MARCC-2014

MONGOLIA SECOND ASSESSMENT REPORT ON CLIMATE CHANGE – 2014

EXECUTIVE SUMMARY

ULAANBAATAR, 2014

GOVERNMENT OF MONGOLIA

MINISTRY OF ENVIRONMENT AND GREEN DEVELOPMENT

MARCC 2014

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This Executive Summary of the **“Mongolia Second Assessment Report on Climate Change 2014”** (MARCC 2014) has been developed and published by the Ministry of Environment and Green Development of Mongolia with financial support from the GIZ programme “Biodiversity and adaptation of key forest ecosystems to climate change”, which is being implemented in Mongolia on behalf of the German Federal Ministry for Economic Cooperation and Development.

Editors-in-chief:

Damdin Dagvadorj
Zamba Batjargal
Luvsan Natsagdorj

MONGOLIA SECOND ASSESSMENT REPORT ON CLIMATE CHANGE – 2014

Executive summary

Global and Regional Climate Change: Observed Changes and Future Projections

Observed Changes in the past

In its report, the Intergovernmental Panel on Climate Change (IPCC) Working Group I on the physical science basis of climate change (WGI AR5 2013) states with greater certainty than ever that climate change is happening and that human activity is the principal cause. The AR4 (2007) 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 temperature of the land and ocean surface has increased by 0.85°C during the period of 1880 to 2012, while the AR4 estimated average of warming across the globe over the past century (1906-2005) was 0.74°C.

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 (Figure S.1). For the longest period when calculation of regional trends was sufficiently complete (1901 - 2012), almost the entire globe has experienced surface warming. In the Northern Hemisphere, the period of 1983–2012 was likely the warmest 30-year period of the last 1,400 years.

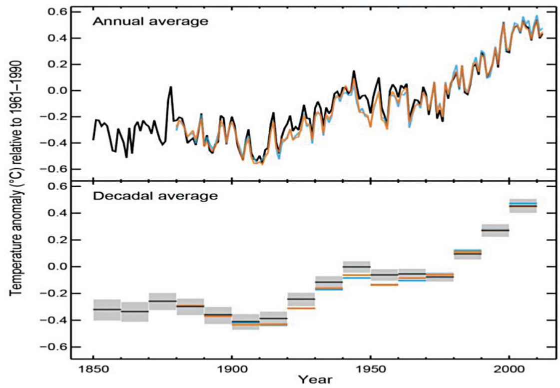


Figure S.1 The anomalies of the observed global mean combined land and ocean surface temperature, from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961-1990. *Source: WGI AR5 2013, Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis*

Level of confidence in the precipitation changes 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 (Figure S.2). For other latitudes, area-averaged long-term positive or negative trends have a low confidence level.

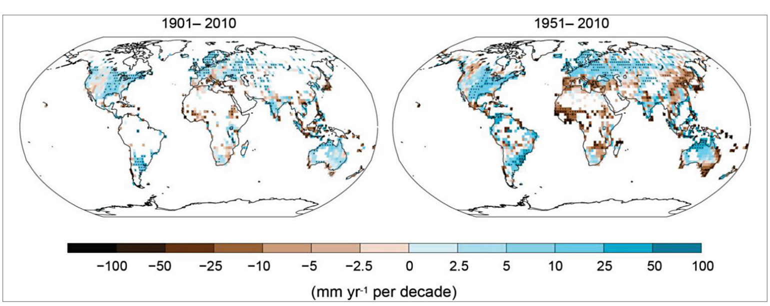


Figure S.2 Maps of observed precipitation change from 1901 to 2010 and from 1951 to 2010 (trends in annual accumulation calculated using the same criteria as in Figure 2.1) from one data set; *Source: WGI AR5 2013, Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis*

Changes in many extreme weather and climate events have been observed since approximately 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. Flooding was the most reported extreme event during the decade in many parts of the world. North East Asia had a cold period during its 2012-2013 winter season, associated with negative Arctic Oscillation conditions and blocking patterns around eastern Siberia. During this period, most of Siberia experienced cold by 2-3˚C below seasonal average, making this one of the coldest winters for the region in the 21st century (WMO 2014).

The AR5 also states that glaciers have shrunk worldwide, and that the Greenland and Antarctic Ice Sheets have lost a significant mass over the past two decades. Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in area. Northern Hemisphere snow cover decreased on average 1.6% per decade for March and April, and 11.7% per decade for June, over the period of 1967 – 2012. There is also a high confidence that permafrost temperatures have increased in most regions since the early 1980s. Warming of up to 2- 3˚C was observed in some regions and a considerable reduction in permafrost thickness and areal extent over the period of 1975 – 2005.

After a period of rapid warming observed in the 1990s, global mean surface temperatures have not warmed as rapidly over the past decade. In addition to a robust multi-decade warming, global mean surface temperature exhibits substantial decadal and inter-annual variability. Strong negative temperature anomalies were observed, for instance, in December 2009 at middle latitudes in the Northern Hemisphere, as great as -8˚C in Siberia, as averaged over the month. 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, are coherent and characterized by a striking warming trend during this period. Rate of increase in the average annual mean temperature for the Mongolian Plateau was 0.23˚C per decade while it was 0.18˚C for the four sub-regions. In the Asian mid-latitude areas, the surface air temperature increased relatively slow from the 1900s to 1970s, and it has increased rapidly since the 1970s (Chen et al. 2009).

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 approximately 1950. The heat wave frequency has increased since the middle of the 20th century in large parts of Asia (WGI AR5, 2013). Over the period of 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 mid-latitude semi-arid part of Asia. Similarly, large warming trend (>2˚C per 50 years) in the second half of the 20th Century was observed in the Northern Asian sector. Precipitation pattern, including extreme ones, are characterized by a strong variability, with both increasing and decreasing trends observed in different parts of Asia in different seasons. In North Asia, the observations indicate 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 inter decadal weakening after the 1970s, due to a natural variability of the coupled climate system, leading to enhanced mean and extreme precipitations along the Yangtze River valley (30˚N), but deficient mean summer precipitation in North China (WGI AR5 2013). A decrease in extra tropical 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.

A recent update made by the World Meteorological Organization (WMO) has demonstrated (2013) that the global average 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. The atmospheric concentrations of these GHGs have increased to unprecedented levels 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. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750. 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.

Future Projections

Global surface temperature change towards the end of the 21st Century is *likely* to exceed 1.5˚C, relative to the period of 1850-1900, and 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. The global mean surface temperature change for the period 2016–2035 relative to 1986–2005 will likely be in the range of 0.3˚C-0.7˚C. Relative to a natural internal variability, the near-term increases in seasonal mean and annual mean temperatures are expected to be greater in the tropics and subtropics than in the mid-latitudes. Increase of the global mean surface temperatures for 2081–2100 relative to 1986–2005 is projected to be likely in the ranges derived from the concentration-driven CMIP5 model simulations, that is, 0.3˚C-1.7˚C (RCP2.6), 1.1˚C to 2.6˚C (RCP4.5), 1.4˚C to 3.1˚C (RCP6.0), 2.6˚C to 4.8˚C (RCP8.5) (Table S.1). The Arctic region will warm more rapidly than the global mean, and mean warming over the land area will be larger than over the ocean surface.

Table S.1 Projected change in the global mean surface air temperature for the mid- and late 21st Century relative to the reference period of 1986–2005.

Scenario	2046 - 2065		2081 – 2100	
	Mean, ºC	**Likely range**, ºC	**Mean,** ºC	**Likely range**, ºC
RCP2.6	1.0	0.4-1.6	1.0	0.3-1.7
RCP4.5	1.4	0.9-2.0	1.8	1.1-2.6
RCP6.0	1.3	0.8-1.8	2.2	1.4-2.1
RCP8.5	2.0	1.4-2.6	3.7	2.6-4.8

Changes in the global water cycle in response to the warming over the 21st Century will not be uniform. The contrast in the precipitation level 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 become thinner and that Northern Hemisphere spring snow cover will decrease during the 21st Century as the global mean surface temperature rises. Global glacier volume will further decrease. The AR5 projects that the Arctic Ocean will be ice-free during the summer before 2050 under a high emissions scenario.

Mongolia Climate Change: Observed Changes and Future Projections

Observed Changes in the past

The records between 1940 and 2013 from 48 meteorological stations that are evenly distributed across the country, indicate the increase of the mean air temperature at the land surface by 2.07^{0}C. Certain fluctuations were observed as well, namely decrease of the mean winter temperature for the period of 1990-2006 (Figure S.3). The temperature increased more intensively in the mountainous regions and less in the Gobi and steppe regions. The warmest 10 years of the last 74 years have all occurred since 1997.

