed for each technology. Moreover, the report provides project ideas for each technology including concrete actions for realization of the Technology Action Plans for each selected technologies. TNA Volume 2 describes key mitigation technologies in priority sectors for Mongolia such as energy production, industry, large scale hydro-power plants, and wind parks, super critical coal fired power plants, energy efficient lighting, and improvement of insulation of panel apartment buildings. The report provides project ideas for each technology including concrete actions for realization of the TAPs for each selected technologies.
- *Pilot Asia-Pacific Climate Technology Network and Finance Center:* The Climate Technology Centre and Network (CTCN) is the operational arm of the UNFCCC Technology Mechanism and it is hosted and managed by UNEP in collaboration with UNIDO. One of the goals of the CTCN is to transfer technologies for adaptation to climate change in developing countries. Mongolia has expressed its interest to receive technical support by the joint ADB-UNEP Project “Pilot Asia-Pacific Climate Technology Network and Finance Center” which implementing by the CTCN in 2013. To implement the project and to transfer the climate technologies (identified by TNA project), Mongolia is identifying source of funding, sectors and actions in collaboration with ADB and UNEP.

Possible financing streams for NAMAs

Except the assistances of international donor organizations and developed counties it’s necessary to establish domestic financial mechanism towards to reduce GHG emission and implement NAMAs in collaborations with domestic banks and other commercial organizations. Mongolia needs to clarify the financial sources at the beginning stage of development of any NAMA projects and actions and possible financing streams are shown in the below (Figure 6.10).

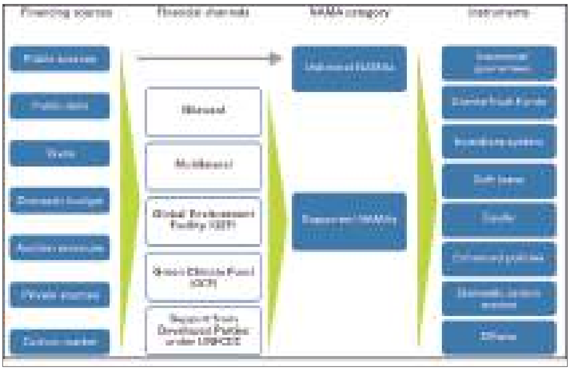

Figure 6.10 Possible financing streams for NAMAs
Source: Perspectives Climate Change (2013)

6.5 International Mechanisms and Opportunities to Implement GHG Mitigation Measures

Clean Development Mechanism (CDM)

Mongolia is a non-annex I party that ratified the United Nations Framework Convention on Climate Change (UNFCCC) on September 30, 1993 and its Kyoto Protocol on December 15, 1999. Every non-annex I country has a responsibility to establish a Designated National Authority (DNA) in order to implement Clean Development Mechanisms under the Kyoto protocol. The main task of the DNA is to assess potential CDM projects to determine whether they will assist the host country in achieving its sustainable development goals, and to provide a letter of approval to project participants in CDM projects.

The Clean Development Mechanism National Bureau of Mongolia (CDM-NB) was established at Ministry of Nature, Environment and Tourism (MNET) on November 14, 2004. Since its establishment, the Bureau has been dealing with the acceptance of CDM project proposals for comment, assessment and issuance of a no objection and approval letter. The supervision of CDM-NB has been delegated to the Climate Change Coordination Office as stipulated in the Law on Air, which was initially approved by Parliament on June 24, 2010, and revised on May 17, 2012. CDM NB has been assigned the additional responsibility of GHG mitigation issues including Nationally Appropriate Mitigation Actions and new market mechanisms. MNET was restructured as Ministry of Environment and Green Development (MEGD) in August 2012. CDM project approval procedures and sustainable development criteria were renewed on May 30, 2013 by the MEGD.

As of July 2014, there are five registered CDM project activities hosted by Mongolia and three of the projects, including the Durgun Hydro Power Plant, the Taishir Hydro Power Plant and the Salkhit wind farm project, received their CER issuance. A brief description of CDM projects in Mongolia is shown in Table 6.7.

A Study of barriers to face during implementation of the CDM project in Mongolia condition is summarized in Table 6.8.The Current situation on CDM is inactive due to several challenges such as the CER price downturn on the market, limited GHG reduction commitments and European Union-Emission trading scheme acceptance on CERs from Least Developed Countries (LDCs) starting in 2013.

Table 6.7 Current Status of CDM projects in Mongolia (as of July 24, 2014)

	CDM project titles	Registration date for UNFCCC (year/month/day)	Annual ER (tCO_2/yr)	Status
1	Durgun Hydro Power Plant	2007/03/23	30,400.00	57,768 of CERs are issued
2	Taishir Hydro power Plant	2007/03/16	29,600.00	19,182 of CERs are issued
3	A retrofit program for decentralized heating stations in Mongolia	2006/07/28	11,904.00	Registered
4	Salkhit Wind Park	2012/03/30	178,778.00	54,422 of CERs are issued
5	MicroEnergy Credits-Microfinance for Clean Energy Product Lines-Mongolia (Program of Activities)	2012/12/12	50,133	Registered

Source: Clean Development Mechanism National Bureau, CER-Certified emission reduction equal to 1 ton of CO_2 –eq emission reduction

Table 6.8 Barriers for implementing CDM projects in Mongolia

Barrier	***Barrier Historical significance***	***Barrier Current significance***
Size – transaction cost barrier	Medium	High
Type – methodological complication barriers	High	High
A/R Market barrier	High	High
CDM consultant barrier	Low	Low
Institutional barrier	High/prohibitive	Very low / none
Documentation barrier	Medium/low	Medium/low
Financing barrier	High	High
Awareness barrier	Medium/high	Very low
Demand barrier	None	High

Source: MNET (2011a) Carbon finance in Mongolia. Ministry of Environment, Nature and Tourism of Mongolia (MNET). Ulaanbaatar

Joint Crediting Mechanism (JCM)

In Copenhagen in 2009, the Parties agreed to limit the rise in the global average temperature to 2° C. The mitigation targets announced by the developed countries and the mitigation measures of developing countries are not enough to avoid exceeding this global limit (State of negotiations. Doha 2012. UNFCCC. COP18 and CMP8). Moreover, Parties agreed that market mechanisms under Kyoto protocol are still not enough to reach the reduction goal or to link the mitigation efforts of developing countries to financial and technological support from developed countries.

One of the several initiatives for mitigation measures by the Japanese government, is Joint Crediting Mechanism (JCM) which was started in 2013. At the moment, JCM activities and efforts such as feasibility studies, information diffusion, capacity building and development of project inventory is underway. Joint Crediting Mechanism (JCM) facilitates diffusion of leading low carbon technologies, products, systems, services, and infrastructure as well as implementation of mitigation actions, which contributes to sustainable development of developing countries. It appropriately evaluates contributions to GHG emission reductions or removals from Japan in a quantitative manner, by applying measurement, reporting and verification (MRV) methodologies, and uses them to achieve Japan's emission reduction target. The JCM contributes to the ultimate objective of the UNFCCC by facilitating global actions for GHG emission reductions or removals, complementing the CDM.

Since Japan and Mongolia signed bilateral documents on the "Low carbon development partnership" to implement JCM on January 8, 2013 for the first time to start this mechanism, the number of partner countries has increased to 12 as of August 2014. The JCM scheme between Mongolia and Japan is shown in Figure 6.11.

For Mongolia, the implementation of JCM would assist in achievement of the NAPCC strategic objective 3: "Mitigate GHG emissions and establish a low carbon economy through the introduction of environmentally friendly technologies and improvement in energy effectiveness and efficiency". Also, JCM will promote the actions listed in Mongolian NAMA submitted to UNFCCC secretariat in January, 2010 according to the Copenhagen Accord.

To implement JCM, both sides established a Joint Committee (JC) which consists of representatives from the two sides. The JC may develop or modify the Rules of Implementation and other rules and guidelines and designates the third-party entities to verify GHG mitigation amounts received under JCM activities.

Studies and activities on the JCM conducted in Mongolia between 2011-2013 are listed in Table 6.9.

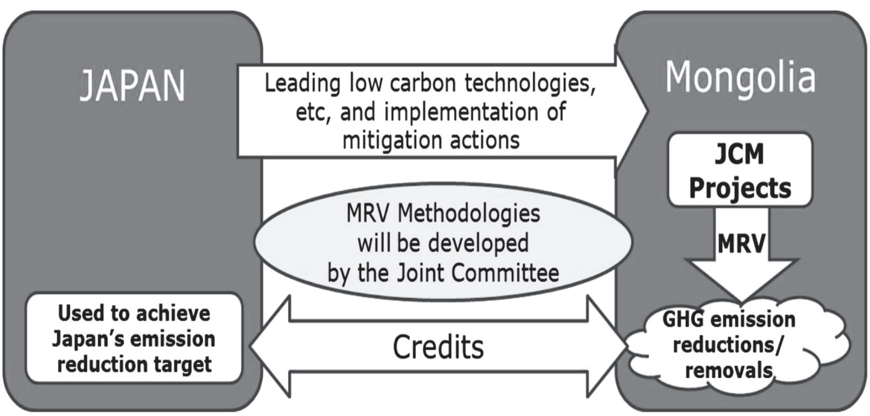

Figure 6.11 The JCM scheme between Mongolia and Japan.

Source:https://www.jcm.go.jp/mn-jp/about. http://climatechange.gov.mn/index.php/mn/market-new-mechanism-mn.html

Table 6.9 Studies on the JCM conducted in Mongolia between 2011-2013

Year	Project type	Project name
2013	JCM Project Planning Studies (JCM PS)	10MW-scale solar power plant and rooftop solar power generation system(Durgun and Ulaanbaatar)
	JCM Methodology Demonstration Studies (JCM DS)	Centralization of heat supply system by installation of high efficiency heat only boiler (HOB) (Ulaanbaatar City, and Bornuur Soum)
	JCM Feasibility Studies(JCM FS)	10MW-scale solar power generation for stable power supply (Govi-Altai province, Taishir Soum)
		Energy Conservation in Cement Plant (Darkhan-Uul Province)
		Improvement of thermal insulation and water cleaning/air purge at power plant (Ulaanbaatar)
		Research on developing projects on wind power generation (Umnugobi province, Tsogttsetsii soum)
		GHG emission reduction by introducing an energy efficient complex in Ger area of Ulaanbaatar (Ulaanbaatar)
2012	MRV Demonstration Studies (DS) using model projects	Replacement of Coal-Fired Boiler by Geo-Thermal Heat Pump for Heating(Tuv province, Zuun mod soum)
		Upgrading and Installation of High-Efficiency Heat Only Boilers (HOBs) (Ulaanbaatar)
2011	New Mechanism Feasibility Study for Multiple Application of Energy Efficiency Improvement Measures at Coal Thermal Power Plants in Mongolia	
	New Mechanism Feasibility Study for Energy Saving at Buildings by Utilizing Geothermal Heat Pump and Other Technologies in Mongolia	

Source: http://gec.jp/main.nsf/en/Activities-Climate_Change_Mitigation-nmfsrepDB-List

6.6 Green development and GHG emission reduction

Assumptions were calculated by GHG mitigation scenarios to promote green growth in the energy sector (Dorjpurev J. 2013). The result shows that per capita GHG emissions (in the reference scenario) was 2.93 tons in 2010 and will increase to 5.1 tons in 2020 (1.7 times), and to 6.86 tons in 2030 (2.3 times). However, Figure 6.12 shows that if all mitigation measures are implemented per capita GHG emissions will be reduced to 4.51 ton in 2030. According to the country's development policy documents, the population will increase by 37% in 2030 compared to 2010 and GDP will increase 7.8 times. GHG emission in the BaU scenario will increase 3.2 times and in the total mitigation scenario performed, GHG emission will increase 2.1 times in 2030.

Table 6.10 Per capita and per GDP emissions from energy industry

	2010	2015	2020	2025	2030
Population, 1000 person	2761.0	2989.1	3236.0	3503.3	3792.6
GDP, Billion USD	5.7	8.0	13.2	23.7	44.4
GHG Emissions, million tons					
Reference scenario	8.1	11.0	16.5	20.5	26.0
Renewable energy (RE) scenario	8.1	11.0	14.7	17.1	20.5
Energy efficiency (EE) scenario	8.1	10.8	14.6	17.5	21.3
Total mitigation scenario	8.1	11.0	13.4	14.6	17.1
Per capita GHG emissions, ton/capita					
Reference scenario	2.93	3.68	5.10	5.85	6.86
Renewable energy (RE) scenario	2.93	3.68	4.54	4.88	5.41
Energy efficiency (EE) scenario	2.93	3.61	4.51	5.00	5.62
Total mitigation scenario	2.93	3.68	4.14	4.17	4.51
Per GDP GHGemissions, kg/USD					
Reference scenario	1.42	1.38	1.25	0.86	0.59
Renewable energy (RE) scenario	1.42	1.38	1.11	0.72	0.46
Energy efficiency (EE) scenario	1.42	1.35	1.11	0,74	0.48
Total mitigation scenario	1.42	1.38	1.02	0.62	0.39

Source: Dorjpurev J. (2013) GHG mitigation scenarios in Energy sector of Mongolia. MNET. Ulaanbaatar

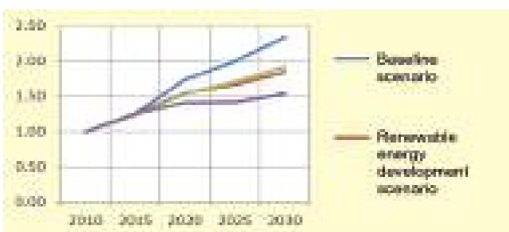

Figure 6.12 Per capita GHG emissions, ton/capita.
Source: Dorjpurev J. (2013) GHG mitigation scenarios in Energy sector of Mongolia. MNET. Ulaanbaatar

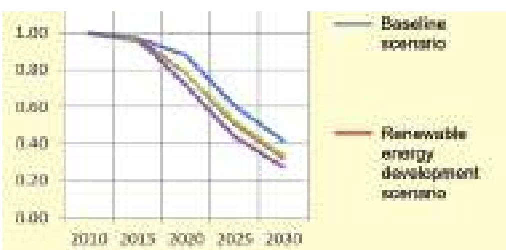

Figure 6.13 Per GDP GHGemissions, kg/USD.
Source: Dorjpurev J. (2013) GHG mitigation scenarios in Energy sector of Mongolia. MNET. Ulaanbaatar

6.7 Enhanced Carbon Sequestration by Land Ecosystems

Carbon Dioxide Removal Methods (CDR)

To slow or perhaps reverse projected increases in atmospheric CO_2, several methods have been proposed to increase the removal of atmospheric CO_2 and enhance the storage of carbon in land, ocean and geological reservoirs. These methods are categorized as "Carbon Dioxide Removal (CDR)" methods. Another class of methods involves the intentional manipulation of planetary solar absorption to counter climate change, and is called the "Solar Radiation Management (SRM)". CDR methods aim at removing CO_2 from the atmosphere by deliberately modifying carbon cycle processes, or by industrial (e.g., chemical) approaches. Some CDR methods rely on biological processes, such as large-scale afforestation/reforestation, carbon sequestration in soils through biochar, bioenergy with carbon capture and storage (BECCS) and ocean fertilization. Others would rely on geological processes, such as accelerated weathering of silicate and carbonate rocks—on land or in the ocean (Figure 6.14).

The CO_2 removed from the atmosphere would then be stored in organic form in land reservoirs, or in inorganic form in oceanic and geological reservoirs, where it would have to be stored for at least hundreds of years for CDR to be effective. Large-scale industrial methods such as carbon capture and storage (CCS), biofuel energy production (without CCS) and reducing emissions from deforestation and degradation (REDD) cannot be called CDR methods since they reduce fossil fuel use or land use change CO_2 emissions to the atmosphere but they do not involve a net removal of CO_2 that is already in the atmosphere. However, direct air capture of CO_2 using industrial methods (Figure 6.14) will remove CO_2 from the atmosphere and is thus considered as a CDR method. The distinction between CDR and mitigation is not clear and there could be some overlap between the two. More important that CDR methods, listed below (Figure 6.14) would give expected positive results without any negative side effects and feasibility each of them needs to be estimated in advance.