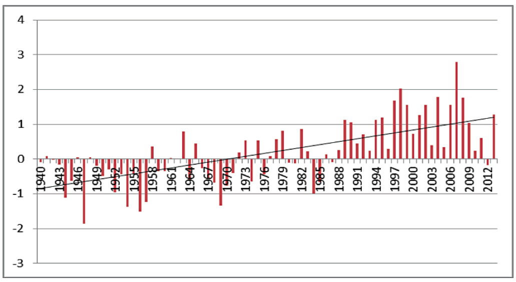


Figure S.3 Deviation from the multi-year average (1961-1990) of the annual mean temperature averaged over the territory of Mongolia

The warming trend is observed in all ecological zones of the country during the last four decades and is relatively synchronous (Batjargal and Enkhjargal 2013a) despite the big distance between them.

The annual precipitation pattern is characterized by the precipitation in warm seasons, especially by the summer precipitation which constitutes 70% of the annual total precipitation. Figure S.4 shows the multi-year trend of accumulated annual and winter precipitations.

The winter precipitation, on the other hand, may increase gradually (Figure S.4). In terms of the precipitation change, according to the meteorological observations, the warm season precipitation has increased slightly in the Altai mountain region, Altai Gobi region and far south - eastern part of the country since 1961. For the rest of the country, precipitation has been decreasing at an annual rate of 0.1-2.0 mm per year. During the same period, only a slight decrease has been observed in the eastern steppe and southern Gobi region.

Future Projections

In the recent years, climate projection research in Mongolia has gained momentum, and significant progresses have been achieved in the following areas: downscaling of global climate model results using regional dynamic models, atmosphere and land cover interaction assessment, etc. Regional dynamic downscaling is carried out using a regional climate model RegCM3 on the global climate model results in order to identify region-specific historical trends and to estimate the future climate trends in detail (Gomboluudev P. 2013).

Reference periods are estimated using the RCP scenarios of RCP 2.6, RCP 4.5 and RCP 8.5, with the intra-annual change of winter and summer temperatures and precipitation amounts over the country from 2016 to 2100 with respect to the 1986-2005 reference periods. In general, it was evident that the intensity of temperature change is directly correlated to the intensity of increase in GHG concentrations. However, the winter intensity and intra-annual changes are slightly higher than in the summer season. At the beginning of this Century, the temperature change was almost equal in all

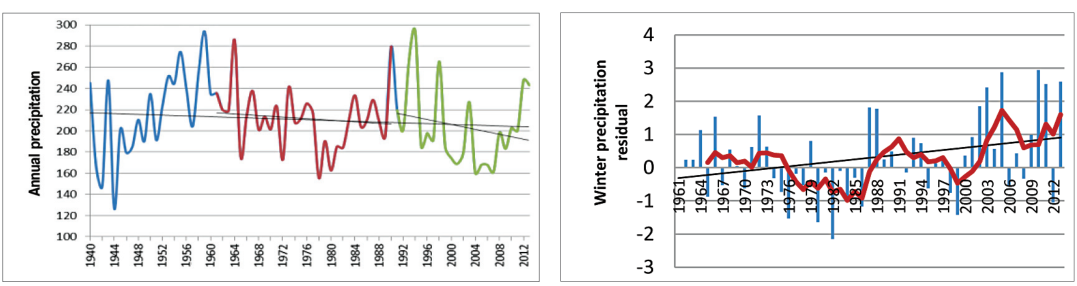


Figure S.4 Multi-year trend of annual (left) and winter (right) total precipitation (average of 48 meteorological stations)

RCP scenarios. Nonetheless, differences among the scenarios are evident since that period. For example, the winter temperature change is projected to increase by nearly 2.1-2.3^{0}C with RCP scenarios in 2016-2035, 2.5^{0}C in RCP2.6, 3.7^{0}C in RCP4.5, and 6.7^{0}C in RCP8.5 scenario respectively (Table S.2).

According to the projected precipitation analysis, winter precipitation will increase and there will be almost no change in summer precipitation. 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 scenario (Table S.2). All seasonal change estimates of the climate change projection in Mongolia are derived from every RCP scenarios in Table S.2.

In terms of the spatial pattern change, the climate change projections over Mongolia in the near future (2016-2035) and in the distant future (2081-2100) are shown in Figure S.5 and Figure S.6 for winter and summer temperature and precipitation. Here, only RCP8.5 scenario simulations are shown, as all spatial patterns are similar and differ by their intensity only.

At the end of the 21st Century, a high intensity pattern of temperature is projected by 5.5-7.5^{0}C in eastern and western regions of the country in winter, and by 5.0-5.5^{0}C in the western region in summer. Winter precipitation is projected to increase by 55-75% in the central, western and eastern regions, whereas the summer precipitation is projected to decrease by 5-10% in the western Mongolia.

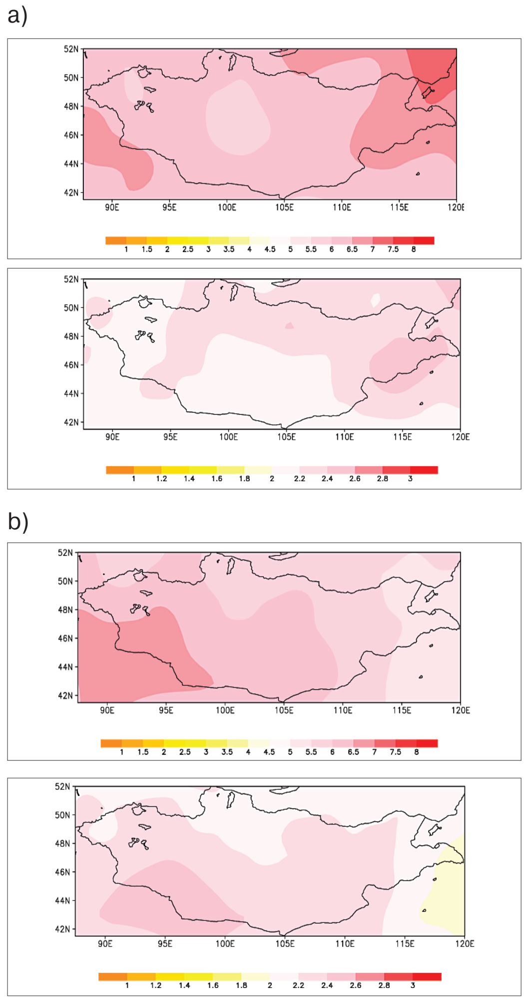


Figure S.5 Spatial pattern of a) winter temperature change and b) summer temperature change in 2081-2100 (top) and in 2016-2035 (bottom), ^{0}C

Table S.2 Seasonal climate change in Mongolia under different scenarios (ensemble mean of 10 GCMs)

GHG scenarios	Seasons	Near future, 2016-2035		Distant 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

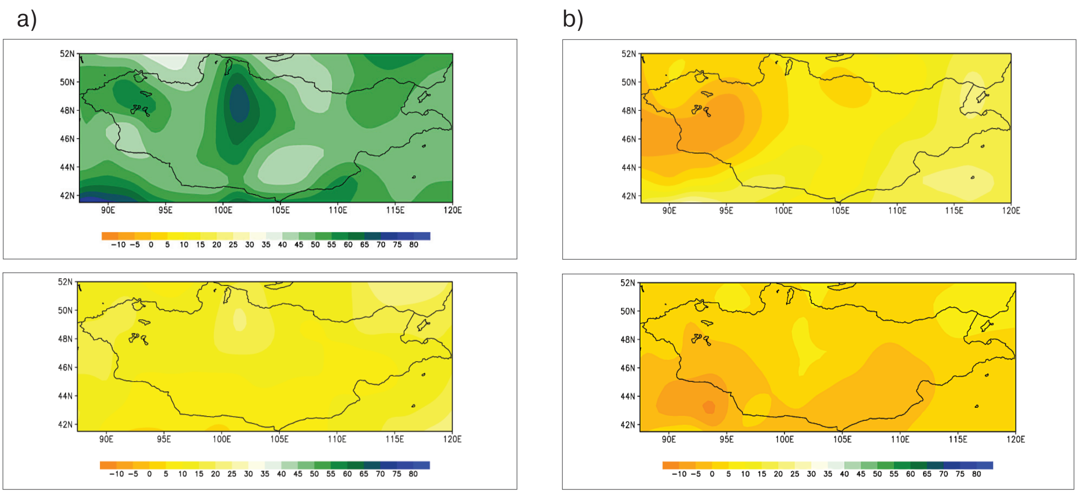


Figure S.6 Spatial pattern of a) winter precipitation change and b) summer precipitation change in 2081-2100 (top) and in 2016-2035 (bottom), %

Climate Change Impacts, Vulnerabilities and Risks

Mongolia is one of the most vulnerable countries to the impacts of climate change due to its geographical and climate conditions as well as the structure and development level of the economic sectors, and the lifestyle of the people. Therefore, the climate change impact and vulnerability assessment of the country is essential in addressing the climate change challenges and risks.