Figure 6.14. Carbon Dioxide Removal methods: (A) nutrients are added to the ocean (ocean fertilization), which increases oceanic productivity in the surface ocean and transports a fraction of the resulting biogenic carbon downward; (B) alkalinity from solid minerals is added to the ocean, which causes more atmospheric CO2 to dissolve in the ocean; (C) the weathering rate of silicate rocks is increased, and the dissolved carbonate minerals are transported to the ocean; (D) atmospheric CO2 is captured chemically, and stored either underground or in the ocean; (E) biomass is burned at an electric power plant with carbon capture, and the captured CO2 is stored either underground or in the ocean; and (F) CO_2 is captured through afforestation and reforestation to be stored in land ecosystems. Solar Radiation Management methods: (G) reflectors are placed in space to reflect solar radiation; (H) aerosols are injected in the stratosphere; (I) marine clouds are seeded in order to be made more reflective; (J) microbubbles are produced at the ocean surface to make it more reflective; (K) more reflective crops are grown; and (L) roofs and other built structures are whitened. Source: WGI AR5, 2013.

Enhanced Carbon Sequestration by Land Ecosystems

The key driver of these CDR methods is net primary productivity on land that currently produces biomass at a rate of approximately 50 to 60 PgC yr^{-1}. The principle of these CDR methods is to increase net primary productivity and/or store a larger fraction of the biomass produced into ecosystem carbon pools with long turnover times, for example, under the form of wood or refractory organic matter in soils.

Estimates of the global potential for enhanced primary productivity over land are uncertain because the potential of any specific method will be severely constrained by competing land needs (e.g., agriculture, biofuels, urbanization and conservation) and sociocultural considerations. An order of magnitude of the upper potential of afforestation/reforestation would be the restoration of all the carbon released by historical land use (180 ± 80 PgC;). It was estimated that (House et al., 2002) the atmospheric CO_2 concentration by 2100 would be lowered by only about 40 to 70 ppm in that scenario (accounting for the 'rebound' effect).

The capacity for enhancing the soil carbon content on agricultural and degraded lands was estimated by one study at 50 to 60% of the historical soil carbon released, that is 42 to 78 PgC (Lal, 2004a). The proposed agricultural practices are the adoption of conservation tillage with cover crops and crop residue mulch, conversion of marginal lands into restorative land uses and nutrient cycling including the use of compost and manure. Recent estimates suggest a cumulative potential of 30 to 60 PgC of additional storage over 25 to 50 years (Lal, 2004b).

Finally, biochar and biomass burial methods aim to store organic carbon into very long turnover time ecosystem carbon pools. The maximum sustainable technical potential of biochar cumulative sequestration is estimated at 130 PgC over a century by one study (Woolf et al., 2010). The residence time of carbon converted to biochar and the additional effect of biochar on soil productivity are uncertain, and further research is required to assess the potential of this method (Shepherd et al., 2009).

CDR could also have climatic and environmental side effects. For instance, enhanced vegetation productivity may increase emissions of N_2O, which is a more potent greenhouse gas than CO_2. A large-scale increase in vegetation coverage, for instance through afforestation or energy crops, could alter surface characteristics, such as surface reflectivity and turbulent fluxes. Some modelling studies have shown that afforestation in seasonally snow-covered boreal regions could in fact accelerate global warming, whereas afforestation in the tropics may be more effective at slowing global warming (WGI AR5, 2013).

Estimation of technical mitigation potential through carbon sequestration in Mongolia

There have been few studies of grassland soil carbon sequestration potential in Mongolia. For this assessment (Unique Forestry and Land Use, 2012), an estimate of the national technical mitigation potential was made using the IPCC GHG inventory methodology (IPCC 2006) to estimate change in soil carbon stocks due to adoption of improved management across the whole of Mongolia. The resulting estimate of national technical mitigation potential of improved grassland management is very large, at around 29 million tCO_2e p.a (Figure 6.15 and Table 6.12). This is one-third of energy sector technical potential and 18 times larger than industry sector potential, but there are more barriers to adoption in grassland management. The spatial distribution of technical mitigation potential is quite uneven (Figure 6.15) with some aimags having a much higher technical mitigation potential than others (Table 6.12). This big difference mainly caused by soil features and geographical zones. For instance, soil carbon sequestration potentials are much higher (5,293,481 -5,655,995 tCO_2e p.a.) in Dornod and Tuv aimags where dominant soils are dark rather than in Khentii and Selenge aimags (9650 - 43,237 tCO_2e p.a.). Generally, there are very limited carbon sequestration potentials in Gobi desert areas with low quality sandy and stony soils.

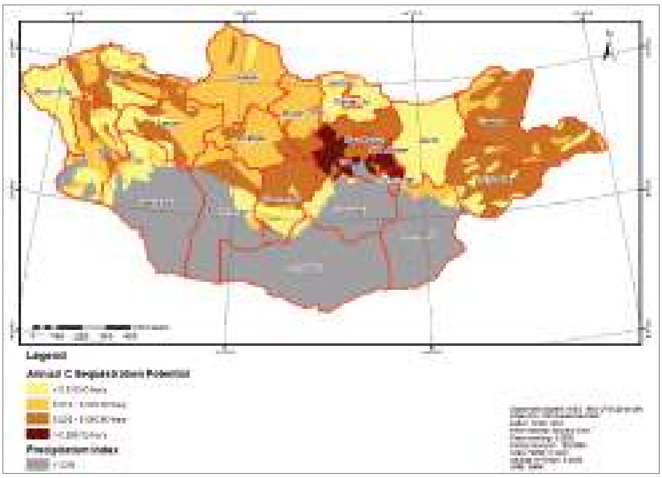

Figure 6.15 Distribution of technical potential for soil carbon sequestration in Mongolia

GHG Mitigation Potential of Selected National Livestock Program Activities

Mongolia has communicated to the international community its interest in implementing Nationally Appropriate Mitigation Actions (NAMAs) in the agriculture (livestock) and sustainable land use sectors, with international support. The ADB-supported regional capacity development technical assistance project, Strengthening Carbon Financing for Regional Grassland Management in Northeast Asia, assisted the Government of Mongolia in elaborating a concept for a NAMA to support sustainable grassland and livestock management. ADB (2014) report provides technical analysis to support the development of a NAMA in the grassland and livestock sector.

Table 6.11 Estimated technical mitigation potential per aimag

Aimag	tCO_2e p.a.	Aimag	tCO_2e p.a.
Arxangai	1,626,705	Orxon	1,078,452
Bayan-O'lgii	387,741	O'vorxangai	1,883,066
Bayanxongor	1,348,840	Selenge	353,555
Bulgan	945,815	Su'xbaatar	2,460,381
Darxan-Uul	0	To'v	5,655,995
Dornod	5,293,481	Ulaanbaatar	237,994
Dornogovi	236,952	Uvs	1,939,033
Dundgovi	43,237	Xentii	271,658
Govi-Altai	160,518	Xovd	1,377,178
Govisu'mber	139,684	Xo'vsgol	1,942,782
O'mnogovi	9650	Zavxan	2,049,414
		Total	29,442,132

Source: Unique Forestry and Land Use, 2012

Biochar studies in Mongolia

The beneficial potential of biochar as an approach to address several environmental challenges: the need for waste management, clean bioenergy, improving degraded soils and mitigating climate change is widely spurred interest in last two decades in the world. Activities related biochar in Mongolia have started since establishment of Ulaanbaatar Biochar Initiative (UBI) in 2008. The Mongolian Biochar Initiative (MoBI), one of the sib projects of UBI, is working with an emphasis on family level low technology production units (5 - 100 t/yr) which utilize feedstock sources such as forest waste, cow dung etc., common to the rural areas of Mongolia. Mongolian Biochar Research Institute (MoBRI) is newly established at Mongolian State University of Agriculture in 2014 to accelerate biochar research and application. The initial studies on biochar properties, its affect on soil and plant, and production technology are conducting by K.Frogner; B.Munkhbat; D.Bayarmaa et al; B.Sanchirmaa, S.Munkhtsetseg et al., ; J.Dugarjav; J.Byatshandaa; and E.Sanaa et al., (Agricultural EngTech Journal, 2014).

Further research is necessary to clarify sequestration potential of biochar made by various feedstocks in different soil type in Mongolia. Moreover, study on the potential opportunity for the cooperative marketing of carbon credits generated from the individual and community units is important to promote significant production and sequestration of biochar from thinly distributed sources of biomass by small scale primary producers.

Carbon Capture and Storage

Carbon Capture and Storage, or CCS is a low carbon technology which captures carbon dioxide (CO_2) from the burning of coal and gas for power generation, and from the manufacturing of steel, cement and other industrial facilities. The carbon dioxide is then transported by either pipeline or ship, for safe and permanent underground storage, preventing it from entering the atmosphere and contributing to anthropogenic climate change (CCS Association. http://www.ccsassociation.org/).

The IEA BLUE Map scenario (IEA, 2010a) shows how it might be possible to reduce by 2050 CO_2 emissions from energy use to 50% of their 2005 level. The scenario indicates that 19% of total emission reductions could come from CCS which is a technically immature (at least in terms of integrating capture, transport and storage in full-scale projects) and, unlike renewable energy and energy efficiency. It does not generate revenues if there is no carbon price or a commercial market for the captured CO_2 for enhanced oil recovery. Potential benefits of CCS are greater for countries that are coal and gas producers, consumers, or those that anticipate chronic effects from climate change (OECD/IEA, 2012). Mongolia might fulfill these criteria and has opportunity to implement CCS through NAMAs or other mechanisms. Preliminary study on CCS in Mongolia is initiating with some international research institutes such as BGR, Germany.

There are some efforts in Mongolia to produce liquid fuels from coal in Mongolia; however, during the technological process, significant amount of CO_2 will be emitted into the atmosphere. There are also preliminary discussions that the emitted carbon dioxide can be injected into ground petroleum layers not only to remove GHG emissions, but also to improve crude oil production. There is a necessity to conduct a comprehensive feasibility study before introducing such technologies.

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7 Technology needs assessment

7. Technology needs assessment

- Mitigation technology assessment	Namkhaihyam B.
- Adaptation technology assessment	Bolortsetseg B.

TECHNOLOGY NEEDS ASSESSMENT

7.1 Mitigation Technology Assessment

This part of the chapter represents findings and suggestions of technologies related to only greenhouse gas (GHG) emissions such as zero or less emitting options. Researchers worlwide agree that the anthropogenic GHG emissions can be reduced with the encouragement of advanced and environmentally-friendly technologies. The Mongolian Government adopted important policies to develop and introduce environmentally-friendly technologies. This includes the Law on Technology Transfer (1998), the Millennium Development Goals-based Comprehensive National Development Strategy (2008), the National Programme of Renewable Energy (2010), the National Programme of Climate Change (2011), and the Green Development Policy Concept (2014). Advanced technologies are an important part of the successful implementation of the above-mentioned policies. This assessment suggest options of the most important technologies, feasible to introduce to Mongolia in the immediate future to reduce the GHG emissions. Assesments of currently used technologies and its needs for each of the sectors are provided: Energy, Industry, Livestock, Land Use and Wastes.

7.1.1 Technology Needs Assessment of Energy Sector

The development of the Mongolian energy sector is heavily dependant on brown coals. The energy sector is a major source of the Mongolian greenhouse gas (GHG) emission. Table 7.1 shows the electricity generation of 50 years from 1960 to 2012.

Table.7.1 Electricity and heat generation of Mongolia, by year (NSO, 2012)

	1960	1970	1980	1990	2000	2005	2006	2010	2012
Electricity generation, billion kW.h	0.18	0.52	1.49	3.1	2.94	3.42	3.54	4.7	4.8
Heat production, million Gcal	0.63	2.44	2.95	5.33	6.9	7.80	7.85	8.32	9.3

In 2012, Mongolia generated a total of 4,797.0 million kW.h of electricity; 4,738.0 million kW.h out of that was generated at combined heat and power plants (CHPs), 47.5 million kW.h at hydro power plants, 0.7 million kW.h at solar and wind plants and 10.8 million kW.h at diesel stations. In addition to that, the country imported 399.3 million kW.h (Dorjpurev D., 2014; ERAoM, 2010-2012). Electricity generated per capita of Mongolia is slightly higher than the world average. It was 1654 kW.h as of 2012. Sources of the energy and their generation schemes in Mongolia are shown in figure 7.1.

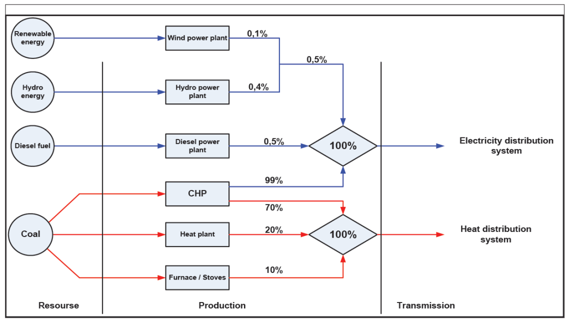

Figure.7.1 Sources and generation scheme of Mongolian energy sector, 2012

Coal-fired Combined Heat and Power Plants (CHP) produce approximately 98.7% of the country's total electrical power energy (2012). Mongolia is rich in renewable energy sources of wind, solar and hydrology. However, utilization of the sources has not reached an efficient level yet. Small-scale hydrological power plants produce electricity but only in quantities less than 1% of the total energy generation.

Electricity Supply

Central Energy System (CES). The Mongolian energy sector consists of three regional inter-connected systems - the Central, Western and Eastern systems, and other numerous isolated grids of those systems. The Central Energy System (CES) is the largest by occupying 92% of installed electricity generation capacity and provides 96% of the electricity supply in the country. Five coal-fired CHPs of the CES generate and supply electricity and heat energy country-wide. The system supplies electricity to the capital city of Ulaanbaatar, larger urban centers, industrial complexes in Erdenet, Darkhan and Baganuur, and aimag and soum centers. In Ulaanbaatar, Erdenet and Darkhan cities, the CHPs also are connected to district heat networks and steam networks for industrial purposes. In addition, the country imports limited amounts of electrical power from Russia. Integrated system of Mongolian energy sector is shown in figure 7.2.

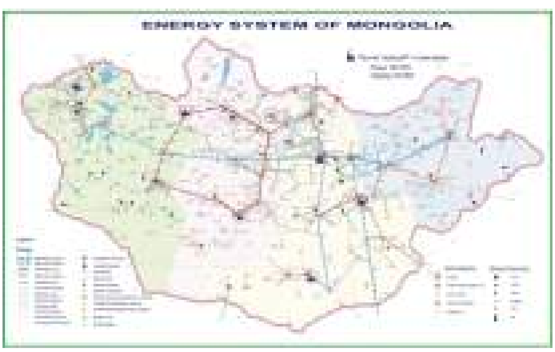

Figure 7.2 Integrated Energy system of Mongolia

The CES is monogenous by its source of electricity generation - it consists of only combined heat and power plants (CHPs) from the beginning. The CHPs generate electrical and heat power utilizing advanced technology. However, lower steam pressure at the CHPs in Mongolia (except CHP 4) does not meet current needs to minimize fuel consumption. The CHPs operate by steam with pressure of 3.5 MPa and 9.0 MPa and this results in a high level of the specific fuel consumption for electricity generation of the CHPs ranging from 370-410 grams CE/kWh.

In contrast, specific fuel consumption for electricity generation of the CHP-4 in Ulaanbaatar is 300.0 grams CE/kW.h on average, relatively lower than others as its steam pressure is 13.0 Mpa and the relevant temperature is 565^0C.

Suggested technology options to be introduced in the immediate future are:

- New large-scale thermal power plants will be constructed at major coal deposits of Baganuur, Shivee-Ovoo and Tavantolgoi. It will create opportunities to introduce super-critical technology of steam pressure to these plants and reduce the GHG emissions. Utilization of the technology is expected to reduce 360 thousand tons of CO_2 per billion kW.h electrical power generated.
- In 2015-2020, it is planned to construct 220 MW Hydro power plants either at the Eg or Selenge river and 50 MW wind park in Sainshand city. Completion of these projects will greatly contribute to increasing efficiency of the integrated energy system and further to the GHG reduction. Large-scale hydro power plants can reduce 897 thousand tons of CO_2 from one billion kW.h electrical power generated.

Renewable Energy Sources. Mongolia adopted the National Renewable Energy Programme to increase the share of the renewable energy in the total energy generation to 3-5% by 2010 and 20-25% by 2020. However, the program implementation is still insufficient and the share of the renewable energy generation accounts for only 1.5%. The share shall increase in the future.