Since MARCC 2009, considerable progresses have been made in assessing climate change impacts, vulnerabilities and associated risks. Impacts of climate change on environmental components, biophysical elements, economic sectors and social spheres were assessed to determine vulnerabilities to and risks associated with any changes in the climate system. Also, adaptation policies and measures should be based on the outputs of these assessments.

Climate change impacts are visible in Mongolia through the intensification of soil and pasture degradation, drying up of rivers, lakes and springs in the Gobi and steppe regions, and loss of biodiversity (MARCC 2009). Regular monitoring of glaciers in the Altai mountains since 2003 show that glacier areas have decreased by 30% since the 1940s (Davaa G. et. al. 2010). Erdenetsetseg B. and others conducted comprehensive assessments of climate change impacts on soil and grassland using field monitoring data, as well as simulation models. In terms of climate change impacts on forest ecosystems, work has been done by Dulamsuren Ch. et al. from the University of Goettingen, Germany and scientists from Columbia University, USA and the National University of Mongolia. Natsagdorj L., Bujinlkham Ts., Khaulenbek A. (Natsagdorj L. Khaulenbek A. 2013) have identified a correlation between forest seed quality, forest area affected by pests and drought intensity, and attempted to assess future trends. In addition, comparative analysis of annual growth of tree rings from the Kharkhiraa-Turgen mountain and other regions of the country indicates a potential improvement of the conditions for forest growth in the Mongolian Altai since the 1940s.

Climate change risk assessment was conducted on water resources, biodiversity, ecosystem services, forest, agriculture/animal husbandry, arable farming, social health and infrastructure and an integrated assessment of all sectors was undertaken using multi-criteria analysis.

Soil and Pasture

As of 2012, pasture monitoring data from the nationwide network established by the National Agency for Meteorology, Hydrology, and Environment Monitoring suggests that 90% of the total pastureland experienced changes to some extent (Erdenetsetseg B., 2014). They indicate changes in pastureland plant population and species. Almost 60% of the total pastureland is able to recover within 3-5 years under the sustainable management. Approximately 40% of the total pastureland endure serious changes and may require 5-10 years to recover.

The Century model for plant-soil organic dynamics was used to assess climate change impacts on pastureland. In the process, climate, soil, and pasture use data from about 40 meteorological stations were used. The Century model results suggest a drastic decrease in soil organic carbon in forest steppe and steppe regions in the future (6.4-5.8% by 2020, and 9.5-8.4% by 2050). They also indicate that Mongolia's fertile soil is likely to lose its quality, be affected by external impacts, and become fragile by 2050 and thereafter. In desert and desert steppe regions, a relatively small reduction is projected, 0.32-1.06%, in soil organic carbon, whereas the soil organic nitrogen will increase marginally by 0.2-0.3%. Therefore, soil and plant species in the desert and desert steppe regions will likely become more robust under the future climate change. In high mountains, less reduction in soil organic carbon and a slight increase in soil organic nitrogen is expected. Increased pasture use will cause reduced biomass, which will lead to a decrease in soil organic carbon. Therefore, soil organic carbon stock in degraded pasturelands is always lower than that in optimal pasturelands. It makes the soil less fertile and more vulnerable to degradation.

Soil organic carbon and nitrogen stock in the Kharkhiraa/Turgen River basin are 1.130-1.260 g/m^2 and 56-62 g/m^2, respectively, when grazing is limited. When grazing is allowed at medium level, the carbon stock decreases by 1-3% while nitrogen stock reduces by 0.1-0.3%. However, with intensive grazing, the soil organic carbon and nitrogen stocks decrease by 10-16% and 1-3%, respectively. The Century model results also suggest that, the aboveground biomass decreases by 10-23% and 50-70%, respectively with medium-level and intensive grazing.

Forest ecosystem

Relatively limited research results can be found on the impact of climate change on taxonomy and growth rate in forest resources. Mijiddorj R. and Ulziisaikhan B. used the FORET dynamic forest growth model on Siberian larch in the Eroo River basin area. Results indicated a forest biomass reduction by 27.2% with twofold increase in atmospheric carbon dioxide level (Mijiddorj, Ulziisaikhan 1998). Decrease in the annual forest growth is observed in western Khentii due to drought and aridity (Dulamsuren 2010).

Climate change impacts on forests are evident through the increased frequency of forest fires, forest disease and frequent pest invasion, reduced forest seed production, annual growth of biomass and forest vegetation change. The increasingly dry conditions due to warming temperature and decrease in precipitation cause more frequent forest fires and pest invasion and thus, are the main factors for the degradation and loss of Mongolian forests. Between 1999 and 2011, the Mongolian forest cover (deciduous, coniferous and saxaul forest) decreased by 944,300 hectares or by 7.5%; which is 73,000 hectares every year or by 0.62%. Some studies estimate a decrease in Mongolia's forest cover by 512,000 hectares or by 9.2% due to fires between 2014 and 2030.

The correlation between the annual forest area affected by pests and the summer drought index was identified (Figure S.7). Pest affected forest cover with different greenhouse gas emission scenarios were estimated at 460-1149 thousand hectares and 4390-5317.5 thousand hectares respectively for the period 2011-2039 and period 2046-2065. This implies that the area affected by pests may increase significantly. The multi-year average of pest affected forest area was estimated at approximately 324,3 thousand hectares. On the other hand, the number may increase by 1.4 to 13 times (Natsagdorj 2012).

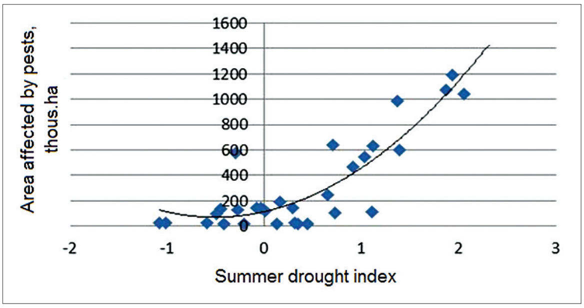


Figure S.7. Correlation between the annual forest area affected by pests and the summer drought index

Annual growth of forest biomass is directly dependent on weather conditions in a given year, which is confirmed by the width of tree rings. Dulamsuren Ch., jointly with German scientists observed growth rings getting closer in the Siberian larch in Mongolia since the 1940s. As a result of the warming climate in Mongolia, the upper forest edge or tree distribution line in high mountain subalpine zones may advance upwards. In the future, due to the permafrost thawing in high mountain areas, and associated increase in soil moisture and accumulated heat during the growing season, the upper forest edge is expected to rise further up and the photosynthesis could intensify. On the other hand, the probability of deteriorating conditions for forest growth is high in lower mountains and valleys. Alpine tundra and the taiga may decrease by 0.1-5% by 2020 and 4-14% by 2050, and the forest steppe in Khangai, Khentii, Khuvsgul, and the Altai Mountain regions may decrease by around 3% in the first quarter and 7% in the second quarter of the 21st Century.

Fauna

Due to the changing climate, a decrease in wildlife habitat and shift in ecosystem borders from south to north would occur. Desertification causes degradation of wildlife habitat which is an arising challenge for conservation of biodiversity.

Research work on current and future climate change impacts on biodiversity is very limited in Mongolia. Since 2000, Ganbaatar T. made attempts to assess distribution trends of locusts that are considered as endemic to Munkhkhairkhan mountain using present and future trends of certain bioclimatic indicators. Under a national research project implemented at the Institute of Meteorology, Hydrology and Environment between 2008 and 2010, distribution of certain grassland pests were evaluated using the MaxEnt programme software (Philips et al. 2006, Turbat and Altantsetseg 2013). In addition, the main outputs and results of the impact assessment using the MaxEnt model on key species in the Kharkhiraa-Turgen and Ulz River basin in western region are (MEGD/UNDP/AF Ecosystem-based Adaptation Project report 2013):

- In western Mongolia, the habitat of mountain ungulates will hardly change with the changing climate. However, habitat fragmentation may occur due to the impacts of climate change.
- There is a risk of fragmentation of marmot habitat in the western region. The core habitat area will remain in the north-western and northern segment of the habitat in Kharkhiraa Siilkhem, Altan Khukhii, in the southern part of Mongol-Altai and Khantaishir range and the south-western segment of Khangai region.
- Climate change will not significantly impact Mongolian gazelle, the steppe ungulate in its core region of eastern steppe. However, grassland degradation and more frequent drought would affect gazelle breeding habitat. Climate change will impact small birds habitat that are widely spread in Mongolia such as the Lark family species which play an important role for ecosystem health.
- For the conservation of white-naped crane population, the Ulz, Kherlen and Onon River basins as well as the Tuul River, are habitat of national and global significance. In the next 30 years, climate change is not a key factor to affect the habitat of the white-naped crane.
- The wetlands area covers merely 4.3% of the country’s territory but it is essential habitat for rare migratory birds. The east and northeastern Mongolia, including the Dornod-Mongol and Mongolian Daurian Steppe is important for the conservation of steppe biodiversity, including birds and the Mongolian gazelle.