Small hydro-power plants. Small-scale hydropower plants categorized by operation period (as of 2012) are shown below:

Box 7.1

One of the optimum solutions to reduce the GHG emissions is to provide an efficient increase of the energy generation and to make improvements of the energy source compositions. The following options are suggested:

- Power stations/plants of the CES shall be equipped with clean and high-efficiency technologies and techniques and, if necessary, to stop some of the stations where renovation is impossible;
- In case a new power generating source is mandatory, one of following plants shall be selected based on principles to improve energy sources compositions:
  - Hydropower plants with higher capacity;
  - Pumped storage power plants ;
  - Super critical thermal power plants at coal deposits;
  - Solar and wind park

a. Summer and fall seasons:

- Chigjiin river 200Kw in Uvs aimag;
- Bogdiin river 2000 kW in Zavkhan aimag;
- Mankhan and Munkhkhairkhanii 150 kW in Khovd aimag;
- Uenchiin river 930 kW in Khovd aimag;
- Guulingiin river 400 kW in Gobi-Altai aimag;
- Erdenebulganii 200 kW in Khuvsgul aimag;
- Tosontsengeliin 380 kW in Zavkhan aimag and

b. Year-around:

- Durgunii 12 MW in Khovd aimag;
- Taishiriin 11 MW in Gobi-Altai aimag (Dorjpurev D., 2014).

*Wind power generators.*Wind power generators with a capacity ranging between 100-150 kW operate at 10 soum centers of southern aimags of Mongolia. Also, about 20,000 households generate electricity from 50-100 W wind propellers. Wind park of 50 MW was constructed at Salkhit Mountains in Sergelen soum of Tuv aimag, located at 80 km from Ulaanbaatar city in 2013.

*Photovoltaic (PV) Solar System.*Over half of 128,000 herder households use 50 W capacity solar panels and about 40% use 20-30 M panels.The system of 443 kW was constructed in Ulaanbaatar city with Japanese grants in 2011 and are now in operation. The country has conducted various research to utilize solar energy for the heat supply and have gained significant experience in using solar energy for heating of small-scale buildings and water. Currently, solar panels are widely used by tourist camps to heat water for shower purposes. However, solar energy is not as well used for building heating.

Heat pumps of geothermal energy. Interest in using heat pumps of geothermal energy for heating of buildings has increased in Mongolia since 2008. In the past, 3-4 heat pumps were installed in Ulaanbaatar city and Zuun mod city of Tuv aimag; however, those did not operate at reliable regime with high efficiency.

Electricity Generation Technology from Renewable Energy Sources. The below table shows expected GHG emission reductions in case of replacing coal-fired thermal power plants with renewable energy sources.

Table 7.2 Expected GHG emission reductions per electricity power generation unit (MEGD, 2013)

No	Technologies	Average GHG emission reductions
1	Wind park	850 kg CO_2/thousand kW.h
2	Solar electricity PV system	850 kg CO_2/ thousand kW.h
3	Small-scale hydro power plants	850 kg CO_2/thousand kW.h

Heat Supply

Mongolia is characterized by its sharp continental climate with cold and long winters with drops of air temperature to -30-40^{0}C. About 70% of the country's population lives in four major cities, and 330 soum centers of 21 aimags. Ulaanbaatar, Darkhan, Erdenet and Choibalsan cities and 9 aimag centers are connected to the district heating network. Other aimag centers have small-capacity hot water boilers and soum centers have low-pressure water boilers.

The national heat supply system is divided into three categories by its capacity, coverage and efficiency:

- District Heating system (by CHP) in Ulaanbaatar, Darkhan, Erdenet and Choibalsan cities;
- Medium-capacity heating system in aimag and urban centers;
- Small-capacity hot water boilers.

District heating systems of big cities. Total of 6 CHPs (TPP) of different capacities in Mongolia, specifically in its big cities of Ulaanbaatar, Darkhan, Erdenet, and Choibalsan, generate approximately 70% of the country's total heat energy generate. Numerous projects have been implemented to improve efficiency of outdated steam boilers and install new equipment at the CHPs. The projects resulted in significant improvement of the reliable operation and efficiency of the energy production of the CHPs.

Medium-capacity heating boilers. District heating systems in aimag centers and industrial settlements belong to medium-capacity category. Installed capacity of this category is 20-30MW and the efficiency coefficient is not high (η=0.6-0.65). Currently, Khovd, Ulgii, Ulaangom, Sainshand, Sukhbaatar, Murun, Bulgan, Dalanzadgad, and Baruun-Urt cities have access to the district heating network. On the average, calculated heat load of one aimag centers is about 10-15MW and annual coal consumption ranges between 12 000 to 15 000 tons. In the near future, Arkhangai, Bayankhongor, Dundgobi, Uvurkhangai, Khentii, Tuv, Zavkhan and Gobi-Altai aimags have planned to construct new heat plants and renovate networks.

Small-capacity hot water boilers. Small-capacity boilers are the hot water boilers with a capacity higher than 100 kW. Mongolia has over 1100 small-capacity hot water boilers used in all 350 soum centers of the country, and state border sites, villages and ger districts of big cities. As of 2012, Uliastai, Altai, Arvaikheer, Bayankhongor, Mandalgobi, Undurmod, and Zuunmod cities did not have a district heating network. One aimag center at these aimags has 6-8 heating boilers, on the average, to generate heat for public facilities and residential buildings. Also, there are approximately 150 boilers in Ulaanbaatar, 40 in other cities with district heating network, and 50 in cities with no district heating systems. Technology used at the above-mentioned small-capactiy boilers are very old and the efficiency rate doesn't meet current technical and efficiency requirements. Fuel often doesn't combust completely due to the poor designof the most small-scale hot water boilers and their incompabaility with fuel quality and purposes. The efficiency coefficient of the hot water boilers ranges between 0.4 to 0.5 and thus, coal combustion of the boilers is very high.

Low-pressure hot water boilers. In recent years, there is an increasing need to heat newly constructed small-scale buildings such as private residential buildings, schools, kindergardens, khoroo hospitals, khoroo administrations, drug stores, police units, canteens, shops, bath houses and barbershops, ger districts in Ulaanbaatar, Darkhan, and Erdenet cities, aimag and soum centers. Over 4000 small-capacity hot water boilers operate in ger districts of bigger cities of Mongolia consuming 2.0 million tons of coal, 20% of the total coal consumption. The boilers don't meet current technological requirements.

Suggested options of technologies to introduce in the immediate future are:

- Technologies suggested for energy efficiency and saving of the CES and its GHG emission reduction are:
  - Speed Controlled Main Pumps;
  - Control and monitoring system;
  - Heating units at directly controlled by consumers;
  - Balancing and blocks valves in residential buildings;
  - Individual meters and Heat load control
- *Increasing efficiency of the small capacity and low pressure heating boilers* is one of the solutions to reduce the GHG emissions. Thus, the following technologies are suggested for that purpose:
  - Install newly designed boilers with high efficiency in areas which not connected to the central power grid;
  - Replace the boilers located in remote centers (in distance over 150) from coal mines but connected to the central power electricity grid, with electric boilers;
  - Heat pumps of geothermal energy;
  - To resolve this, each boiler house should be installed with water treatment facilities;
  - Install oil or gas fired boilers.

Furnaces and coal stoves. In Mongolia, about 55% of the total population lives in cities and aimag centers, while 14% live in soum centers and settlements, and 31% live the in countryside, i.e. individually far from any settlements. Seven of every 10 Mongolian people live in gers or private houses and use about 330-360 thousand furnaces/stoves[1] as of 2012.

Approximately 50% of the city and aimag center residents live in residential buildings and others live in gers or private houses. These private houses and gers have over 180 thousand coal-fired furnaces/stoves used for heating and cooking. The efficiency of the stoves/furnaces is 30 - 40%.

The annual average coal consumption of all furnaces/stoves in the country is 750 thousand tons [4]. Due to large number of low-efficiency stoves and dust emission, residents in cities and aimag centers are under risks of disaster-level pollution. Designs of most small-capacity and low-pressure hot water boilers, coal furnaces and stoves are outdated and

[1] NSO statistics bulletin 2007

made only to burn coal put shelves without any processing. It is the most popular technology since the country has no source of natural gas.

An introduction of technology to increase efficiency from 0.45 to 0.70 of coal stoves of the aimag centers heat supply network (heat load 15 gCal/hour, heat consumption 40000 gCal) would result in a reduction of 13680 tons of CO_2 emission per year on average.

Coal- Primary energy source of Mongolia. Mongolia is rich in coal resources. Therefore, coal has been the primary energy source and its consumption accounts for 98% of the total fuel utilization. In 2008-2012, coal exploration has increased three-fold and reached 27 millions tons due to increased export of coxing coal. In 2013, the coal export was reduced and so did its exploration.

Larger coal mines of Baganuur, Shivee-Ovoo, Aduunchuluun and Shariin goliin supply basic coal needs of CHPs of the CES, major industrial cities and other users. Other coal mines provide coal for local heating networks and households.

Table 7.3 shows coal consumption of Mongolia for a period from 2000 to 2012 (MEGD, 2014)

About 7.5 million tons of brown coal consumed per year (NSO, 2012). However, about 30% of the total consumed coal burned with old technology, in other words coal put at specific shelves and burned later. In 2012, 50% of the totally explored coal was coking coal, 29% sub-bituminous coal and 21% was brown coal.

Introduction of coal combustion technology "Fluidized bed combustion" in thermal power plants planned for construction. Larger- capacity boilers of TPPs in Mongolia utilize technology that burns coal after grinding it to dust. This method has been used for many years. In recent years, a new technology of fluidized bed combustion (FBC) to burn bad quality coal has been introduced. The technology shall be also introduced to large-capacity thermal power plants to be newly constructed.

The air pollution in Ulaanbaatar city reached disaster level because of large amount of raw coal burned in different types of boilers and stoves during the cold seasons. The level of the air pollution is 6 to 8 times higher than the accepted level and outbreak of pulmonary diseases is very high among residents, especially children and the elderly.

Table 7.3 Coal consumption,thous.ton

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
4838	5039.8	5040.9	5286.6	6823.9	5468.2	5402.3	5242.8	5436.9	6305.53	6905	6815.3	7381.3

CHPs use 70% of the total coal, medium and small-scale boilers 20%, and low-pressure and household stoves consume outstanding 10% of the total coal.

One of optimum solutions to reduce air pollution in big cities and aimag centers is to utilize coalbed methane as an alternative energy source. Recently, Mongolia

Box 7.2 Coal combustion Technology in Mongolia

There are three methods of burning coal:

- Whole coal is dropped at fuel bed and burned with a direct feed of air. This technology does not process coal and is commonly used in medium- and small–capacity and low-pressure boilers, furnaces and stoves.
- Pulverized coal combustion systems are used at high-capacity steam boilers of Thermal Power Plants to achieve high efficiency for a short term. In plants that burn pulverized coal, coal is ground to fine grains (powders), mixed with air and burned.
- Coal is ground to the size of 1.0-1.5 cm (on average) and directly fed intothe firebox . It is burned from the bottom with high-pressure air floating (combustion method in the weighted condition). Unburned coal, parts that went up, are fed into the cyclone burners and re-dropped at the firebox for complete burning. This technology is called *circulation Fluidized bed combustion*

started acknowledging the importance of coalbed methane utilization. The geology and exploration also started to take into account coalbed methane. Utilizing coalbed methane for hot-water heating boilers would reduce the GHG significantly. Replacement of 1.0 Gcal/hour heat load coal boilers with gas boilers will cut the GHG emission by 7200 CO2 equivalent per year. About 60% of the emission reduction is accounted for by collecting methane gas to be emitted into the air and utilizing for fuel.

Energy Distribution Systems

The industrial sector consumes about 75% of the electricity and 32% of the heat generated.

Electricity distribution system. Technology needs assessment of the electricity distribution system is conducted for each of the categories.

Motors and Drives. Motor systems consume about 70% of industrial electricity in Mongolia. Its load level was at 20-30% as identified by audits. Most of the motors have old technologies.

Motor efficiency improvement technologies include:

- energy-efficient motors;
- improvement of power factor;
- variable speed drives.

Heat distribution system. Technology needs assessment of the heat distribution system has been carried out by its each component. Thermal energy is utilzied for two major purposes:

1. Heating and hot water supply of private and public buildings, and residential buildings;
2. Production of various goods and services and food preparation.

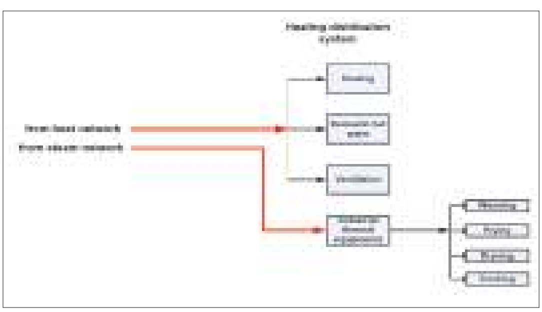

Figure 7.3 Structure of electricity distribution system

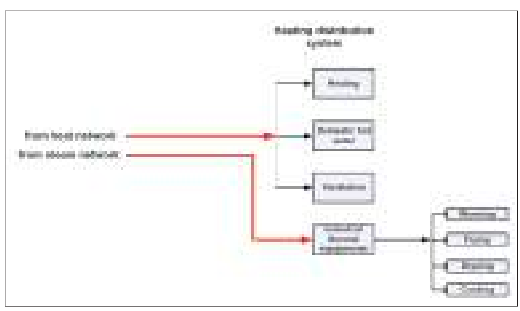

Figure 7.4 Structure of heat distribution system

Mongolia is different from other countries in that it uses 90% of the overall energy only for building heating. In that sense, introducing technologies that improve the building insulation system is important.

Insulation technology of the building. Loss of heat means the load of heat of buildings. Houses have relatively higher heat losses because the heat conductivity level in houses is lower than the standard level by 2-3 times (*Construction Heat Techniques of the Building Norm and Rules (BNaR) 2.0.03-93*). It shows that most houses, old houses of 1950-1990and bad quality houses of 2000s, in Mongolia have a higher rate of heat loss.

Additional insulation of the houses at the current standard requirements would increase heat supply system capacity reserves by 400-500 Gcal/hour. In other words, there will be no need for an additional thermal power source in Ulaanbaatar with such increased reserves. This further results in the GHG emission reductions as well.

Other developed countries have been implementing "zero energy" and "energy efficient" building technologies with special attention to construct buildings with less heat loss.

It has been estimated that additional insulation ofconcrete residential buildings at the standard level will reduce 1.4 tons of CO_2 emission per household with 60 m^2.

Control and measuring equipment for heat consumption in residential buildings. Since 2000, numerous light-industry factories and service entities in Ulaanbaatar, and Darkhan cities have started using heat meters to save thermal energy. However, rural residents are not as strongly interested in thermal energy saving. About 30% of the country's population lives in public residential buildings connected to the district heat network. None of those residential buildings have heat meters and their heating tariff is calculated based on a fixed rate. Also, the residential buildings are not installed with specific technical tools to adjust indoor heat consumption and owners have to open windows when it gets hot inside.

Technology shall be introduced that allows customers of the district heat network to adjust their heat consumption. In other words, each household or an individual costumer with a separate financial account shall have installed a specific heat adjusting tool.

7.1.2 Technology assessments of transportation sector

About 62% of the total load and 99% of people are transported by vehicles as of 2012. The total of the load and human transportations of Mongolia is shown in figure 7.5.

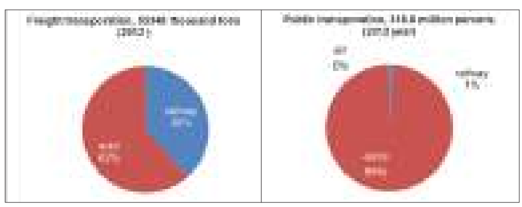

Figure 7.5 Structure of freight and public transportation

Mongolia does not produce any liquid fuel and imports all types of liquid fuel from its neighboring countries of Russia and China.

Railway transportation.

The national railway transportation is executing 38% of the national freight. Its fuel consumption is very high due to old diesel locomotives that are already out of production. In 2014, Ulaanbaatar city introduced the railbus for the public transportation. Also, 1800 km of new raily of Ukhaakhudag- Tavantolgoi-Sainshand-Khuut-Choibalsan, Khuut-Bichigt will be constructed under “New railway” project.

Auto transportation.

It executies 62% of the national freight, and 99% of the public transportation as of 2012. The number of vehicles has being increasing year by year. As of 2012, a total of 346 thousand vehicles were counted nationwide. About 63% of the total vehicles are registered in Ulaanbaatar city. Table 7.4 shows the increase of vehicles.

- Created only-for-bus lanes and prohibited other vehicles from driving on that lane;
- Over 30 junctions were expanded and installed with traffic lights;
- Procedures that prohibits vehicles to participate in city traffic once a week by car plate number are in place.