Water resources

Mongolia's total surface water resources are derived mainly from lakes at the rate of 500 km^3 (J.Tserensodnom, 2000) and glaciers of 19.4 km^3 (G.Davaa, 2012). Only 6.2% of the total surface water resources, i.e. 34.6 km^3/year, are river water, with 1.9% base flow and 4.4% direct runoff from rainfall and melting snow. The amount of 34.6 km^3/year consists of the river runoff formed within Mongolia (30.6 km3) and surface water inflow of 4 km^3/year from the adjacent countries of Russia and China (B.Myagmarjav and G.Davaa, 1999).

Climate change impact on water resources within the Great Lakes Depression was calculated by "WaterGap" (Lener B., Batima P., 2004) model. By using this model, the runoff of Khovd River was calculated and the model parameters were modified, and the runoff trend between 2011-2040 was estimated based on the results of Hadley center's climate model. Specially, the runoff of Khovd and Buyant Rivers tend to decline approximately by 25%. However, in the "WaterGap" model, snow and glacier melting, its accumulation process and runoff that feeds the rivers and lakes were not considered, and only the future trend of temperature and precipitation served as a basis. Results show that by the A1B GHG scenarios, river runoff in the Arctic Ocean basin will increase by 4 mm by 2020, 8 mm by 2050, and 13 mm by 2090. River runoff in the Pacific Ocean basin will inclrease by 5, 8 and 9 mm respectively, and in the Central Asian Internal drainage basin the increase is expected at 2, 3 and 4 mm, respectively, for the same period. However, the projected increase in evaporation from surface water will exceed the increase in runoff by 138, 77 and 48 times in the Arctic Ocean basin, by 115, 75 and 101 times in Pacific Ocean basin, and by 144, 168 and 111 times in the Central Asian Internal drainage basin by 2020, 2050 and 2090, respectively. 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 will decrease for the months of April to October by 43% in 2011-2030, and by 49% in the period from 2080-2099.

Detailed assessments of future climate change and its impact on selected river basins, namely the Buyant, Ulz, Kharkhiraa and Turgen Rivers in Mongolia, were carried out (Davaa G. 2013). The chosen periods for climate baseline were 1981-2000 for the Buyant and 1981-2010 for Ulz, Kharkhiraa and Turgen Rivers. Future climate change impact is estimated in a river basin with respect to the climate baseline period. The HbV model was applied for the Ulz and Buyant River runoff modeling using observation data, as well as climate and hydrology data resulted by models (J.Odgarav, 2012). The HBV model output for the emission scenario A1B, according to the GCM ECHAM and RegCM3 was obtained for the Ulz River at Ereentsav station. The outputs of the climate change impact modeling show that Ulz River discharge for the months of April to October is nearly equivalent to the annual average discharge. The annual average discharge will decrease by 5.4% in 2011-2030, and may increase by 0.5% for the period of 2046-2065, and will decrease by 1.1% for the period of 2080-2099 (Figure S.8).

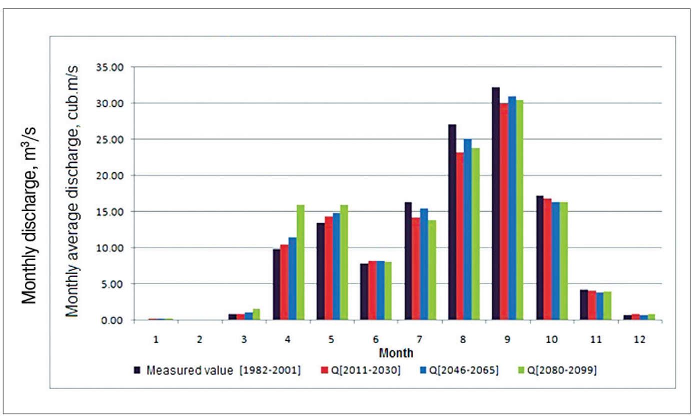


Figure S.8 Current (1980-2010) and projected monthly average discharge values of the Ulz River at Ereentsav hydro-station, ECHAM5-GCM

The model output for emission scenario A1B, according to the GCM ECHAM and RegCM3, was obtained for Buyant River. Outputs of the climate change impact modeling show that Buyant River discharge for the months of April to October will decrease by 43% for the period of 2011-2030, and by 49% for the period 2080-2099.

Glaciers

According to the estimations made by G.Davaa, the total glacier area in the Mongolian Altay decreased by 27.8% in the last 70 years. As a consequence, the total volume of Mongolian glacier water may decrease by around 40%. On the Potanin glacier, the cumulative ablation rate at the altitude ranges of 2,977-2,998 m, 3,033-3,057 m, 3,116-3,123 m, 3,234-3,247 m, and 3,339-3,366 m was 29.44-33.72 m, 25.34-28.06 m, 21.68-25.37 m, 19.54-23.00 m and 13.05-19.24 m respectively, during the period of 2004-2011.

The annual ablation (M) and accumulation (A) of glaciers within the Kharkhiraa River basin were estimated using air temperature, precipitation data as simulated by RegSim. The annual change in area of glaciers was estimated with Landsat ETM+ data for the period of 1992-2011. The change in glacier area and annual glacier mass balance (B), which is a change in glacier thickness, are linearly correlated and therefore allows an estimate of the annual total glacier area in the Kharkhiraa River basin. The mean annual accumulation rate was estimated at 1.43 m/year, 1.45 m/year, 1.64 m/year and 1.56 m/year for time periods of 1982-2010, 1911-2030, 2046-2065 and 2080-2099, respectively. The annual accumulation rate for the period of 2011-2030 is projected to be nearly at the same level as ablation, and will increase by 14.3% in 2046-2065, and 8.9% in 2080-2099, in comparison to the current level. The mean annual ablation rate was estimated as 3.11 m/year, 3.21 m/year, 4.04 m/year and 5.19 m/year for the periods of 1982-2010, 1911-2030, 2046-2065 and 2080-2099, respectively. The annual ablation rate for 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 periods, in comparison to the current level. Accordingly, the mean annual mass balance has been estimated at -1.68 m/year, -1.76 m/year, -2.40 m/year and -3.63 m/year for time periods 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%. Similarly, approximately 43.3% decrease is expected in 2046-2065, and 116% in 2080-2099, in comparison with the current level (Figure S.9). Total glacier mass in the Kharkhiraa River basin is projected to decrease to 13.7 sq.km by 2030 and to totally disappear by 2049 (Figure S.10).

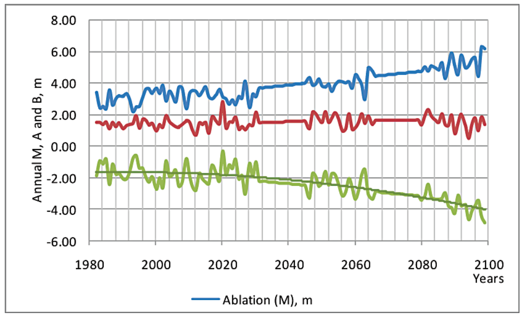


Figure S.9 Dynamics of annual ablation (M), accumulation (A) and mass balance of glaciers in the Kharkhiraa River basin

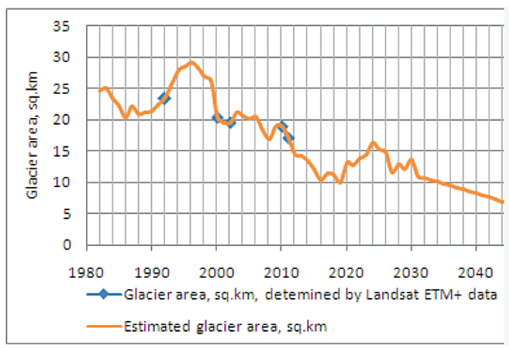


Figure S.10 Dynamics of total glacier area in the Kharkhiraa River basin

The annual mean discharge of the Kharkhiraa River at the Tarialan hydrological station is projected to decrease by 6.18% for the period of 2011-2030, to significantly decrease by 76.9% for the period of 2046-2065, and to moderately decrease by 24.0% for the period of 2080-2099, in comparison to the 1980-2010 discharges. The monthly average discharge will increase by 9.0% in June, 2.2% in August, and slightly decrease to 4.0% in July, 2011-2030. In rest periods, June, July and August (JJA) discharges will decrease 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 slightly improve due to increases in snow and rainfall in the period of 2080-2099.

Permafrost

Main parameters of permafrost change are temperature at certain depths below soil surface and its thickness. Permafrost itself is a product of climate conditions and is very sensitive to changes in climate. Permafrost temperatures as low as -23.6°C were observed in the Antarctic, whereas in Mongolia, the temperature generally ranges between -3°C to 0°C. Permafrost temperatures at -3°C was recorded in Tsagaannuur soum of Hovsgol aimag and Gurvanbulag soum of Bayanhongor aimag (Jambaljav, 2013).

The permafrost studies began in 1950s in Mongolia, however, temperature has been continuously recorded during the last 5-15 years. Recently, there are more than 120 active boreholes for permafrost monitoring in Mongolia. At some of these boreholes temperature was measured once in the 1960-1980s. Using these data, changes in permafrost temperatures are estimated for 20-30 years. In Northern Mongolia, permafrost temperatures have warmed and thawing and talik formation took place in southern Mongolia. During the last 2-3 decades, the permafrost temperatures increased by 0.4 °C-0.9°C in northern and mountainous regions and by 0.1°C in the southern edge of permafrost area in Mongolia. Higher temperature increases were observed in cold permafrost area during the period of 1960-1980, due to heat absorbed by partial melting of interstitial ice, showing and attenuating temperature change. After permafrost melted , the ground temperature increased rapidly, for example, soil temperature at 10 m depth was -0.1°C in 1984 and increased to +1.45°C in 2010 in Umnudelger soum of Hentii aimag.

Climate related disasters

Heavy rains, snowfall, strong winds, sand- and 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 hardship of nomadic herders. Zud is the Mongolian term for an extreme harsh winter that deprives livestock of grazing and a specific phenomenon that takes its toll in winter and spring with a high number of livestock dying of starvation. Winter snow cover in Mongolia reached 90% of the territory by the end of 2009, 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 of end of April 2010, over 10 million, or about 22% of the country's entire livestock in Mongolia was lost as a result of the 2009-2010 winter zud disaster and the livelihoods of over 200 thousand rural herdsmen living in the affected regions were severely threatened. The social impacts and associated costs of the zud are difficult to estimate, due to the lack of data.

Spring and summer droughts occur approximately every five years in Gobi desert area, and once in every 10 years over most parts of the country. The recently published "Mongolian Desertification Atlas" illustrates that between 2000 and 2010, the drought intensity increased in western Mongolia, particularly, in the Great Lakes Depression, in the valley of lakes and in some other regions (Tsogtbaatar and Khudulmur eds. 2013). Drought tend to induce forest and steppe fires that have become more frequent and the size of burned areas has also increased. With rapid desertification, dust and sand storms originated from Gobi desert severely affect Mongolia's neighboring countries, China, Korea and Japan. Sometimes, it goes as far as to the west coast of the USA.

There is a clear indication that the frequency and magnitude of natural disasters are increasing due to global climate change, as it was noted in AR5.

According to the study report by German watch, Mongolia ranks at 8 out of 10 countries in which the climate risk index is highest in the world according to 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 most affected are low income population and the herder households.

In order to reduce the disaster risk, the Government adopted the Law on Disaster Protection in 2003. In addition, a National Emergency Management Agency was created in January 2004, with aim to shift the focus from civil defense to disaster preparedness and management.

Land Degradation and Desertification

In line with the 'National Action Plan to Combat Desertification 2010-2020', which was approved by the Government of Mongolia in 2010, a nationwide assessment and mapping should be implemented every five years and reported directly to the Government. In 2011, therefore, with support from the Swiss Agency for Development and Cooperation (SDC), the fourth nationwide assessment with mapping of land degradation and desertification was completed. Every measurable indicators were evaluated for the entire territory of the country to produce the spatially estimated mapping of land degradation and desertification (Figure S.11).

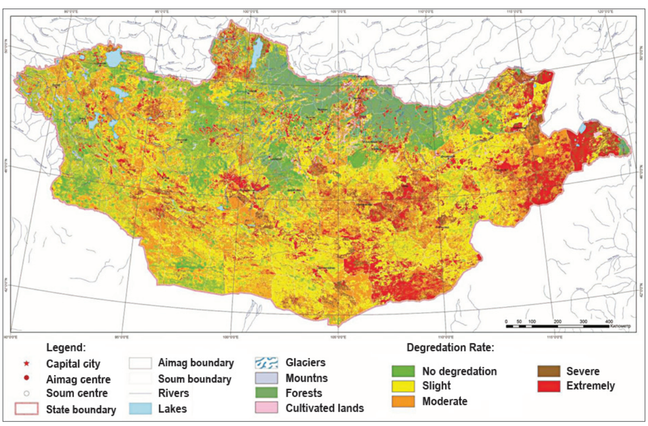


Figure S.11 Land degradation and desertification map of Mongolia (as of 2010)

The level of desertification and prevailing factors of land degradation was estimated and mapped in 2013. Results of this research indicate that 77.8% of the country's territory is affected by degradation, of which 35.3% was defined as slightly, 25.9% was moderately, 6.7% severely and 9.9% extremely degraded. Comparing these results with previous assessments, it can be concluded that in average, land degradation changed a little in Mongolia; however, a spatial distribution of heavily and extremely degraded lands changed significantly, including new regions with extreme degradation.

The analysis of land degradation factors shows that 10.4% has no effects from factors or no sign of desertification, 1.9% is attributable to the anthropogenic 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 anthropogenic and climate factor, and 23.9% is a combined anthropogenic and wind factor. It means 10.4% has no sign of desertification or no influencing factors, 39% is from human actions prevailed or combined, and 50.6% is from natural factors prevailed or combined. In other words, natural factors contribute 56% and anthropogenic factors contribute 44% to heavy or very heavy desertification (Mongolian desertification atlas, 2013).

Researchers noted that an increase of degraded land may adversely affect regional climate (Xue Y., Shukla, 1993; Xue, 1996) and pointed out potentials of large-scale changes taking place in land cover to eventually affect a moisture regime in regional climate (Gomboluudev, Natsagdorj, 2004). If degradation processes continue gradually and barren land increases, the precipitation and evapotranspiration will also 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, in accordance with regional climate model outputs.

Temporal analysis of Mezentsev aridity coefficient, which was calculated for all meteorological stations, showed there is a decreasing trend, implying the climate becoming increasingly arid. An overall decrease of humidity intensified from the late 1990s and the average index of humidity level decreased by 3-4%. The greatest decrease within the last decade was marked in 2002, 2005, 2007 and 2009 when the annual humidity level dropped by 7-9% (Natsagdorj et al. 2002).

Animal husbandry

Climate change can impact pastoral livestock in two ways: directly and indirectly. Hot weather, precipitation changes, storms and heavy snows are the direct negative factors influencing animal grazing. Under these conditions, animals cannot gain sufficient weight in summer and autumn and would ultimately face challenges to overcome harsh winter and spring. Also, indirect factors can affect pasture green mass production which impacts the weight and mortality of animals. According to several climate change scenarios, precipitation amount will not significantly change during the growing season and drought will become more frequent due to warming. While winters become warmer, increase in winter precipitation may cause extended zuds in terms of frequency, as well as magnitude. Analysis of annual drought and zud indexes and animal mortality rates (includes only adult animals) resulted in a high correlation (Figure S.12) in research work by Natsagdorj L and others (AIACC, 2005). However, the correlation between drought and zud indexes and the animal mortality rate has declined when the traditional herd composition is distorted. This implies that the animal mortality rate increased in recent relatively mild conditions compared to the more severe winters of the 1940's (Natsagdorj L, 2014).

As mentioned previously, the intensity of the drought and zud will increase within the projected climate change scenarios. Drought and zud indexes were calculated and animal mortality rates were estimated (Table S.3) for time periods of 2011-2030 and 2046-2065 under high and low emission (A2 and B1) scenarios by the Global Climate Model of UK Hadley centre- HADCM3, which estimated the past climate change in Mongolia with the highest estimated accuracy.

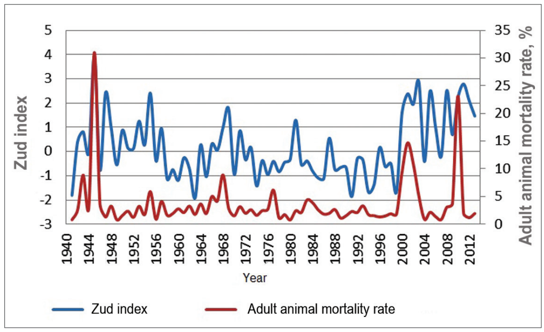


Figure S.12 Relationship between annual zud index and the adult animal mortality rate, %.