Box 7.3

The following technologies are suggested for the transportation sector to reduce GHG emission:

- Improve inter-city paved road quality;
- Increase the number of hybrid vehicles;
- Improve Ulaanbaatar city auto road network;
- Reduce the number of passengers driving by private cars by constructing a metro;
- Encourage bicycling

Table 7.4. Number of vehicles, by year (NSO, 2012)

Vehicle types	2000	2002	2004	2006	2008	2010	2012
Public transportation	44051	63224	79691	94442	127538	172583	228650
Trucks	24671	24610	25430	29389	41138	61841	83718
Bus	8548	10841	10645	11726	15780	16366	21642
Special purpose	4423	5230	4652	5315	6003	3696	11463
Total	81693	103805	120418	140872	190459	254486	345473

As of 2012, about 3% of the total cars are aged 0-3, 15% are 4-9 years and an outstanding 84% are aged more than 10 years.

Numerous infrastructure projects to expand auto road networks and improve road quality have been recently implemented. It increased the length of the paved road from 2830 km in 2009 to 4350 km in 2012. Currently, most of major urban and rural centers are connected by the paved roads; residents greatly benefit. Benefits include reliable and comfortable driving, time-saving, and less mechanical damage to vehicles.

Ulaanbaatar city implemented the following measures to reduce the traffic:

7.1.3 Technology assessments of industrial sector

The industrial sector does not include all kinds of factories, only ones that emit the GHG during the production process. Some examples of production processes are listed below:

- Domen furnaces of steel production;
- Chemical products and ammiak emitted from organic fuels, chemical raw materials;
- Cement production etc.

Cement and lime factories are the only major industrial sources of the GHG emission in Mongolia. There are no other types of industrial factories.

Cement production. Annual cement needs of the country have increased to 1.5-1.8 million tons in 2013; and it is expected to reach 3.0 million tons in 2014.

There are four cement factories operating in Mongolia with capacity to produce 550 tons of cement per year (Khutul, Darkhan, and Nalaikh). In 2013, they met only 25-30% of the domestic needs.

In 2014, Khutul Cement factory started its operation. It has installed capacity to produce 1 million tons of cements by dry technology.The following factories will start operating in 2015:

- Senj Sant cement factory of 0.5 million tons, of Mon Polimet LLC in Urgun soum of Dornogobi aimag;
- Khukh tsaviin cement factory of 1 million tons, of “Mongoliin Alt” LLC in Dalanjargalan soum of Dornogobi aimag;
- Cement factory of 1.0 million ton, factory with 100% investment of China in Sergelen soum, Tuv aimag.

Above-mentioned factories will use dry technologies, as suggested by this report. This dry technology can reduce the GHG emission by two times.

7.1.4 Technology assessment of livestock sector

The livestock sector is a primary source of income and a traditional lifestyle of Mongolia. The country’s economic development largely depends on that. As of 2012, the agricultural sector accounted for 14.8% of the GDP. The livestock sector solely produces about 80% of the agricultural products.

In recent years, the number of livestock has being increasing. Especially, due to strong market demand of the cashmere, the share of goats has increased to 43% of the total livestock.

Table 7.5 Number of livestock, 2000-2012

	2000	2002	2004	2006	2008	2010	2012
Cattle	3097.6	1884.3	1841.6	2167.9	2503.4	2176	2585
Sheep	13876.4	10636.6	11686.4	14815.1	18362.3	14480.4	18141.5
Goats	10269.8	9134.8	12238	15451.7	19969.4	13883.2	17558.7
Horses	2660.7	1988.9	2005.3	2114.8	2186.9	1920.3	2330
Camels	322.9	253	256.6	253.5	266.4	269.6	306
Total	30227.4	23897.6	28027.9	34803	43288.4	32729.5	40921.2

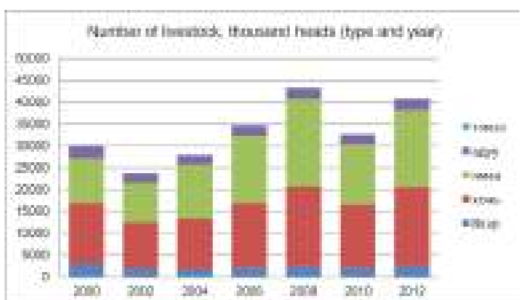

Figure 7.6 Number of livestock, thousand heads (by type and year)

Any kind of pastoral livestock products in Mongolia belong to the organic category. Pastoral livestock are exclusively fed by natural pasture plants.

Over the past decade, the country is getiing more interested in increasing the quality of livestock rather in increasing its number. One of solutions for reducing the number of livestock is intensive livestock farming. As of 2012, there were over 1050 dairy and meat farms in peri-urban areas with approximately 60,000 farm animals.

Increasing dairy and meat output will not only reduce the total number of livestock, but also cut the GHG derived largely from enteric fermentation. In the future, it is suggested that livestock farming should be encouraged, especially in crop areas, for better food supply and less GHG emission.

7.1.5 Technology assessments of land use and forestry

Land in Mongolia is classified as follows:

- Agricultural (grassland, cropland, mea);
- Residential;
- Transportation use (road and network areas)
- Forestry

Total agricultural areas was 115,400 thousand hectares as of 2012; 97.7% of which is grasslands, 1.5% is meadows and 0.9% is croplands.

Croplands. Mongolia has a relative short period for cropland use. The country had intensively converted grasslands to croplands for agricultural productions during a period from 1958-1980s - over 1.2 millions hectares became croplands. Drop irrigations technology shall be applied for croplands to attain high-efficiency water use and better crops.

Grasslands. Over 80% or 111.0 milllion hectares of Mongolian territory is grasslands. Recent research of the pastureland use identified that over-grazing and water shortage of grasslandsis at serious levels in the countryside. In 2012, 7.8 million hectares of the pastureland was damaged, 2.3 million hectares of which were severely degraded, 2.2. million hectares were damaged by insects and parasites, and 2.7 million hectares were under desertification. In addition to that, an average dry forage yield per hectare is not more than 400 kg.

Two major reasons for the pasture degradations are: (1) climate change and (2) increased number of livestock, especially goats. Another external factor is dryness of rivers, springs and streams. If no preventive measures are taken place, there mightbe negatively affects on the agricultural food supply.

Suggested options of technologies for grasslands protection are:

- Preserve traditional pastoral livestock sector (organic production) and at the same time to improve livestock output (breeding) and cut number of livestock;
- Encourage high-efficiency livestock farming in crop areas;
- Control livestock herding structures, specifically keep optimum number of goats;
- Implement sustainable grassland management.

Residential areas. Buildings and facililties areas, public land such as streets, mine lands, industrial areas and ger districts belong to this category that occupied about 702.0 thousand hectares of land in 2012. Over the past period, the residential area has become larger and consequently, there is less vegetation cover.

Transportation use land. Over 435 thousand hectares of land used for railways, auto roads, and other networkas as of 2012. The country is planning to construct more major autoroads and railways. This would inevitably decline vegetation cover in the country, thus GHG absorption capacity would decline.

Forestry. In 2012, forest sources covered 14.257 million hectares of land or 9.1% of the total territory, areas covered by forests covered 8.56% or 12.1 million hectares. 75.6% of Mongolian forests are needle forests and 24.6% are saxaul tree forests. About 432.0 thousand of hectares were degraded in 2012 – 50% by fire, 34.2% from the cuttin of trees and shrubs, and 14.6% from insects and parasites (Source: Environmental Impact Assessment of Mongolia, 2011-2012).

Fire. Due to climate change, dryness, anthropogenic activities, insects and forest diseases, and biological changes, the frequency of natural fries has increased. About 340.9 thousand hectares of forest lands and 4700.0 thousand hectares of steppe were damaged by the fire in 2012.

Forest use. 831.1 thousand cubics of tiimber were prepared in 2012- 235.2 thousand of which were prepared for general uses and 595.9 thousand cubic meters were used as fuel.

Afforestation. As a result of the annual afforestation measures, 9512 hectares in 2008, 7605 hectares in 2009, 9167 hectares in 2010, 10927 hectares in 2011 and 8400 hectares in 2012 were afforested. It is suggested that the following technologies be introduced in the immediate future:

- Improve forest protections;
- Intensity afforestation;
- Introduce well-developed irrigation technologies;
- Reduce area of the plantation by increasing yield per hectares.

7.1.6 Technology assessments in the waste management sector

There are 447 waste-disposal open dumps that cover over 3146 thousand square meters in Mongolia[2]. In 2012, approximately 1.1 million tons of wastes were generated; 500-550 thousand tons of wastes were generated in Ulaanbaatar and 30 thousand were in Darkhan city. Ulaanbaatar city generates 1100 tons of wastes daily – 60% of which is from households, 30% is industrial and the remaining is produced from streets and other sources. The city has three final-disposal sites (landfills of Moringiin davaa, Narangiin Enger, and Tsagaan Davaa) where wastes are transported (UCO, 2012). In 2007, JICA conducted research on Ulaanbaatar waste management and identified that a person living in a ger or private house produces 0.2 kg of wastes a day and 72.9 kg a year. In contrast, one citizen of a city produces 0.6 kg of waste a day and 130.5 kg a year. On the average, a city resident produces 0.34 kg of waste a day and 130.5 kg a year.

Residential waste is a sum of wastes generated by commercial entities and offices and households. A city resident generates 0.84kg of residential waste a day and 306.8 kg a year

About 65% of the municipal solid wastes in Ulaanbaatar city are transported to the final waste disposal sites. Other cities and aimags and urban centers do not dispose of waste properly and leave it at open dumps. In that case, methane is almost not emitted.

It is suggested to introduce technologies that generate energy either from producing methane from solid waste treatment or by burning the wastes.

[2] The National Waste Reduction Programme, 1999

Domestic wastewater. Wastewater (WW) management system is divided into three categories of waste water:

- *Central sewage system and WW treatment plants[* in Ulaanbaatar, Darkhan and Erdenet city. Amount of WW in Ulaanbaatar city was increased to 190 000 m^3/day in 2010-2012. Bottom ash disposal is the most critical issue for the WW treatment plants. The plants use the most outdated method of sludge treatment by leaving at open sites to dry naturally.
- *Sewage system of* Zuunkharaa cities and other aimag centers. However, equipment and technologies of the plants are outdated and cannot operate at normal regime for the past years.
- *Outdoor pit latrine* used by households and commercial organizations in ger districts of Ulaanbaatar, Darkhan, Erdenet cities and other aimag centers. All households and commercial entities that are not connected to the central sewage system dig a pit at their land and dispose of wastewater. The pit depth is usually around three meters, which is enough for methane emission.

WW treatment plants in big cities and aimag centers do not have biogas generation facilities.

Renovation of the WW management system and expansion of its capacity is a high priority issue at this moment of the reporting. Because of the poor treatment of the WW, the Tuul river (Ulaanbaatar city) is far from its boundary of natural recovery and is critically polluted.

Industrial wastewater. Ulaanbaatar has a good number of wool processing, leather processing and food factories. Even though, these factories have its wastewater treatment facilities (khargia), they are no longer in use because of the technology applied. The factories fed wastewater to the city's central sewage system intentionally but in secret caused serious problems. Taking into account the current situation, the city is looking for options to minimize the number of any kind of processing factories within the city boundaries.

Methane is only emitted from wastewater generated by food processing factories, not from the factories that use chemicals for the processing. The food processing factories include meat, dairy, alcohol and bewerage productions that generate wastewater composed of organic solutions. Wastewater treatment facilities with methane emission tanks that the factories used to have are no longer in use. Newly constructed factories feed directly to the central sewage system with no preliminary treatments.

Wastewater generated by the food processing factories, on average, are:

- Slaugtherhouses and meat processing factories -13 m^3/ton;
- Dairy factories – 7m^3/ton, alhocol beverages- 24 m^3/ton,
- Bewerage factories – 6.3m^3/ton.

It is suggested for the above-mentioned types of factories to renovate wastewater treatment systems.

Conclusions and Recommendations

Mongolia has certain constraints to introduce clean, environmentally friendly technologies.

- Tangible results to introduce clean technologies are not yet achieved despite sufficient dialogues and discussions that have already taken place. The Government of Mongolia shall develop and implement comprehensive action plans to introduce climate change mitigation and environmentally-friendly technologies based on the international best practices. At the given moment, these initiativesare only limited by the research and investigations of the experts and researchers;

- Mongolia has a shortage of financial resources to support projects based on clean technologies. Therefore, the country shall consider opportunities to cooperate and get assistance from the International Technology Transfer Fund to introduce environmentally-friendly and climate change mitigating technologies;
- A research and analysis Institute shall be operated next to each of the infrastrucrual sectors that are responsible for development of advanced technologies and the introduction of best technologies from other countries. Further, its findings and recommendations shall be incorporated into the national development policies.

7.2 Adaptation Technology Assessment

The purpose of the Technology Needs Assessment (TNA) is to assist in identifying and analyzing priority technology needs, which can be the basis for a portfolio of environmentally sustainable technology (EST) projects and programmes. This can facilitate the transfer of, and access to, EST's and know-how in the implementation of Article 4.5 of the UN Climate Change Convention[3].

Mongolia undertook the Technology Needs Assessment for climate change mitigation and adaptation in 2011 to 2013 under the TNA project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEPRisoe Centre (URC) in collaboration with the Regional Centre Asian Institute of Technology.

The Technology Needs Assessment on adaptation was done for the first time in Mongolia, which was an opportunity to determine the highest priority sectors and technologies for adaptation.

Mongolia is a developing country with a small population and vast territory where traditional nomadic livelihoods coexist with modern urban lifestyles. In recent years, climate change related challenges have become a major risk for the country's development. Ecosystems in Mongolia are fragile to climate changes, and the livelihoods of people are highly dependent on the weather and environment. The assessment showed that climate change would impact the well-being of people and the country's socio and economic development.

The Parliament and the Government of Mongolia passed several important policies and strategic documents for long term sustainable development. The main policies and strategies of development have clearly stated the importance of adaptation to climate change in major sectors such as agriculture, animal husbandry and water, and include objectives to cope with climate change related risks.

3 TNA definition, source: http://unfccc.int/ttclear/templates/render_cms_page?TNA_home

The TNA for adaptation of Mongolia consists of four sections as below:

1. Section 1: The Technology Needs Assessment Report described key adaptation technologies in priority sectors for Mongolia such as a system of wheat intensification; vegetable production system with drip irrigation and mulches, potato seed production system; seasonal prediction and livestock early warning system; high quality livestock through breeding and animal disease management; sustainable pasture management.
2. Section 2: The Barrier Analysis and Enabling Framework Report accessed the barriers and measures identified for all six technologies in two sectors that have been selected.
3. Section 3: The Technology Action Plan (TAP) Report described Action Plans for each technology. During the preparation of TAP, measures have been assessed, taking into account their priorities, time scale, related stakeholders, key indicators of outputs, implementation and funding resources.
4. Section 4: The Project Idea Report provided project ideas for each technology including concrete actions for the realization of the Technology Action Plans for each of the selected technologies. The present report was the result of a fully country-driven process and the views and information contained herein are the product of the National TNA team, led by the Ministry of Environment and Green Development (MEGD) of Mongolia.

7.2.1 Potential Adaptation Technologies in Vulnerable Sectors

Based on the research and Multi Criteria Decisions Analysis (MCDA), arable farming and animal husbandry sub-sectors were identified as the most vulnerable to climate change sectors. Social, economic and environmental losses in these sectors caused by climate change adverse impacts are expected to be higher than in other sectors such as human health, infrastructure and forestry. The agriculture sector is an important economic sector in Mongolia and the livelihoods of the big portion of the population rely on agriculture. Many of the government's development policies focus on sustainable development of the agriculture sector.

Water is a cross cutting issue, which is related to other sectors and sub-sectors including arable farming and animal husbandry. Consequently, the water sector is not prioritized, however water saving technology options have been included within the arable farming and livestock subsectors.

Climate change impacts on prioritized sub sectors and the current status of technology applications were defined based on research from existing studies and documents.

Technology Fact Sheets with detailed information were developed for 17 potential adaptation technologies (Table 7.6) and were discussed through an intensive stakeholder engagement process. In the identification of technologies, both 'hard' and 'soft' types of technologies were considered. The prioritization of adaptation technologies was completed and the following six technologies which contribute to reduced agriculture sector vulnerabilities were prioritized as highlighted in Table 7.6.