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

Due to the climate change in the last 20 years, net primary production of pasture green mass declined by 5-13% more than the average of 1961-1990 in the central and western parts of eastern Mongolia. The reduction of the pasture biomass and the increase of hot waves cause heat stress on animals (Natsagdorj L., 2008). This will lead to changes in animal body, making them smaller and vulnerable due to insufficient gain of weight through grazing.

Aside from meat production, this results in decline of wool productivity of sheep as well. Sheep weight change was estimated for future periods under high and low emission scenarios (AIACC, 2005).

The estimation demonstrated a decline in sheep weights in the forest steppe and steppe region

Table S.3 Drought and zud indexes and animal mortality rate in the past and future projections

SRES Scenarios	Time period	Drought- summer index	Winter index	*Zud* index	Animal mortality rate, %
A2	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
B1	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 toward the middle and end of the Century (MARCC, 2009). Estimation of sheep weight changes in winter and spring is particularly challenging due to the need for accurate prediction of snow thickness and density on pastures. However, snow amount would increase by 20%, with a 40% increase in snowfall towards mid 21st Century and a 50% increase towards the end. Winter precipitation increase will be a factor for decreased animal weight in winter and spring. Economic cost-benefit analysis shows sheep weight changes under SRES B2 scenarios in the future. Total economic loss of meat production was estimated assuming the number of animals and composition to be same as the average of 2008-2010. Even under low emission scenarios, loss of meat production was estimated at approximately 50 billion Tugrugs in the first decade and at 160 billion Tugrugs in 2030, which would be three times higher than the first ten years. If no actions taken, in 2050, the above loss would reach up to 280 billion Tugrugs which would be 5.4% decrease of the total livestock production (Enkhtaivan L., 2012). This estimation was mainly based on meat production and would be even higher, if other animal products and a direct animal loss of zud are considered. The harvesting dates for goat cashmere and sheep wool will be shifted earlier by ten and five days, respectively.

Herders livelihood. A number of herding families was counted as more than 100 thousand. About 250 thousand people were engaged in herding approximately 23-25 million heads of state owned animals in the socialist period. After the 1990's the number grew rapidly when livestock were privatized and unemployment increased in urban areas. However, number of people engaged in herding decreased back after the zud for three consecutive years in 1999-2002 and in 2009-2010 because many rural families lost their animals. As of 2013, there were 210 thousand families engaged in herding and 286 thousand herders according to the national statistics. Increase in frequency of natural disaster such as drought and zud, decline in animal productivity, and the remoteness from the market continue to impact herders' livelihood negatively and cause migration to urban areas, urbanization and related challenges. Consequently, a number of animals per herding family increased. According to statistics, the number of herders owning more than thousand animals has doubled in the last four years. The average livestock density per 100 ha of pasture was counted as 40 sheep units in 1967 and incread to 60 in 2012. On the other hand, in the Khangai region and near Ulaanbaatar, livestock density per 100 ha of pasture was counted as 102-325 sheep units, which is 42-265 units higher the national average. As a result, pasture carrying capacity exceeds in semi-urban areas close to market access and in rural areas with sufficient water resources. This shows an increasing trend of animal density which causes intensified pasture overgrazing and degradation in those areas.

Animal health. Studying climate change impact on animal health is a challenging task with many uncertainties (Mauricio Ret.all, Juan L, and Thornton P, et all, 2013). There is lack of detailed research with evidence in Mongolia. According to available reports and international research, the following risks will emerge in the future:

- Outbreak of animal epidemics related to climate change (new types and increased incidences), natural disasters and anthropogenic activities;
- Trans-boundary transmission of new and recurring infections and animal epidemics;
- Host landscape and territory expansion of current emerging epidemics of animals;
- Evolving and mutation of new types of viruses bringing new challenges in animal epidemiology.

According to animal health scientists, 26 types of animal diseases were newly registered, 8 types of diseases recurrent, and 6 types of diseases were expanded in terms of territory in Mongolia in recent decades (Orgil., et all.,2013).Overall, a study of animal diseases with climate change and environmental factors is greatly needed in Mongolia.

Animal water supply. Water supply plays key role in pastoral animal husbandry. According to statistics, there were approximately twenty thousand engineering electric pump wells out of a total of forty thousand wells. The remaining wells were manual/mechanical withdrawal wells and 60% of the total pastureland area was supplied with water resources. A census of water sources in 2009 counted approximately ten thousand electric pump wells and seven thousand manual/mechanical ones. Thus, animal water supply has declined in recent years (Nergui D, 2011). Research of climate change on water resources (Davaa G. and others, 2005 and 2012) noted a significant depletion of cryosphere and a high number of shrinking lakes and natural ponds due to climate change impact. Number of small lakes and ponds reduced greatly with 295 lakes dried up and 50 small lakes and ponds disappeared, according to the 1999-2002 census. Due to the global warming, water temperature will increase and riparian ecosystem productivity will improve in cold mountainous region, favorably affecting animal water supply. However, intensified potential evapotranspiration will lead to increased dryness for the entire territory of the country. Eventually, one of challenges caused by climate change will be water resources that will affect pastoral livestock husbandry.

Arable farming

Mongolia practices arable farming on 1.279 million hectares of land, of which 70.9% is in the central region, 15.9% in the eastern region, and 13.2% in the western region. 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, 77.3% is produced in the central region, 13.3% in the west, and 4.4% in the east. UN Food Security Assessment of 2006 concluded that 30% of Mongolian population is consuming food staple that does not meet food security 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 Mongolia's agricultural region tends to expand to the north, thus the arid steppe zone in eastern Mongolia is advancing to the north. As a result, the high mountain and forest-steppe region is decreasing, and the steppe and desert-steppe zone expanding (Tserendash et al. 2005, Mandakh et al. 2007).

Negative impacts of climate change are becoming evident in Mongolia through loss of pasture, limited yield from cultivated land and pasture vegetation, decrease in livestock productivity, which will eventually affect the regional and national food production capacity (Batjargal et al. 2000). There are number of factors that affect agricultural production, and these factors may become limiting parameters due to climate change. Researchers noted that until the 1980s, the amount of machinery, technology, fertilizer, pesticides and herbicides in arable farming multiplied several times, while average yield per unit land remained relatively unchanged, with small fluctuation depending on weather conditions. In other words, arable farming practiced in Mongolia is characterized by high risk, as the crop yield can fluctuate up to 50% depending on the weather. (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. Research reports address climate change impacts on arable farming starting from the 1960s, when land was cultivated in Mongolia and arable farming was developed as an important sector of agriculture. From 1960s to 2013 numerous collective farms and fodder farms were established along with meteorological stations in order to provide enabling conditions for achieving self-sufficiency in wheat, potato, and vegetable production. Arable farming in the western, central, and eastern regions are covered using parameters such as daily mean temperature, accumulative annual precipitation, precipitation in growing season, sum of active heat for plant growth (above 10^0C), number of days with temperatures above 26^0C, and change of frost time in the spring and autumn.

The report applies results from the dynamic DSSAT model of cultivated plant growth to estimate future impacts of climate change in Mongolia (2011-2030, 2046-2065, 2080-2099) on non-irrigated wheat and potato crops and identifies certain adaptation options.

DSSAT model simulation with data inputs from selected 16 meteorological stations representative of arable farming regions, estimated wheat yields for 2020 (2011-2030), and 2050 (2046-2065) based on the following scenarios:

- if monthly mean temperature increases by 1, 2, 3, 4, and 5 degrees;
- if the atmospheric carbon dioxide reaches 440 ppm 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, the study shows that if air temperature increases by 3^{0}C, 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.

Due to the future increase of mean air temperature, heat supply during the growing season will increase in throughout the arable farming regions, which will make earlier sowing and later harvesting possible. However, with an increase in number of extreme hot days, a total potential evaporation could exceed the increase in precipitation (Dagvadorj D., Bolortsetseg B., Tuvaansuren T. 2001). As such, negative impacts on cultivated plants could potentially outweigh the positive ones. Climate change scenarios indicate 12.3% increase in spring precipitation, which will provide for earlier sprouting. However, this positive change will depend on biological characteristics of a given plant. In recent years, it was observed that the extreme heat during the growing season related to the consecutive droughts led to drying and withering of plants, which may often occur in the future. In general, amount of precipitation may slightly increase. However, air temperature increase and associated decline in soil moisture necessary for plant growth, may unfavorably affect the plant growth.