Table 7.6 Final technology prioritization using multi criteria decision analysis tool[1] in arable farming and animal husbandry

Technology	Benefits						Investment cost (low-3, meduim-2, high-1)	Contribution to reduce vulnerability	Overall weight	Ranking
	Economy		Environment		Society					
	Asset	Business and market activity	Biodiversity	Ecosystem service	Health and livelihood	Employment				
Arable farming										
Crop planting under plastic mulches	1	4	9	0	9	3	23	6	54.7	**V**
Vegetable production system with drip irrigation	3	4	17	1	9	1	23	6	64.6	**II**
System of wheat intensification through conservation tillage	3	6	17	1	9	1	23	6	66.5	**I**
Forest strip protection of agriculture land	0	0	26	0	3	1	0	6	36.4	**VII**
Breeding of new varieties of crops using marker assisted selection (MAS)	1	4	0	1	0	0	23	0	29.8	**VIII**
Proper rotation system of planting cereals	0	4	26	1	6	1	23	0	62.0	**IV**
Integrated Nutrient Management	1	4	9	1	3	1	23	0	42.9	**VI**
Potato seed production system using aeroponics	1	4	9	0	3	0	47	0	63.4	**III**
Using intelligent nutrient management- micronutrient gel for crops and trees	0	2	17	1	3	0	0	6	29.4	**IX**
Animal husbandry										
Seasonal to inter-annual prediction and livestock early warning system	23	0	23	3	4	15	23	8	97.5	**I**
Planting of forage perennials resistant to drought and cold winter for fodder production	11	0	23	3	2	8	0	8	53.8	**VI**
Selective breeding of livestock	23	0	23	3	4	0	23	0	74.7	**II**
Producing supplement feed for winter and spring	11	0	11	0	2	8	23	0	55.1	**V**
Rain and snow water harvesting for herder groups	11	0	23	0	4	8	0	8	53.2	**VII**
Producing supplement forage with bacterial enzyme for livestock	11	0	0	0	2	8	23	0	43.7	**VIII**
Sustainable Pasture Management	0	0	23	3	0	8	23	8	63.3	**IV**
Livestock Disease Management	23	3	11	3	4	15	0	8	65.8	**III**

High ranking technologies scored relatively higher rates of economic asset, environment biodiversity and livelihood benefits for the country.

Arable farming.

System of wheat intensification (SWI): The system of wheat intensification that integrates conservation tillage practices and holistic plant management is a viable alternative to the current crop production practices in Mongolia and provides prospects for future sustainability.

Vegetable production system (VPS) with drip irrigation: This technology aims to intensify vegetable production through a set of water saving equipment such as drip irrigation, and low cost green house or mulch.

Potato seed production system (PSPS): This comprises the development of varieties, producing mini tubers or elite seeds, multiplying seeds, and storage and delivery systems. The technology can improve the supply of good and healthy potato seeds and increase the potato production per area. The technology will be the basis of a sustainable supply of potato seeds of adapted potato varieties, and free from virus infections.

Animal husbandry.

Seasonal to Inter-annual Prediction and Livestock Early Warning system (SPLEWS): The current livestock sector is based on the traditional nomadic pasture system, and herder families' livelihoods are highly dependent on and influenced by the weather and climate. SPLEWS integrates main components such as risk knowledge, monitoring and predicting, disseminating information and response. Precise seasonal prediction and proper preparation for *zud* would result in saving about 80% of animals' losses every winter.

High quality livestock (HQL): Through selective breeding and animal disease management: Improving animal quality rather than quantity is the best method to ensure high production and livestock development in Mongolia. The livelihoods of about 160,000 herding families depend on livestock. HQL technology aims to improve the quality of all animals based on selective breeding using these core herds as well as improved animal health services. Diffusion of the technology would enable Mongolia to control livestock numbers within its pasture carrying capacity and to reduce overgrazing and desertification.

Sustainable Pasture Management (SPM): Pastureland is the backbone of Mongolian agriculture. Pasture degradation and desertification are among the most serious environmental problems. Comprehensive sustainable pasture management will conserve natural resources and thereby increase livestock productivity.

Selected adaptation technologies are systems which are a combination of hard and soft techniques, as with early warning systems that combine hard measuring devices with soft knowledge and skills that can raise awareness and stimulate appropriate action.

According to the guideline, three adaptation technologies of arable farming and HQL for animal husbandry can be classified as consumer goods which would be introduced and diffused based on market principles. Two adaptation technologies, Seasonal to Inter-annual Prediction and Livestock Early Warning System and Sustainable Pasture Management of Animal Husbandry, belong to non-market goods or 'soft technologies', because they are very much related to a system and network establishment, information sharing, awareness raising, capacity building and behavior changes.

7.2.2 Barrier Analysis and Enabling Framework

Once the adaptation technologies have been identified and prioritized, barriers were identified that hamper the development and transfer of technologies. These barriers were diverse as they refer to insufficient legislation to support the technology, or counter-productive legislation (e.g., feed in tariff effects could be neutralized by an import tariff on the hardware), insufficient human capacity to support the operation and maintenance of the technology, insufficient legal and financial supporting service, poor communication system, lack of media interest in promoting technology, etc.

In order to explore the barriers and problems that prevent or slow down the progress of technologies, a system mapping technique was used. Such an approach allowed the adaptation group of stakeholders to characterize the whole system environment into which the new technology for adaptation must be developed, deployed and diffused. By framing discussions in this way, different stakeholders exchanged information to build a picture of the whole system encompassing the enabling environment for introducing a new technology (legal, institutional, organizational, cultural), the actors involved in the system and their power and connections, as well as the supporting services (e.g., finance, quality control, enforcement, standards, etc.) needed to make the system function. Key barriers and enabling framework for arable farming technologies are given in Table 7.7.

In the analysis of barriers (and measures to overcome barriers), many are technology specific and fall within a broad categorization for barriers. However, there are some common strands. Although not identified among the key barriers, some of the similar measures were identified in the preliminary list of barriers on a number of occasions. This suggests the ability to follow a common approach to address these barriers.

Inadequate finances: In the category of Economic and Financial barriers, the most commonly cited barrier was the high cost of equipment, supplies and implementation for all three technologies. Mongolia has limited financial and human capacity to locally produce agriculture machines, equipment and supplies – most are mainly imported from other countries. Limited access to long term and soft loans were identified as barriers in systems of wheat intensification (SWI) and the vegetable production system with drip irrigation and mulches (VPS). Inadequate funding was directly identified in the case of the potato seed production system (PSPS). The arable farming sector has seasonal patterns in Mongolia so access to loan services from banks and micro-finance organizations are limited especially for small and new enterprises and poor farmers due to high interest rates, required collateral and re-payment in the short term.

Insufficient policy framework: Policies affect implementation of measures in all three categories of technologies. A subsidy policy by the government is needed to support climate and environmentally sound technologies. A tax exemption or deduction policy is required in order to ensure affordability of equipment, systems and supplies. Efficient enforcement of the law of procurement of legumes in the State Emergency Fund is needed to support proper rotation systems for cereals in technology SWI. Overall, policy is identified as an area that presents a barrier to promoting selected technologies.

Table 7.7 Key barriers identified for the three prioritized technologies in the arable farming sector

No	Key barriers identified		
	System of wheat intensification	Vegetable production system with drip irrigation and mulches	Potato seed production system
Economic and financial barriers			
1	High cost of equipment and supplies	High cost of equipment and facilities	High cost of equipment and materials
2	Limited financial capacity of grain producers	Limited access to long term soft loans	Inadequate availability of financial resources
Non-financial barriers			
	Policy, Legal and Regulatory Barriers		
3	No incentive policy for grain producers to apply climate adaptation technologies	Lack of subsidy policy	Lack of subsidy policy for potato seed producers
	Human Skills Barriers		
4	Insufficient human resource and professionals	Limited knowledge and skills	Lack of skills and knowledge esp. about aeroponic system
5	Limited knowledge and skills to use equipment, crop rotation, supplies		
	Institutional and organizational capacity barriers		
6	Lack of adaptive research and foundation research capacity	Lack of training and demonstration	Few producer of potato mini tubers
	Market Failure/Imperfection Barriers		
7	Low quality of agriculture equipment and supplies	Underdeveloped local market and value chain system	Underdeveloped local supply chain of potato seed production
8	Limited access to international market		
9	Inadequate infrastructure		
10	No seed bank of legumes		
	Social, Cultural, Behavioral Barriers		
11	Conflict between animal husbandry and arable farming	Lack of knowledge and attitude towards water saving behaviour	
12	Low demand of legumes		
	Information and Awareness Barriers		
13	Inadequate information about legumes		
	Network Failure Barriers		
14	Poor coordination between key actors	Poor coordination between key actors	Poor coordination between major actors
	Technical Barriers		
15	Lack of standards for imported equipment and chemicals as well as for export market	Insufficient quality assurance of drip irrigation equipment, mulches and supplies	
16		Inadequate investments into infrastructure	

Inadequate human skills: College and university curriculums do not sufficiently focus on climate change and adaptation technologies. Systematic development of professionals through the education system is of critical importance to R&D of selected technologies.

Poor research and development: Research on climate change adaptation technologies and their practical applications is not sufficient, which leads to a poor understanding and knowledge about technologies, and the proper application of herbicide and fertilizers by farmers and agriculture professionals. Alternative sets of measures required to overcome these common barriers were identified. For the four common barriers, technology-specific enabling measures are identified and summarized in Table 7.8.

Key barriers and enabling framework for animal husbandry technologies area shown in table 7.9.

Table 7.8 Key measures identified for the common barriers to prioritized technologies in the arable farming sector

Commoners	Technologies affected	Measures to overcome key barriers
Inadequate finance	SWI, VPS, and PSPS	Set up financing mechanisms for specific technology packages Import tax exemption of technology related equipment and supplies and income tax deduction of local manufacturing of equipment and supplies and service providers Introduce incentive packages for climate technologies
Insufficient Policy framework	SWI, VPS, and PSPS	Establish consultative mechanisms with the representation of all stakeholders Review and improve current incentive policy according to emerging needs of climate change adaptation Review and improve current tax policy regarding the importation and local manufacturing of agriculture equipment and facilities related to adaptation needs Strengthen State Arable Farming Fund and improve its policies and business regulations Set up legal and financial environment frameworks for professional consulting services at provincial and local levels Develop insurance scheme
Inadequate human skills and knowledge	SWI, VPS, and PSPS	Review current curriculum for agriculture specialists and strengthen them with climate change theories and practices Develop training packages on climate change and adaptation technologies for different audiences including farmers, agriculture specialists of private enterprises and governments Develop awareness raising packages for different audiences and conduct systematic awareness raising regarding to climate change impacts and promising adaptation technologies for public through media and press
Poor research and development	SWI, VPS, and PSPS	Increase support to public and private R&D institutions Strengthen provincial agriculture extension centers to test and demonstrate climate technologies in local context and transfer knowledge and skills to local farmers Support researchers and specialists to study in overseas institutions and conduct research on climate technologies

Table 7.9 Key barriers identified for prioritized three technologies in the animal husbandry sector

No	Key barriers identified		
	Seasonal prediction and livestock early warning system	High quality livestock through selective breeding and animal health system	Sustainable pasture management
Economic and financial barriers			
1	Inadequate financial resources	Inadequate financial resources from the government for local veterinary/breeding units	Lack of financial resources for adapting sustainable pasture management technology
2		Lack of financial support for the research and development of livestock breeds	Lack of taxation mechanism for pasture usage and management
3		High cost of imported breeding equipment and supplies, veterinary medicines, vaccines and diagnosing facilities	
Non-financial barriers			
	Policy, Legal and Regulatory Barriers		
4		Insufficient consideration of livestock adaptation to climate change in legal frameworks	Lack of land tenure rights
5		Inadequate incentive policies and regulations	
6		Unclear roles of state and private veterinary/breeding workers and units	
	Human Skills Barriers		
7	Insufficient research and development	Insufficient numbers of animal breeding technicians and veterinarians	
	Institutional and organizational capacity barriers		
8		Inadequate technical and human capacity of local veterinary and breeding units	Lack of regulation authority and mechanism for pasture usage
	Market Failure/Imperfection Barriers		
9		Low access to tested and proved breeds, qualified veterinary medicines and services	
10		Underdeveloped market and trade mechanism	
	Social, Cultural, Behavioral Barriers		
11		Reluctance by herders to use breed high quality of livestock	Complexity of pasture system with different socio economic and natural conditions
12		Lack of understanding of the importance of the technology application	Mobile herding system
13			Uncontrolled animal numbers
	Information and awareness Barriers		
14	Inadequate awareness and understanding	Lack of information and awareness	Lack of awareness and knowledge of herders
	Network Failure Barriers		
15	Poor coordination between organizations in the current early warning system	Poor coordination between key actors	Poor coordination between key actors
	Other Barriers		
16			Frequent drought and harsh winter disasters

There are common characteristics in identified technologies in animal husbandry sector. These common barriers are followed:

Lack of financial resources: Low funding allocation was a barrier for all three selected technologies in the animal husbandry sector. SPLEWS lacks improvements in the current system to provide adequate quality information to prevent or mitigate animal losses during droughts and *zuds*. Financial resources are not sufficient for high quality livestock through selective breeding and animal disease management in order to deliver necessary services to herders. Pasture and land management measures and actions which are milestones for sustainable pasture management are under-funded. Research and development of all three technologies face financial challenges.

Inadequate policy and regulations: This barrier has high rank for SPLEWS and HQL. With regard to HQL, the livestock sector related policies have not included adaptations to environmental and climate change risks including soil and environmental degradation. Also, the Mongolian Law on Livestock Gene Pool and Animal Health is not enforced efficiently due to lack of finance and human skills. Pasture Law which has been under discussion for more than 4 years is an emerging issue for SPM. For SPLEWS, roles and responsibilities between organizations and institutions are still too vague to make the system complete and efficient.

Insufficient awareness and information: End users of all three prioritized technologies struggle with low access to good information and have low confidence in adapting positive practices. In SPLEWS, the high tariff of communication and the poor infrastructure is an issue to disseminate real time and updated information. With regard to the other two technologies, inadequate information and awareness among herders and government officials hinders transfer and diffusion.

Lack of partnerships: This barrier affects all three technologies. There are many government agencies and organizations involved in the early warning system, but effectiveness of the coordination cannot ensure to achieve the main goal to deliver accurate, timely, reliable and unambiguous information. In terms of HQL, relations and collaboration between market and non-market players is too weak to deliver advanced breeding equipment and veterinary services to herders. For SPM, the current level of cooperation among key actors, such as herders group, NGOs, research institutions, national and international project implementers and local governments cannot support this technology. Key measures to overcome common barriers to technologies in animal husbandry re displayed in Table 7.10.

Table 7.10 Common barriers to technologies in animal husbandry

Common barriers	Enabling framework to overcome barriers	Technology
Lack of financial resources	Allocate more funding from the government Explore funding opportunities from international donors Support private enterprises to invest in identified technologies with income and import tax deduction/exemption	SPLEWS; HQL; SPM
Inadequate policy and regulations	Identify appropriate solutions for legal entities for herder groups for Pasture Law Lobby for required law endorsement Improve business regulations for livestock production	HQL; SPM
Insufficient awareness and information	Develop training packages for specific technologies Identify and certify qualified training organizations at local levels Conduct awareness and training for livestock specialists and government officials Facilitate periodical events for discussions, sharing experiences and learning from other countries programs and projects	SPLEWS; HQL; SPM
Lack of partnership	Set up permanent consultative forum on each technology Define clear roles and responsibilities of key actors and seek opportunities to legalize Develop and set up related indicators in the performance evaluation of government and other organizations	SPLEWS; HQL; SPM

7.2.3 Technology Action Plan

An action plan was developed for each prioritized adaptation technology. Technology Action Plan includes a definition of innovation stage, key measures, priority ranking, responsible entities, implementation period, cost and risk and success indicators. The most common key measures for the two sectors are: allocation of the government funding, tax exemption and soft loans, subsidy policy for environmentally sound and climate technologies, systematic capacity building, supporting research and development, and strengthening of international cooperation and networks.

Table 7.11 shows compiled key actions to overcome barriers which are included in the TAP of each technology.

Table 7.11 Common actions for prioritized technologies and their TAPs

Common measures	Arable farming sector technologies			Animal husbandry sector technologies		
	System of wheat intensification	Vgetable production system	Potato seed production system	Seasonal prediction and early warning system	High quality livestock	Sustainable Pasture Management
Secure the Government funding	✓✓✓		✓✓	✓✓✓	✓✓✓	✓✓✓
Tax exemption and provision of soft loans	✓✓✓	✓✓✓	✓✓✓		✓✓✓	
Setting up subsidy policy	✓✓✓	✓✓✓	✓✓✓		✓✓✓	✓✓
Amendment of laws or enforcement of new laws	✓✓					✓✓✓
Enforcement of quality assurance standards	✓✓	✓✓	✓✓✓			
Systematic capacity building of professionals/ specialists	✓✓✓	✓✓		✓✓	✓✓	✓✓
Create stakeholder networks and partnership	✓✓✓	✓✓		✓✓		
Increase awareness raising	✓✓	✓✓			✓✓✓	✓
Support R&D	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Market system support	✓	✓✓	✓✓		✓✓	
Strengthen international cooperation and links	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓

The most common actions are:

Secure government funding: First of all, funding from the government would support these six technologies transfer and diffusion. This can be done through national program implementation, efficient law enforcement and the local government budgeting process.

Tax exemption and soft loans: For the four technologies from the consumer goods category, import tax exemption, tax deduction for local manufacturing and access to long term soft loans would enable efficient transfer and diffusion of technologies of SWI, VPS, PSPS and HQL.

Subsidy policy for sound environmental and climate technologies: The government of Mongolia should develop a comprehensive subsidy policy which supports sound environmental and climate technologies. The policy will enable the accomplishment of action plans of all six technologies within expected timeframes.

Systematic capacity building: Systematic capacity building of agriculture and climate specialists and professionals is very essential for all six technologies. Climate change adaptation concepts and practices need to be focused sufficiently in curriculums of public and private educational institutions.

Support R&D: Research and development is required in all technologies. Sufficient funding and human resources will enable good scientific research to facilitate all technologies transfer and diffusion.

Strengthen international cooperation and networks: Learning from experiences and the practical applications of technologies in a similar context is important to accelerate R&D and the deployment of all six technologies in the country. Many types of learning events such as forums, exposure trips, short and long term studies, exhibitions, trade fairs and others can be facilitated to ensure the efficient deployment and diffusion of these technologies.

7.2.4 Project ideas

Based on sector and technology prioritization, the barrier analysis and Technology Action Plans, five project ideas were developed by key experts and stakeholders from different entities. Key stakeholders from the Ministry of Industry and Agriculture, the Ministry of Environment and Green Development, research institutions, private enterprises, representatives of farmers and herders were consulted during the project idea preparation process. In each of the project ideas, key stakeholders and their roles were described.

Table 7.12 Project ideas in the arable farming sector

Technology	Project name	Implementation period	Estimated budget, US$
System of wheat intensification	Pilot project of SWI in Mongolia – Phase 1	2 years	800,000
	Scaling up SWI technology in Mongolia– Phase 2	4 years	1,350,000
Vegetable production system with drip irrigation and mulches	Drip irrigation project	6 years	2,250,000

Project ideas in the animal husbandry sector were identified with a stakeholder participatory process based on the technology needs assessment, barrier analysis, enabling framework and the technology action plans. Three project ideas, one for each of the prioritized technologies, have been developed and are listed in Table 7.13. Detailed information of the project ideas are available in the full version of TNA report from UNFCCC web site.

Table 7.13 Project ideas in the animal husbandry sector

Technology	Project name	Implementation period	Estimated budget, US$
Seasonal prediction and livestock early warning system (SPLEWS)	Improving seasonal prediction and livestock early warning system	4 years	1, 200 000
High quality livestock through selective breeding and animal health (HQL)	Strengthening animal health	7 years	2,400,000
Sustainable Pasture Management (SPM)	Improving pasture monitoring system	5 years	2,220,000

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8 Policy framework, institutional arrangements, international cooperation and public awareness

8. Policy framework, institutional arrangements, international cooperation and public awareness

- Legal and policy framework - Other climate change policies and strategies - Institutional arrangements	Gerelt-Od Ts., Dagvadorj D.
- Green development policy and its climate change aspect	Dagvadorj D.
- International cooperation on climate change	Saruul D., Dagvadorj D.
- Climate change public awareness and education	Gerelmaa Sh.

POLICY FRAMEWORK, INSTITUTIONAL ARRANGEMENTS, INTERNATIONAL COOPERATION AND PUBLIC AWARENESS

8.1 Legal and Policy Framework

The United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol is the main international treaty which commits its Parties to take action to protect global climate system, to adapt to the adverse impacts of climate change and to mitigate GHG emissions. This will be accomplished by promoting national policies and strategies including the provision of financial and technological support to countries, cooperating in preparing for adaptation to the impacts of climate change, and by reducing greenhouse gas emissions. The Government of Mongolia ratified the UNFCCC in 1994, the Kyoto Protocol in 1999. These documents are the main legal rationale for the development and implementation of climate change policies for Mongolia.

Currently, Mongolia does not have a specific laws on climate change that regulate the cross-sectoral and nationwide activities to address climate change challenges, but some amendments of existing laws reflect climate change concerns and challenges and promote climate change related activities. In other words, these issues are not well coordinated in the various related laws and the main national development policy documents which include the basic concepts, principles and legal framework of climate change have been compromised. In 2012 the amended Law on Air includes an Article on climate change that guided to establish the Task Force Unit of Climate Change responsible for the management and coordination of activities under national legal and regulation documents, action plans and national programs, fulfillment of reporting and other obligations and provisions under international agreements.

The National Action Programme on Climate Change (NAPCC) while addressing challenges relevant to climate change was approved by the State Great Khural (Parliament) in 2000 and updated in 2011. The action programme includes the national policy and strategy to tackle the adverse impacts of climate change and to mitigate greenhouse gas emissions. The NAPCC is aimed not only at meeting the UNFCCC obligations, but also at setting priorities for action and to integrate climate change concerns into other national and sectoral development plans and programmes. The NAPCC is based on the pre-feasibility studies on climate change impact and adaptation assessment, GHG inventories, and GHG mitigation analysis. This Action Programme includes a set of measures, actions and strategies that enable vulnerable sectors to adapt to potential climate change and to mitigate GHGs emissions.

Its goal, strategic objective, implementation period, results to be achieved, and achievement indicators were developed in line with the implementation of the Comprehensive National Development Strategy. In the program five strategic objectives and 96 main activities were proposed to be implemented in two phases over a period from 2011 to 2021. Besides the Government of Mongolia has already developed and implemented the National and sectoral adaptation strategies, and sub-programmes and strategies at the local level. The Green Development Policy document recently was approved by the State Great Khural (Parliament) in June 2014 and climate resilient development is considered as one of main priorities of this document.

At the international level, Mongolia has joined many environmentally related UN Conventions and Treaties, such as the UN Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD) and the Convention to Combat Desertification (CCD), and The Vienna Convention for the Protection of the Ozone. The UN implementing and specialized agencies like the United Nations Development Programme (UNDP), the World Bank, and the United Nations Environmental Programme (UNEP) support capacity strengthening of concerned national and local institutions to assist them to fulfill their commitments and use provisions received under these conventions, to implement and monitor related policies, and to enhance coordination among them. The international organizations and partner countries also cooperate with local governments, civil society organizations, research organizations and the media for a wider outreach of environmental awareness campaigns.

The NAPCC will be implemented in two phases over the periods from 2011 to 2016 and 2017 to 2021. The implementation plan for the first phase (2011-2016) of NAPCC was approved by the Government on November 9, 2011. The measures to achieve the five strategic objectives of NAPCC will result in the accomplishment of the first phase of the proposed measures, which is the establishment of the proper legal environment, structure and improvement in the cooperation between related institutions.

The following five strategic objectives have been identified in NAPCC:

- Establish the legal environmental, structures, institutions and regulatory framework supporting the activities directed to solve the issues due to climate change;
- Ensure environmental sustainability and reduce socio-economic vulnerabilities and risks through strengthening national capacity to adapt to climate change;
- Mitigate greenhouse gas emissions and establish a low carbon economy through the introduction of environmentally-friendly technologies and improvement of efficiency and productivity in consumption and production;
- Expand national climate observation network, research and assessment works, and reform technologies and strengthen the capacity of human resources; and
- Conduct public awareness raising activities and support citizen and communities in participating climate change mitigation and adaptation actions.

To ensuring environmental sustainability, the development of socio-economic sectors adapted to climate change, reduction of vulnerabilities and risks, and mitigation of GHG emissions as well as promoting economic effectiveness and efficiency and implementation of green growth policies, will help Mongolia create the capacity to adapt to climate change and establish a foundation for green economic growth and sustainable development by 2021.

8.2 Other climate change policies and strategies

With the support of GIZ (Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH) the Government of Mongolia developed the National Adaptation Strategy and Action Plan integrating with relevant sectorial policies and as well as the NAPCC. Also, the vulnerable to climate change sectors were identified which are the Forest, Water and Agriculture sectors, and sectorial adaptation plans were individually drafted for these sectors. The Ministry of Health has developed and implementing the strategy for climate change adaption and human health. At the same time the Risk Management Strategy of Disasters associated with climate change has been drafted and also reflects climate change concerns. Other sectors are also undertaking climate change related activities, and sub-strategies on climate change adaptations are starting to develop and to be integrated at the local level.

The annual reports of implementation status of the NAPCC are submitted to the Government of Mongolia and the Standing Committee for Environment and Agriculture of the State Great Khural (Parliament). The programme identified the participation and roles of each stakeholders including government organizations, local communities, private sectors and the government body that is responsible for the environment and is representing the role for coordination and management of the implementation of the Programme.

By the end of 2013, 60% of the goals and objectives of the Implementation plan for the first phase (2011-2016) of NAPCC has been achieved. Goals and objectives such as establishing the legal and policy framework, expanding national climate observation network, research and assessment, and conducting public awareness raising activities are on target to achieve these goals, but budget approval on these issues is still a concern.

The Millennium Development Goals-based Comprehensive National Development Strategy (MDG-based CNDS) of Mongolia approved by State Great Khural (Parliament) in 12th February 2008 defines the development policy of Mongolia. The top six priorities of the MDG-based CNDS are identified in the comprehensive strategy, and climate change is considered as one of the priorities. The fifth priority is "to create a sustainable environment for the development by promoting capacities and measures on adaptation to climate change, halting imbalances in the country's ecosystems and protecting them." Within the framework of the fifth priority is to "Promote capacity to adapt to climate change and desertification, to reduce their negative impacts." These goals are mainly reflected in the Ministry of Agriculture and Industry, the Agency of Meteorology, Hydrology and Environment Monitoring and other relevant ministries' policy plans; and, the Ministry of Environment and Green Development is coordinating these activities.

A recommendation letter No. 31/24 from July 9, 2010 of the National Security Council recommended The State Great Khural to take action in improving legal framework on climate change, and the Government to establish a Climate Change Coordination Office responsible for climate change policy development, management and coordination of cross-sectoral and nationwide activities in the country.

The Government's main policies such as "21st Century's Sustainable Development

Action Plan, the Green Development policy, and other policies include concrete considerations and recommendations on adaptation on Climate change and mitigation of GHG emissions. The Ministry of Environment and Green Development is coordinating to reflect these activities into the annual Government action plans and other relevant Ministries plans and strategies. But setting the budget is currently a big challenge for these activities.

8.3 Institutional arrangements

Climate change issues should be managed as a united effort rather than sectorial. In other words, the responsibilities of all necessary activities should be coordinated and made explicit to all institutes and authorities involved. In order to tackle this issue in 2012, the Government of Mongolia established the Climate Change Coordination Office (CCCO) within the Ministry of Environment and Tourism (former) under direct supervision of the Minister for the Environment and Tourism to carry out day to day activities related to the implementation of commitments and duties under the UNFCCC and Kyoto Protocol, to manage the nationwide activities, and to bring into action the integration of climate change related problems in various sectors. The Climate Change Coordination Office includes Clean Development Mechanism National Bureau which is responsible for climate change mitigation, reduction of greenhouse gases, implementation of low carbon development, GHG inventory and Bilateral and Multilateral offset crediting activities as stipulated in the revised Law on Air.

The Government has also established an inter-disciplinary and inter-sectorial National Climate Committee (NCC) led by the Minister for Environment and Green Development, to guide national activities and measures aimed at adapting to climate change and mitigating GHG emissions.

At the local level there is no entity or officers that are directly responsible for the implementation of the NAPCC and its strategies as well as other climate change related strategies and plans, but the local agencies of the Ministry of Environment and Green Development, Development Policy and Planning Departments of Local Governors offices, and in some cases the Local Centers of Meteorology, Hydrology and Environment Monitoring are responsible for implementing these activities.

The NAPCC and The Millennium Development Goals-based Comprehensive National Development Strategy (MDG-based CNDS) are the main policy frameworks of National and sectorial development plans and the other relevant strategies. Therefore, the success of the measures and actions identified in the NAPCC will depend directly on the level of the integration with these national and sectorial development policy documents.

Currently, climate change concerns and challenges are not fully reflected in national and sectorial development plans and programs. In order to do that there is a need to develop a new law on the coordination of all climate change related activities. Some countries have set an example and have already passed laws that coordinate climate change policies as well as identified Ministries that are responsible for climate change policies and activities. Existing environmental regulations, sectorial development policy documents and other related laws need to be amended if this is required for adaptation or mitigation actions. Passing new laws or amending existing laws, particularly policy or development programmes or plans guiding different economic sectors, and development of improved strategy documents should be carefully reviewed, revised and implemented for the protection and preservation of the unique Nature and Cultural heritage of the country.

8.4 Green Development Policy and its climate change aspect

The concept that the development of a given country is defined by its economic development directed toward the welfare of society, and the enhancement of coherence between these factors and environmental sustainability, is an emerging necessity. Within this framework, the terminologies including "sustainable development," "green growth," "green development" and "green economy" are widely used. Even though international organizations and researchers conclude that many definitions and notes on this, fundamentally, those are for the concept of development in which environmental issues should be integrated. Since the Rio Summit (1992), sustainable development has become a matter of discussion, and relevant international organizations have developed a number of documents and programs as well as some countries have mainstreamed the concept into their development policies and strategies. In common words, sustainable development means that in order to enhance the development of the country and to guarantee a better life for the people, the three main subjects, namely, the economy, society and the environment, should be considered at the same level. So, that under the concept of green development, out of these three components, environmental issues should be taken more into account and proper measures should be taken. In terms of the green economy, so as to develop the economy, environmental issues are also taken into account. The other issues including the production of more waste–free goods, organic, re-usable and recyclable goods with less raw materials and resources, and the creation of green job places, are under consideration. At present, one of the main reasons behind the development pattern, directed more at environmental issues, is a rapidly changing climate of the world induced by the depletion of natural resources, environmental imbalances, and the accumulation of a great amount of greenhouse gases in the atmosphere due to the expansion and development of manufacturing services, and the use of natural resources in an uncontrolled, unlimited and wastefully extravagant way; and thus, climate change impacts and consequences have gone far beyond our imagination and have already reached the level which could severely affect the world development. Therefore, worldwide negotiations on climate protection and green development are underway and every nation in the world has to implement it as a priority.

Initially proposed at UN Conference on "Environment and Development" held in Rio De Janeiro, Brazil in 1992, the idea of "sustainable development" has been expanded and enriched, and now it is raised as an issue of the "green economy", "green development" and "green growth." The concepts and basic principles of "Green economy," elaborated by the UNEP, were reflected in the document "The future we want" (UN 2012a) which was approved by Rio+20 Summit held in 2012. In the document, it was recommended that every single country is to develop nationally appropriate green economy which is main instrument for sustainable development and poverty reduction.

Green development goals are directly related to climate change issues. In general, the main approach to deal with challenges and impediments induced by climate change is guiding principles and elements of green development concept. The issues relevant to climate change mitigation, greenhouse gases reduction and adaptation to changing climate are associated with green development concept under the following two sets of issues. It includes:

- Climate resilient development,
- Low carbon development or carbon and emission free development.

Climate resilient development refers to a development trend or concept aimed at reducing or if possible fully eliminating adverse impacts and risks caused by climate change, and coping to changing climate and using favorable conditions induced by climate change. Therefore, measures in this area are more linked to climate change adaptation, and it is possible to reach these goals through the implementation of green development objectives. The second issue is more related to climate change mitigation and reduction or if possible full zero-emission of greenhouse gases and other climate-altering polluters emitted from manufacturing, services and business activities.

Mongolia introduced its first presentation on sustainable development at the UN Conference on "Environment and Development" in 1992, and set an important goal to take more than 30% of its total territory under conservation. Further, "Mongolian Action Program for the 21st Century" (MAP-21) was ratified by the Parliament of Mongolia in 1998, and its implementation was succeeded in a certain degree in ensuring all central and local level stakeholders' engagement and accessibility available for all the citizens (Khuldorj 2012). In the MAP-21, the main ideas on implementing and mainstreaming climate change issues into the country's development goals were initially integrated.

The new Government which was established after 2012 Parliamentary Election paid special attention to environmental issues, and proclaimed green development policy as a country's fundamental concept of the development. In order to implement this new concept, the Government restructured the former Ministry of Nature, Environment and Tourism into the Ministry of Environment and Green Development, and upgraded its status to the core ministry. The Parliament of Mongolia approved "Green Development Policy of Mongolia" in June, 2014 (SGKh 2014). In the document, green development was defined as "a pattern of development that reduces poverty through an inclusive economy in which resources are used efficiently and without waste, supports ecosystem services, lowers greenhouse gas emissions and waste". Therewith, above mentioned terms were respectively defined as follows:

"green economy" is one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities;

"green growth" means economic growth with reduced greenhouse gas emissions that ensures environmental sustainability, supports social inclusiveness and participation;

"green industry" is an industrial process that utilizes energy and resources efficiently, with reduced greenhouse gas emissions and without harm or risks to humans and the environment.