The DSSAT 4.0 model estimation with medium emission (A1B) scenario, suggests that the multi-year average yield per land unit in 2011-2030 could decrease by 13%. In the western arable farming region (Baruunturuun) and in south of central region (Ugtaal), the yield may decrease up to 24-33%, respectively. Therefore, it can be concluded that without appropriate use of fertilizer, the yield from non-irrigated field may decrease by 10-15% with changing climate. The research indicates decrease of per hectare yield due to changing climate and thus, it will have a negative impact on crops and arable farming.

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. It is possible that direct and indirect influence will affect the population health, with risk factors in relation to climate change such as heat waves, air pollution, floods, drought, contaminated water and the negatively impacted agriculture produciton. Due to climate change, increased frequencies of cardiovascular and respiratory diseases are possible, including asthma, diarrheal diseases, as well as malnutrition. Also, climate change can increase vector borne diseases and other infections, especially infections among young children. Increased prevalence of emerging and re-emerging diseases are expected, as well. Increase in frequency of natural disasters such as flood, zud, drought, wind and snow storms, can cause death, distress and homelessness and disrupt the supply of essential medical and health services.

Studies on impacts of climate change on human health were conducted, especially the morbidity of some diseases in Mongolia. The study illustrates decrease in morbidity of respiratory diseases (Figure S.13) and increase in circulatory diseases (Figure S.14) in the last 34 years in Mongolia (GoM, 2009; Burmaajav B., 2010).

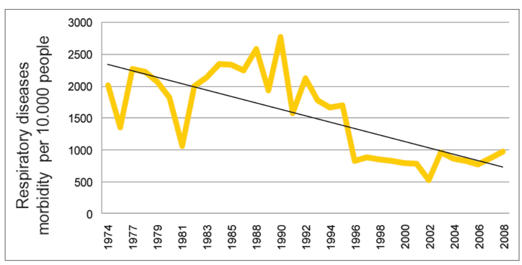


Figure S.13 Respiratory diseases morbidity, Mongolia, 1974-2008

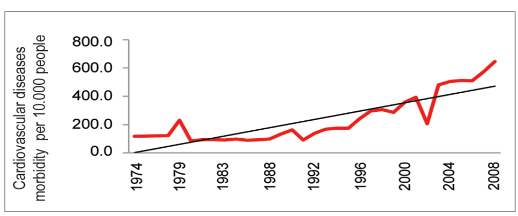


Figure S.14 Cardiovascular diseases morbidity, per 10,000 populations, 1974-2008

The studies confirm that climate change would cause increase in cardiovascular -disease due to increased warming, as well as increase in risk of the spread of certain vector-borne diseases as climate change opens up new areas for the spread of disease vectors. Certain unknown vector-borne diseases are already registered in Mongolia. In addition, there are signs of changes in water resources, water availability and lack of adequate sanitation, and the spread of water-borne diseases in Mongolia (GoM, 2011).

Poverty.

A nationwide comprehensive study of climate change impacts on well being and livelihood of the people has not yet been conducted in Mongolia. According to the Poverty Mapping of Mongolia, jointly undertaken 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 Khangai region. In 2012, a proportion of people living below poverty line is 27.4% of the total population in 2012. Overall, 23.2% of the urban population and 35.5% of the rural population are poor. This indicates vulnerability of country's population to climate change. Although poverty alone does not necessarily make people vulnerable to weather events and climate (IPCC, 2014), at the individual or rural level it deepens the dependency on natural resources, and increases the risk of migration to cities due to the loss of permanent income sources such as livestock and unemployment caused by drought and zud events (Chuluun T. et al, 2012). This can be seen from consequences of zud in 1999-2002 and 2009-2010. Through dzud for three consecutive years of 1999-2002, Mongolian livestock sector experienced losses worth 91.7 million Tugrugs, and living standards of herder households declined, drastically increasing poverty and unemployment in the provinces A total of 2,369 herder households lost their entire livestock and more than 10,000 households were left with no more than 100 heads of livestock (Altanbagana M., 2011). After three consecutive years of zud, the national gross agricultural output of the country decreased by 40% in 2003 compared to that in 1999 (Murray et al, 2012). Furthermore, the 2009-2010 zud caused a loss worth 63.9 billion Tugrugs; 8,711 herder households were left with no livestock, while 32,756 households lost more than half of their livestock (Altanbagana M., 2011). Having suffered natural disasters such as drought and zud, herders increasingly migrate to cities, particularly the capital city of Ulaanbaatar (Bayanchimeg Ch. et al.).

Climate induced variability is likely to increase water stress. Furthermore, 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 in remote rural communities is likely to put certain vulnerable groups, such as pregnant women during prenatal and neonatal stages, infants and elderly, at greater risk (GoM, 2011). Moreover, urban and rural poor households are likely to be net buyers of food staple and therefore, they might fall into persistent chronic poverty from temporary poverty (ADB, 2013).

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, and v) human development. It might be translated as that climate change directly or indirectly affects human development of Mongolia through these mechanisms.

Within the framework of the 2011 National Human Development Report of Mongolia (UNDP, 2012), a survey of 100 households among four aimags, namely Khuvsgul, Uvurkhangai, Tuv, and Orkhon, was conducted. According to the survey, a natural disaster and dzud are emphasized as priority concerns among the climate change and environmental factors that affect the daily life of people. 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).

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

- Climate change can impact the agriculture sector 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. Climate change induced weather variability, the changing pattern of precipitation and intensity and frequency of natural disasters like drought, dzud and thunder storms affect the pasture yield 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 dzuds 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".
- 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 ponds 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.
- 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.
- 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 dzud events, herders told that "Annually we consumed about 10 goats and sheep during the 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 (milk products)." This shows that herders might not get enough nutrition and thus pregnant women, children and elderly people might fall into nutritional deficiency.

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, Asian Development Bank's (ADB) study on "The Economics of Climate Change in East Asia" examined the costs of adaptation to climate change in the infrastructure sector during 2011-2050. The study considers hard infrastructure, and integrates key findings from the previous studies.

Having an adverse impact on infrastructure, the increase in the intensity and frequency of extreme events induced by climate change in Mongolia has caused great amounts of loss 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 heavy rainfall and hailstorm in Tushig soum of Selenge aimag on the 3rd of July, 2013, 4,310.3 m^2 of the timber and metal roofs of public organizations' buildings, including the Governor's Office, health center, 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 (yurts) of 15 households collapsed and 24 people were injured. According to the evaluations of professional organizations, damage worth approximately 3 billion Tugrugs occurred in total (DEMoS, 2013).

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 those climatic factors, highest ranking factors were flash floods due to the intensity of summer precipitation, snow blocks of mountains due to the increase of winter snowfall, 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. 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 road and housing sectors 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 (storm water drainage and municipal building) can be postponed until after 2040. The uncertainty about the 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.

Climate Change Adaptation Strategy and Measures

Mongolia is extremely vulnerable to the impacts of climate change, therefore it is of utmost importance to develop a climate change adaptation policy and strategy to overcome the adverse impacts of climate change. Also, adaptation measures should be integrated closely into the national and sectorial mid- and long- term development programmes and plans. This issue is gaining momentum since 2011 when the Climate change coordination office was established at the MEGD. In order to ensure adaptation measures, an adaptation technology needs assessment was conducted according to the UNEP methodology considering possible costs and benefits for introducing the technology with some vulnerable sectors. A publication was recently made available about the research in this field (MEGD CCCO, 2014).

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 adaptation policy to a certain degree. Mongolian "National action programme 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 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.

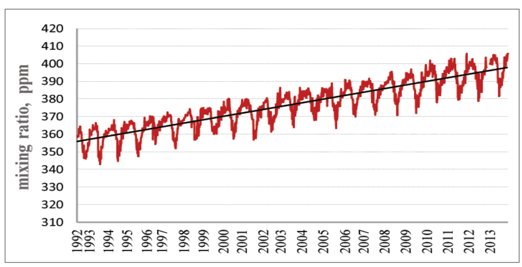
Climate change impacts are visible in Mongolia with the change in water resources and regimes, the drying up of lakes and springs in areas without permafrost, the dropping of ground water tables, pasture and soil degradation due to aridity and extreme heat in the summer and thus, a loss of floral biodiversity, intensified desertification, change of wildlife habitat, and the increasing frequency of forest and steppe fires, with overall environmental degradation. In order to ensure the country's sustainable development, policy and measures for climate change adaptation should be implemented without delay. 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. Climate change adaptation strategies and measures in major vulnerable socio-economic sectors such as animal husbandry, arable farming, water resource, forests and human development were identified. Strategic goals of the livestock sector adaptation are to ensure food security, sustainable supply of raw materials for the food and light industries and to expand the production of ecologically clean products by developing an animal husbandry sector that is resilient and better adapted to climate change. Adaptation measures in arable farming would be focused on meeting 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. Adaptation measures in water resources will help reduce climate change related risks, ensure water quality and the sustainability of the population's water supply, industry and agriculture and also to prevent flooding. The strategic goal of the adaptation strategy in the forest sector is to build and strengthen the forestry sector's adaptive capacities by mitigating negative impacts and maximizing the use of positive impacts of climate change on forest ecosystems.