Therefore, as described in the document, "the green development concept transforms Mongolia into a development model that ensures the improved well-being and prosperity of Mongolian citizens by safeguarding the sustainability of ecosystem services, increasing the effective consumption of natural resources and ensuring economic growth that is inclusive and environmentally sound."

The following principles will be followed for ensuring green development:

- Efficient, effective and rationale use of resources;
- Sectorial policies and planning shall be consistent with green development concepts;
- Promote clean and advanced technologies;
- Ensure citizen's participation in the creation of green economic growth;
- Engrain environmentally friendly attitudes, habits and competencies;
- Transparency, accountability and liability.

The following strategic objectives were identified in the green development policy document:

- Promote a sustainable consumption and production pattern with efficient use of natural resources, low greenhouse gas emissions, and reduced waste.
- Sustain ecosystem's carrying capacity by enhancing environmental protection and restoration activities, and reducing environmental pollution and degradation.
- Increase investment in natural capital, human development and clean technology by introducing financing, tax, lending and other incentives for supporting a green economy.
- Engrain a green lifestyle by reducing poverty and promoting green jobs.
- Encourage education, science, and technology to serve as the catalyst for green development, and develop cultural values and livelihoods that are in harmony with nature.
- Develop and implement a population settlement plan in accordance with climate change, while considering the availability of natural resources and the resilience of regions.

The Green Development Policy of Mongolia is to be implemented in two phases till 2030. During 2014 and 2020, the first phase implementation period, green development models and norms will be established in all economic and social sectors that are based on country circumstances, and a legal framework will be created to ensure green development progress. Infrastructure development and other efforts that are aimed at enhancing long-term sustainable development of the economy will be actively mobilized. A knowledge based economy will mature by implementing Mongolia's sustainable development goals and regionally competitive production and service sectors will be developed. Greenhouse gas emissions per unit of production will be reduced through the use of clean technologies for renewable energy production and environmentally friendly, highly efficient green infrastructure, by introducing green investment and financing mechanisms. During the second phase implementation period (2021-2030), the goals including a socially equitable, inclusive and highly efficient green economy system is established where environmental sustainability has persisted, benefits from ecosystem services are accepted rationally, and adaptations to climate change are customized were set.

The goals and strategic objectives of Mongolian Green Development Policy are directly coherent with the goals and measures identified in National Action Program on Climate Change (SGKh 2011) in addressing climate change challenges. Thus, the implementation of Green Development Policy of Mongolia will play an important role in reducing greenhouse gas emissions and improving natural carbon sequestration. Indicators for the measurement of main results of Green Development Policy implementation are shown below:

In order to implement the Green Development Policy, Mongolia takes sequential measures and simultaneously the country actively cooperates with international organizations and other world nations. For instance, the country is engaged in broad cooperation with the UN Environmental Program (UNEP) and UN Development Program (UNDP). In 2013, Mongolia acceded to PAGE (Partnership for Action on Green Economy) implemented by UNEP. The PAGE is a program aimed at supporting developing countries to implement the principles of green economy proposed at Rio+20 Conference in enhancing sustainable development and poverty reduction. Besides, the country has become a member of Global Green Growth Institute (GGGI), and it actively cooperates with relevant organizations in implementing green development policies at sectorial levels. For example, during 2013-2014, the joint green development policy research in energy and transport sectors was conducted.

Table 8.1 Indicators for Green Development Policy implementation[#]

Indicators	2020 /by percentage/	2030 /by percentage/
Share of renewable energy in total installed capacity of energy production	20	30
Reduction of building heat loss	20	40
Share of waste recycling	20	40
Share of expenditures for green development in total GDP	2	3
Share of expenditures for science and technology research in total GDP	2	3
Share of green procurement in total government procurement	20	30
Share of special protected areas	25	30
Increased investment in environmental protection and restoration	20	30
Share of forest areas	8.5	9
Percentage of population that has access to safe drinking water	80	90
Percentage of population connected to improved sanitation facilities	40	60
Poverty level	24	15
Percentage of greenery spaces in Ulaanbaatar and other settlement areas	15	30
Share if the agriculture and manufacturing sector in total GDP	28	30

Note: # - compared to 2013 indices

8.5 International Cooperation on Climate Change

For countries vulnerable to the adverse impacts of climate change like Mongolia, it is impossible to solve the challenges and problems associated with climate change without international cooperation and the technical and financial support of developed countries and international organizations. Since the Government of Mongolia has ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 30 September 1993 and the Kyoto Protocol on 15 December 1999, the country is more accessible for international channels to establish bilateral and multilateral cooperation in climate change actions.

Following the recent changes (2012) in the Government structure, the Ministry of Environment and Green Development (MEGD) has now become one of four core Ministries with clear abilities to perform in a cross-cutting way with the sectorial Ministries. There is also strong synergy with the aims of climate change policy within the green development agenda. The country is well-placed compared to many countries that climate change is already embedded in development plans and processes, particularly the MDG-based Comprehensive National Development Strategy of Mongolia, National Action Program on Climate Change and the National Development Plan with its development priorities.

The central government administration authority responsible for climate change is the MEGD. The MEGD engages in international talks, dialogues and events related to climate change, develops government policies and strategies on climate change, enforces legal requirements for the protection, conservation and appropriate use of natural resources, improves soil, water and forest resource management, strengthens environmental monitoring networks, conducts necessary research, disseminates scientific information about the environment to individuals and institutions, implements climate change projects using internal and external funding and coordinates the actions of multiple ministries, agencies and organizations.

Besides the MEGD, an important counterpart for the donor community of the Mongolian Government on climate change issues is the Ministry of Finance (MFA), responsible for the general oversight on international grants, financial assistance and cooperation, and the Ministry of Economic Development (MED), responsible for investment, economic growth and technology innovation. Other sectorial ministries and agencies have adequate responsibilities, namely the Ministry of Energy (ME), Ministry of Construction and Urban Development (MCUD), Ministry of Industry and Agriculture (MIA), National Emergency Management Agency (NEMA). Local and provincial authorities have direct responsibilities dealing with climate change related actions and activities. A number of supplementary small-scale or local-scale actions have financed under the donors or other ‘horizontal’ budget lines. All international aid and grants go through Ministry channels in accordance with existing legal regulations.

8.5.1 Cooperation with International Organizations and Partner countries

The major development partners of Mongolia on climate change are the Global Environmental Facility (GEF), World Bank (WB), Asian Development Bank (ADB), The United Nations Development Program (UNDP), the United Nations Environment Program (UNEP) and Governments of Japan and Germany. In addition, cooperation with bodies established under the UNFCCC and its Kyoto Protocol such as the Adaptation Fund, Green Climate Fund, Technology Centers and Networks and their technical and financial support are essential for Mongolia. It should also be noted the support from the government of Australia, The Netherlands, Republic of Korea, USA, Luxemburg and Switzerland, which have contributed to the climate change and related projects in the past.

Mongolia needs to increase its international climate profile to attract more finance on climate change actions. As a small country in terms of population, and as a lower-middle income country, but with serious climate associated vulnerability in both rural and semi-urban populations, Mongolia is not seen as a Least Developed Country, which needed priority support or as a powerful emerging economy which has to be taken into account, like China, India and others. Currently Mongolia receives a low level of international climate funds.

Global Environment Facility (GEF). Since joining the GEF, Mongolia received GEF grants totaling USD 32 million that leveraged USD 342 million in co-financing resources for 27 national projects, with nine of those projects on climate change. Similarly, Mongolia participated in 13 regional and global projects financed by the GEF totaling USD 155 million that leveraged USD 827 million in co-financing resources and two million in climate change. During the current GEF-5 replenishment period (July 2010-June 2014), Mongolia received an indicative allocation to formulate and execute projects for USD 3.2 million on climate change.

The main GEF implementing agencies on climate change issues in Mongolia are UNDP, ADB and WB. The main National Executing Partner on climate change with GEF is the MEGD.

Asian Development Bank (ADB). Since Mongolia joined the ADB in 1991, ADB has been one of Mongolia's largest sources of multilateral official development assistance (ODA), playing a key role in the country's transformation to a market based economy. With ADBs' support in Mongolia, ten climate change related projects at national and sub-regional levels have been implemented and of these projects six were technical assistance, two are grants and two are loans. Current project cooperation with MEGD at the national level is a). Establishment of Climate-Resilient Rural Livelihoods and Energy Efficiency (grant), and b). Energy Efficiency and Urban Environment Improvement (loan).

ADB's future program will focus on: transport, energy and water supply infrastructure; access to education and health; and regional economic cooperation. Whilst investments in energy and water clearly impact climate change policy, climate change has not featured as a policy theme in ADB's program so far for Mongolia. However, discussions revealed that ADB is now keen to help Mongolia access climate funds, and that it could help with project development and management.

UN support to Mongolia. Over the years, Mongolia has received substantial financial, technical, technological assistance and support from UN organizations that gives impetus to the economic and social development of the country. Since 1963 Mongolia has received more than 200 million USD of grants and technical assistance. The first of four priority areas for UN interventions in the development efforts of Mongolia for the period 2012-2016 backed with financial commitments, are determined as: Improved sustainability of natural resources management, and resilience of ecosystems and vulnerable populations to the changing climate. Also, the UN agencies in Mongolia have strongly supported the implementation of MDG-based National Development Strategy (NDS), through technical guidance on the needs assessment approach and procuring the generalized macro-economic framework licensed for Mongolia.

The United Nations Development Programme (UNDP). The Government of Mongolia and the UNDP have entered into a basic agreement to govern UNDP's assistance to the country, which was signed by both parties on 28 September 1976. UNDP opened its representative office in Ulaanbaatar in 1973 after more than a decade of successful cooperation with Mongolia. For climate change adaptation and mitigation, UNDP supports the implementation of the national action programmes for climate change and combating desertification, nationally appropriate mitigation actions (NAMAs) and capacity development of the Climate Change Coordination Authority.

UNDP prioritizes demonstration of proven adaptation measures to maintain ecosystem functionality and minimize vulnerabilities of local communities, including the protection and sustainable management of forest assets to produce globally significant lessons, considering Mongolia's considerable size of boreal forest. In addition, energy efficiency in the building sector will be further promoted as a long term measure for abatement of air pollution and GHG emission reduction. In a country beset by long, harsh winters, heating of buildings requires a substantial amount of individual households' income. Reducing Mongolia's reliance on wood and coal-based fuels for household heating is not only paramount for reducing air pollution in Mongolia, but also for the overall preservation of the global environment and the reduction of carbon-based GHG emissions. UNDP supports energy efficiency through alternative materials for insulation, and in strengthening the national system of building codes, norms and standards. UNDP's support is also extended to the formulation of appropriate pro-poor policies and strategies in the energy sector. Additional work is undertaken on disaster preparedness and response, and working with local herders with a range of livelihood support systems including land, water, forest management and biodiversity conservation.

UNDP has made Mongolia a pilot country for the economics of adaptation, using the Yale methodology and training three officials. With this new program, country teams in Asia will become skilled in ways to design and evaluate climate change adaptation projects, and will develop crucial skills in climate change adaptation economics. Leading decision-makers and technical teams in key ministries throughout Asia will benefit from this ambitious and wide-ranging program, involving further skill development activities, alongside country level studies and analysis. UNDP's ongoing climate change related projects at the national level are a). Nationally Appropriate Mitigation Actions in the Construction Sector in Mongolia, b). Ecosystem Based Adaptation Approach to Maintaining Water Security in Critical Water Catchments in Mongolia and c). Strengthening Local Level Capacities for Disaster Risk Reduction, Management and Coordination in Mongolia.

World Bank (WB). Mongolia became a member of the World Bank Group in February 1991. Since then, the World Bank has provided USD 701.7 million to Mongolia. As of April 1, 2014, the Bank's portfolio in Mongolia has total commitments of USD 160.39 million, composed of seven operations financed by IDA (International Development Association) credits totaling USD 95.05 million, and 14 trust funds totaling USD 65.34 million spread over 12 operations. The majority of the projects support infrastructure development, economic governance and institutional strengthening of the mining sector.

Since 1991, the International Development Association (IDA) has supported rural development, education, improving the livability of Ulaanbaatar, ensuring sound management within the mining sector, sustainable infrastructure development in southern Mongolia, environmental protection, policy development and air pollution abatement measures. The World Bank has focused its activities on the Climate Investment Funds (CIF) in relation to the UNFCCC. However, these are not yet being applied to climate change in Mongolia. Climate change is not a significant focus directly by the Bank, but rather it is supporting energy efficiency and improving resilience projects which can be labeled as climate change mitigation. It did support establishing the Designated National Authority (DNA) for the Clean Development Mechanism (CDM). Currently the bank is focusing on livestock grazing management, the National Sustainable Livelihoods project, but the current project is ending, so the Bank is considering whether the CIFs could be used for the next stage with soil carbon management. A current ongoing project relevant to climate change mitigation is the regional level Ulaanbaatar Clean Air project (loan).

UN-REDD. Mongolia joined the UN-REDD Programme in June 2011. Guided by a Multi-stakeholder taskforce, the national REDD+ Readiness Roadmap is now completed. UN-REDD has meanwhile began its support in designing a framework for strengthening both functional and technical capacities of relevant national institutions to establish a strong foundation for the implementation of the Roadmap. The National REDD+ Roadmap for Mongolia is developed by the MEGD with assistance of the UN-REDD Programme. In April 2014, Mongolia was invited to present its National UN-REDD Programme at the 12th UN-REDD Programme Policy Board meeting, which took place in Lima, Peru on 7-9 July 2014.

Global Green Growth Institute (GGGI). Mongolia became a member of GGGI in Incheon City of the Republic of Korea on June 10-11, 2013. GGGI and the MEGD signed a Memorandum of Understanding (MOU) in November of 2011 for the cooperation in programs and joint activities that foster the promotion of green growth. Sector-specific green growth projects in the transport and energy sectors were launched in 2012. After initial scoping work and a Consultation Workshop in February 2012, the transport and energy sectors emerged as priority areas on which to focus green growth planning. As a result, the Strategies for Green Public Transport and Strategies for Green Energy Systems were developed in 2013. GGGI aims to continue to assist the Mongolian Government in green growth activities, particularly with respect to its National Strategy on Green Development Policy.

The Republic of Korea, as a donor country, is supporting substantially the implementation of the Mongolian National Green Wall Programme.

Bilateral Cooperation

The German Agency for International Cooperation (GIZ). GIZ Mongolia works in priority areas of Sustainable Economic Development and Environmental Policy, including Energy Efficiency. GIZ Mongolia works for the Climate Readiness REDD+ project and forest multi-purpose national inventory. GIZs' ongoing climate change related projects at the national level are: a) Efficiency of grid-based energy supply schemes in Mongolia; b). Biodiversity and adaptation of key forest ecosystems to climate change.

GIZ Mongolia programme supports the strengthening Climate Change Coordination Office newly established within the Ministry of Environment and Green Development providing technical and financial assistance in implementation of activities and events organized by the office. GIZ also assist Mongolia in identifying the Mongolia National Implementing Entity (NIE) and increasing its capacities.

Mongolia-Japan Low-Carbon Development Partnership. Minister for the Environment of Japan and Minister for Environment and Green Development of Mongolia made a Joint Statement on environmental cooperation, climate change and the Bilateral Offset Crediting Mechanism (BOCM) in Doha, the State of Qatar during the 18th Session of the Conference of the Parties (COP18) to the United Nations Framework Convention on Climate Change (UNFCCC). As a result, on January 8, 2013, the Government of Mongolia and Japan signed in Ulaanbaatar a bilateral document "Low Carbon Development Partnership" to implement jointly Joint Crediting Mechanism (JCM) in Mongolia. This Japan-Mongolia partnership is the first partnership signed by Japan for this purpose. Under the partnership, joint studies have been taken to improve Combined Heat and Power (CHP) Plant to identify Business as Usual (BAU) and Nationally Appropriate Mitigation Actions (NAMA) scenarios in the Energy Supply Sector. A total of nine projects were undertaken during 2013 fiscal year with contributions from the Ministry of Environment and the Ministry of Economy, Trade and Industry of Japan. This included five feasibility studies, two demonstration projects, one model project, and one project planning study.

Non-governmental Cooperation. In addition to official government cooperation, there are many forms of initiatives for cooperation between academic institutions, non-governmental organizations, foundations, and the private sector, which has often contributed to the climate change adaptation and mitigation actions. On a practical level, the CCCO under the MEGD does demonstrate its capacity to manage stakeholder engagement and provide leadership. It has ongoing informal working groups on sectors, such as water and forestry and then brings in experts e.g. from universities, private companies, banks and etc. A few examples of these non-governmental and private sector cooperation programs are EBRDs initiative on Salkhit wind farm development, Xac bank sustainable energy loan, and the Swiss development cooperation (SDC), which has been taking a lead with the cooperation of Mongolia Society for Range Management on pastureland such as Linking Herders to Carbon Markets, Green Gold/ Mongolian disaster relief and prevention projects.

It should also be noted that actions are being undertaken to develop projects on hydropower plants (such as Durgun and Taishir), biomass and energy efficiency through the CDM and other private channels.

8.5.2 Barriers to cooperation and an outlook for the future

Looking at the list of past and ongoing climate change cooperation efforts between the governmental, non-governmental and private sector in Mongolia, it is clear that there has been quite a bit of activity. While the official governmental track is certainly not the only means of bilateral cooperation, nor is it always the most effective, it is clearly important for cooperation to occur through official as well as unofficial channels. Despite the efforts of official bilateral and multilateral agreements signed between the Government of Mongolia and donor countries and organizations in the area of climate change, there have been many challenges in aspect of the successful implementation of agreed upon activities.

Official bilateral and multilateral cooperation has suffered in the past from a lack of consistent funding and its mechanisms, as well as from insufficient high-level political support and commitment. In general, from the perspective of the environmental sector, due to a lack of secure funding commitments the periods of stagnation exist in the implementation of some programs, and the MOUs or initiatives signed with donors.

Limited human resources are also a bottleneck that hampers the effective and advanced cooperation with donors. While the list of agreements signed with donors has been well documented by the government, it should be result oriented and require better donor coordination from the Government. The Climate Change Coordination Office (CCCO) has been established by the Government, in order to carry out day to day activities related to the implementation of commitments and duties under the UNFCCC and Kyoto Protocol, to manage climate change activities nationwide, and to integrate climate change concerns into various national and sectorial development plans and programs. With this perspective, the donor coordination on climate change projects and programs is well sustained with the CCCO mandatory of management.

Bilateral and multilateral cooperation on climate change is in many ways just beginning. The role that Mongolia will play in the global and regional climate change solution is just starting to be defined. The Government has taken positive steps to promote low carbon development, renewable energy use , energy efficiency and responsible measures on adaptation. This ambitious political decision of the Government will have the benefit to embrace an opportunity to advance both bilateral and multilateral cooperation in climate change actions.

8.6 Climate Change Public Awareness and Education

It is crucial to introduce climate change related issues to the public and individuals to give them an adequate understanding of the matter, and to have these issues reflected in formal and non-formal educational systems. Climate change should be considered an important part of this country's knowledge for sustainable development education. Activities towards climate change mitigation and adaptation are not only the environmentalists' duty to implement, but also it needs everyone's efforts and participation. In other words, climate change directly or indirectly affects people's daily livelihood. Therefore, being knowledgeable about climate change will help people to choose how to adapt their ways and actions.

Currently the country is implementing the following public awareness activities on climate change:

- Trainings and seminars, including a discussion
- Themed trainings and activities within the certain sectors
- Organizing regional seminars for local areas
- Organizing topic specified integrated trainings to prepare training teachers from aimags and soums
- Distributing publications, newsletters and running a web page

Parliament has approved the National Action Program on Climate Change (NAPCC) in 2011, and public awareness and educational issues were included in it as one of the main objectives. The fifth strategic objective of this program is defined as "Conduct public awareness campaigns and support citizen and community participation in actions against climate change." The following measures were identified under this strategic objective:

- To mitigate climate change, to publish literature, books, handbooks and newsletters about climate change;
- To promptly provide information about government policy and it's decision, science discovery, and advances in technology;
- To include courses about climate change, sustainable development and the green economy in all levels of school curriculums;
- To develop educational curriculums and define new professional indexes and classifications related to climate change and environmental sectors;
- To conduct training and increase awareness about first aid during weather hazards and natural disasters;
- To establish local citizen and partnership based community groups for responding to natural disasters;
- To encourage individuals, community groups, non-government organizations and companies to take action in response to climate change, run "green" businesses, and support the consumption of "green" products;.
- To promote participation of, and partnership among, individuals, community groups, NGOs, business organizations and women in international and regional activities and forums;
- To implement projects and programs aimed to support the livelihoods of socially vulnerable groups (ethnic minorities, female-headed households, poor families), alleviate poverty and promote green jobs.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) is determined to make citizens understand their contributions by raising their scientific knowledge and is structured in the optimal way to mitigate and adapt climate change. Therefore, a "climate change education" program is being implemented under the framework of the United Nation's sustainable development supporting activities with the UNESCO initiative (UNESCO, 2010).

Mongolia's future depends on our actions today. The majority of citizens' attitude is that climate change issues refer to the politics, decision makers and environmental specialists who work in the field. Research shows that 1% of the Mongolian population has a deeper knowledge about climate change or is studying and working in the climate change and environmental sector. Even if the 3000 people who work in this sector collaborate, it is not enough to mitigate greenhouse gas and to prepare the other 3 million people for the climate change adaptation. Therefore, providing climate change education to the public and preparing citizens with sustainable development knowledge is the only way to tackle this issue. Everyone should be required to learn about the climate change mitigation results and negative impacts instead of doing nothing. Responsive actions consist of two issues, including adapting to the climate change, which has been already begun, and to learn mitigation approaches for potential changes and apply these experiences to the daily lifestyles.

8.6.1 Improving public awareness and forming a smart lifestyle

Recently, education on climate change as a serious issue has become priority. It is important to learn from foreign or domestic experiences of environmental basic education to sustainable education transition, and study the appropriate methods and guidelines for Mongolia's condition in detail in order to apply climate change education issues in every educational level and build a capacity for the teachers and educators.

Meanwhile the new concept or paradigm that determines education as "general," "continuous" and "by a lifelong process," is dominating, meanwhile the common understanding of education as classroom training is currently out of date. It appears to be insufficient to limit the mutual knowledge about climate change and the environmental ecosystem value - such as water, plants and it's service to the society and people – to only school age children with in class training. However, it is important to provide climate change vulnerable community such as herders, low income people, unemployed people and local people with education by using modern technology and other effective means of communication depending on the behavior of people. Therefore, in the framework of providing climate change public awareness, changing peoples' daily lifestyle and setting habits, the following activities will contribute to improve understanding and knowledge of the people (Batchuluun.E, 2012):

Pre-school children. Researchers assume most of the children's mental development builds up to two years of age as well as begins before birth. Therefore, it is suitable to start educating children from pre-school age to provide knowledge about climate change mitigation actions and setting their habits. This will start from reducing water consumption while cleaning teeth and putting candy cover papers in designated boxes. In order to accomplish this, teachers from kindergarten and on are requested to learn about climate change.

Primary school students. In secondary schools knowledge is mostly theory and academic based, but at the same time it is likely to be far from practical usage even though biology and geography lessons include climate change, ecosystem, and biodiversity. For example, children graduate from their secondary school with knowledge about hydrospheric physical processes, but do not receive the knowledge about water value and how to reduce water consumption. Reflecting climate change issues in the educational programs are the solution to this. This not only covers environmental sciences, but also it can be implemented when all classes reflect climate change knowledge, ability and approaches, such as in mathematics and physical education etc.

Teachers and educators. The key people having an impact on the people and the implementation of the programs are teachers. Therefore, it is crucial to develop a training content for the teachers and to build a capacity of knowledge for the teachers. Introducing climate change adaptation pre-service teacher training and in service teacher training to the system will be the easy way to tackle this issue.

Universities, colleges and VETC. Universities, colleges and vocational education training centers (VETC) cover not only preparing skilled specialist for the certain sectors but also are important to provide knowledge about the environment and ecosystem degradation and upcoming climate change issues. Universities and vocational education training centers (VETC) are required to develop climate change education programs as individual classes and include them as mandatory courses. Also, climate change campaigns and non-class training can be organized.

Decision-makers and financial officers. Having knowledge about climate change issues on a broad scale appears as support for micro-loans for herders, public initiative supports and implementation of approved laws and legislations. Financial authority and officers will be included in this group so it can impact them to distribute money for having ecosystem services and ecosystem based adaptation.

Journalists and media officers. All different kinds of public media are the most forceful "weapons." Therefore, information sources and content provided by television, radio, newspapers, magazines and social media has to be scientific, realistic and socially responsible to encourage people to understand and accept the climate change mitigation actions.

Entrepreneurs or businessmen. Distributing and providing knowledge about climate change to the businessmen, local famous people, graduates and local people who live overseas will influence environmental restoration, investment and fundraising. For example, it is imperative to make people understand the importance of environmental restoration on the harmed ecosystem of their homeland rather than "building a stupa."

Local citizens. Local partnerships play a main role in implementing domestic climate appropriate climate change adaptation actions and restoring traditional ways to adapt. Therefore, it is important to conduct training among the partnership members to prepare teacher training and also to publicize guidebooks and training materials.

Tourism entrepreneurs. Natural tourism is rapidly developing in Mongolia, and at the same time, it is proven that it is harmful for the environment based on the experience of developed counties and Mongolia's practice today. Especially, it is crucial to provide understandings about climate change mitigation actions for legal entrepreneurs for trophy fishing, eco-tourism and wild animal products affected by climate change and a change of ecosystem regions and borders, as well as plant and animal abundance which are becoming more important to the national economy.

Women and children. Climate change causes inequality among the gender and age groups. Especially the most vulnerable groups are dropped out – children, women who cover most of the work of the livestock sector, and female-headed households. This vulnerability shows from the number of children as well as elders and disabled people affected in natural hazards. Training and information for this group will be suitable to be organized with informal education organizations located in the provinces and sub-provinces.

8.6.2 Good practices of activities, training, projects and programs:

In order to assure climate change adaptation, mitigation of its negative impacts, and to raise public awareness, the aim is to implement training and programs for the study of the general education school students, teachers and educators, herders and farmers.

Local decision-makers. In order to introduce climate change policy documents to the local environmental and other related sectoral specialists nationwide, regional seminars were organized in 2012 and 2013 to provide sufficient information and knowledge about greenhouse gas mitigation,about climate change adaptation, about mitigation activities on the negative impact of climate change and about policy implementation at a local level, and to coordinate implementing a "National Action Plan for Climate Change" and it's first phase plans, "Climate change policy and mitigation actions." Also, teacher training reflecting climate change adaptation in local development policy planning was organized and two people from each province have been trained and certified.

The "Climate change adaptation monitoring and assessment" handbook and guidelines were developed and publicized which aimed at giving support to develop a monitoring assessment for national and sectorial climate change adaptation strategy, local citizens' development plan, National climate fund or environmental research, and information catalogs. This handbook-guideline includes basic information about climate change adaptation action monitoring assessment systems and its four step methodologies, criteria, processes and operation and includes examples as well as international practices and lessons.

Box 8.1: "Climate change and children youth solution" project is initiated by "Mongolian Scout's Union" being implemented in cooperation with UNICEF and the National Agency for Children and consists of four programs, such as "Eco messenger", "Eco passport", "Eco education", "Climate change and children youth solution" reports. Young people who are involved in the Eco passport program initiated a variety of ideas to advertise and raise awareness of the public by planting trees and flowers, protecting the upstream areas, reducing excessive consumption, limiting incandescent light bulbs, and supporting paper bag usage. In total, 11,000 people from 21 provinces were involved in this environmental education program.

Young people between the ages of 15-24: Translate into Mongolian and distribute the guidebook, "Climate change and lifestyle," which is a smart consumer and lifelong education guidebook for youth aged 15-24, that has been translated into 18 different languages worldwide, and is for organized discussions among the university and secondary school students.

A small survey was taken with ten questions for the young people using Facebook. There were 508 in the (A) group which were active participants officially provided with sustainable lifestyle information and there were 207 in the (B) group which were inactive participants who were not provided with sufficient information. 97.04% of the (A) group of people who participated in the questionnaire responded that they worry about climate change while 35.26% of (B) group participants responded the same. To mitigate climate change 95.86% of (A) group and 31.4% of (B) group responded that their active participation is important. Regarding the reasons for climate change, 99.21% of (A) group and 32.36% of (B) group responded that greenhouse gas is anthropogenic. Despite that, most of the (B) group participants responded that this is a naturally oriented issue caused by air pollution, environmental execution, and mining use.

(A) group participants precisely determined impacts caused by climate change on the environment, while the (B) group participants wrote only that desertification and water shortage are obvious climate changes.

Most of the participants from (A) group responded that disposing of waste in open areas, protecting the trees and greens, sufficient energy supply, reducing paper supply, recycling, green trading, restoration, saving freshwater, and using public transportation were climate change mitigation actions. Most of the participants from the (B) group responded that disposing the waste in open area, protecting the trees and greens, sufficient energy supply, reducing paper supply, recycling, and green trading were climate change mitigation actions.

According to the above micro research which included the questionnaire and discussion results from the students who participated in green lifestyle survey, knowledge is still higher for students who were given the sustainable lifestyle information than for the students who did not have proper information. However, students from both groups had ecological knowledge to protect water and forests.

Organizing activities such as using social media to provide information, publications, sustainable lifestyle television programs for students and children, essay and drawing competitions themed, "What can we do to mitigate climate change?" and "Traditional ways to adapt climate change" are important in order to increase climate change knowledge and understanding. This will also encourage people's participation on climate change mitigation actions. However, these activity frequencies and framework will still not be enough.

Scientific groups of MSUE and NUM have done research and evaluated the reflection of climate change issues on policy documents, books, brochures, textbooks of general education schools and knowledge level of the teachers, as well as the coordination between the governmental and non-governmental organizations of the climate change sector. Even though the general education school's textbooks focus more on knowledge and theory, it is insufficient to build the knowledge for applying it to the real conditions.

Box 8.2: There are 53 schools attending the environmental and eco-friendly school project nationwide. In Khovd, Bayankhongor, Gobi-Altai, and Ulaanbaatar, some of the schools are involved in environmentally-friendly school projects under the framework of "Coping with Desertification" which is financed by the Swiss Development Agency. This project aims to provide sustainable development education to the students by recommending an environmental science training conduct manual cooperating with the "Mongolian environmental consortium". The environmentally-friendly schools' objective is to tackle complex obstacles by improving quality of environmental education and the knowledge of environmental protection, and to build a capacity of teachers, students, and parents as well as an external environment of the school.

Climate change education is needed for the future but we are unable to tackle all aspects of this issue by only implementing some projects.

Thus, it is strongly required to restore local neglected adaptation customs suitable for its own condition, to detect the disciplines that can change public attitude, to study in detail about methods of changing people's understanding to practices using activities, to provide information and knowledge to teachers and journalists, and to set and reflect climate change educational standards in every level of educational programming. Furthermore it is crucial to support official and unofficial ways of providing climate change education, to raise public awareness, and to coordinate governmental and non-governmental organizations, decision-makers and implementing bodies.

The following activities in public awareness are underway:

Climate change, ecosystem adaptation educational training program. There are many ongoing activities that promote the awareness of climate change and the ecosystem adaptation educational training program. These include the promoting climate change educational needs assessment research on the system level with various sectoral researchers and scientists, developing educational curriculums, defining new professional indexes and classifications indifferent levels of education and reflecting these in university programs and developing guidebook and textbook contents.(2014). It is imperative to develop educational curriculums and define new professional indexes and classifications related to climate change and environmental sectors.

Education program primary school and universities. The Mongolian Government has coordinated with the Swiss Development Agency and has begun implementing a project to include the climate change education issue in every level of education programs (2014-2020).

Ways Forward

Wide-scale recognition of global climate change challenges on future development of humankind is received not only at scientific, but also political and decision making levels. It is very clear and true in specific case of Mongolia. Thus, country's future sustainable development , which should provide a safe environment, secure society and rapid economic growth, directly depends on the successful implementation of national policies and strategies for establishing climate resilient and low carbon development societies. For Mongola, to achieve these development goals, the following priorities should be undertaken at all levels:

- Integrate priorities and actions to address climate change challenges and concerns into national, sectoral and local development planning;
- Establish legal framework and institutional arrangements to allow smooth implementation of climate change priorities;
- Secure public and private funding: This can be achieved by a national programme implementation, efficient law enforcement and the local government budgeting process.
- Support Research and Development: It is essential to facilitate transfer and introduction of climate-friendly technologies;
- Introduce promotion and subsidy policy for environmentally and climate-friendly technologies, investment and incentives,
- Systematically build capacities of stakeholders, end-users and general public, conduct public awareness campaigns and develop sustainable and green development education programmes,
- Strengthen international cooperation and networking.

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