Greenhouse Gas Monitoring and Inventory

Greenhouse Gas Monitoring

Since 1992, GHG sampling has been conducted at the Institute of Meteorology Hydrology and Environment of Mongolia with GMD, NOAA, USA at Ulaan Uul monitoring site in Erdene soum, Dornogobi aimag of Mongolia. The site is located in the south-east Mongolia (dessert -steppe region) farthest from any anthropogenic emission sources. Air samples are collected weekly and analyzed for CO_2, CH_4, CO, NO_2, and SF_6 and other CO_2 isotopes in NOAA ESRL/GMD of USA.

The data analysis demonstrates constant increase of the mean concentration of main GHG in Mongolia. Concentration of CO_2 has increased by more than 11.4%/40.7 ppm/ (Figure 5.2) and CH_4 3.3% /60ppbv/ (Figure S.15) for the period of 1992-2013. The 2012 average annual concentration of GHG's at UUM site are CO_2 378.8 ppm, CH_4 1887.3 ppbv and SF6 7.8 ppt. The SF_6 has a lowest atmospheric concentration and high global warming potentials. SF_6 concentration has increased twice for the period of 1998-2013. Variability in the annual increase is likely to have been caused by changes in the imbalance between photosynthetic uptake and respiration by plants.



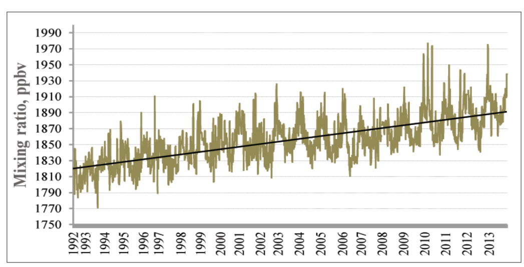


Figure S.15 Atmospheric CO_2 (above) and CH_4 (belove) concentration at UUM site. *Source: GMD. NOAA data*

Greenhouse Gas Inventory

The total GHG emissions in Mongolia, including Energy, Industrial Processes, Agriculture and Waste sectors in Gg CO_2-eq. unit for the period 1990-2012 are presented in Figure S.16. Emissions from Land Use Change and Forestry (LUCF) sector are not included in the net GHG emissions. In 1990, the net GHG emissions were 21,145.5 Gg CO_2-eq., reduced down to 14,826.9 Gg CO_2-eq. in 2001, but further increased up to 26,276.9 Gg CO_2-eq. in 2012. The GHG emission reductions in 1990s and beginning 2000s are mostly due to the socio-economic slowdown during the transition period from a centrally-planned economy to a free market economy.

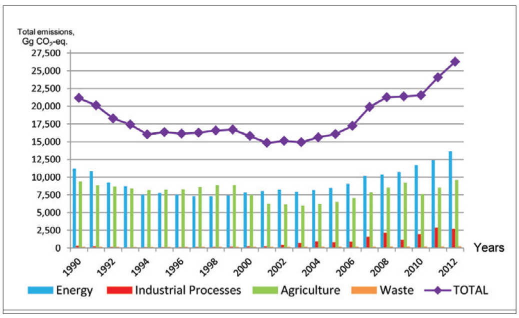


Figure S.16 The total GHG emissions excluding LUCF sector, Gg CO2-eq. *Source: Experts calculation*

Within the total GHG emissions, CO_2 and CH_4 are predominant (Figure S.17 and Figure S.18). In 2012, the total NO_2 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 emit indirect GHGs. 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 S.19.

The main indirect GHG is the 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 various sources in Mongolia. Emissions of SO_2 are directly related to the sulfur content of fuel. During this period, the methane emissions have increased due to an increase in livestock population. In 1998, the methane emissions increased up to 7,752.3 Gg CO_2-eq. While it was reduced down to 5,258.8 Gg CO_2-eq. in 2002, gradual increase is estimated since 2003.

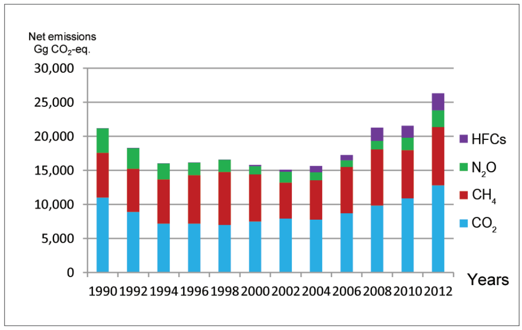


Figure S.17 Mongolia's total GHG emissions by gas types, Gg CO2-eq. *Source: Experts calculation*

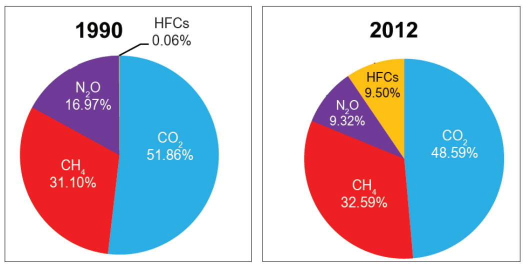


Figure S.18 Mongolia's total GHG emissions by gas types in 1990 and 2012 *Source: Experts calculation*

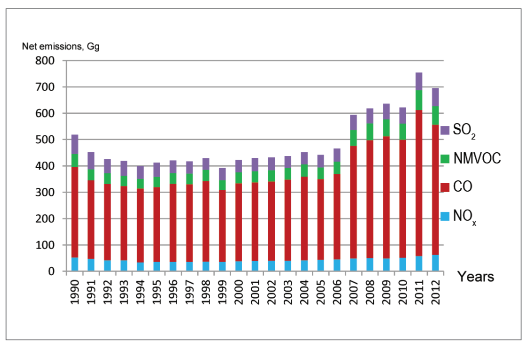


Figure S.19 Non-CO2 emissions, Gg, *Source: Experts calculation*

Sectorial GHG emissions in Mongolia. According to the estimates of the total GHG emissions by categories, energy sector accounted for 53.16% of the total emissions in 1990 and remained at a similar level of 51.99% in 2012 (Figure S.20). The second largest source of GHG emissions is the agricultural sector. Its share in the total emissions was 44.47% in 1990, but reduced down to 36.61% in 2012, due to a reduction in newly cultivated land from 1990. GHG emissions from the industrial sector accounted for 1.55% in 1990, but increased to 10.4% in 2012. The growth of the GHG emissions from the industrial sector is mainly related to the construction boom in the country and associated increase in cement and lime production. In 2012, 98% of CO_2 emissions accounted for the energy sector due to various types of fuel combustion activities. The main contributor to the CH_4 emissions is the agricultural sector, contributing approximately 86% of the total CH_4 emissions. The second largest contribution is originated from the energy sector with about 12%, while the waste sector contributes 2-3% of the total.

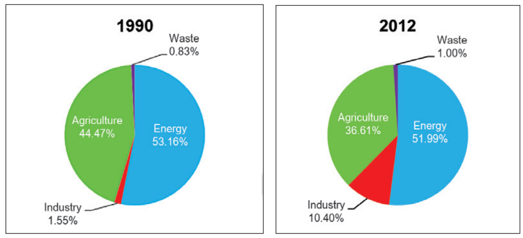


Figure S.20 Total GHG emissions by categories in 1990 and 2012. *Source: Experts calculation*

Although the total GHG emissions in Mongolia remains comparatively low, the per capita or per GDP rate of GHG emissions is relatively high compared to other developing countries. This is related to a high energy intensity, cold continental climate, a predominant use of fossil fuels for energy, and a low efficiency of fuel and energy.

GHG Mitigation Strategy and Measures

Projections of GHG emissions

Mongolia's GHG emission between 2006 and 2030 was projected during the preparation of the Second National Communication in 2010 (MNET 2010). For predicting emissions from energy sector, which accounts for the most of the GHG emissions, LEAP model of Mongolian Long term Energy planning is used. It is a scenario-based energy-environment modeling tool. Its scenarios are based on detailed accounting of how energy is consumed, converted and produced in a given region or economic sector under a range of alternative assumptions on population, economic development, technology and so on. Projected emissions from agriculture, land-use change and forestry (LUCF), and waste sectors up to 2030 was based on the previous trends, taking into account social and economic changes and currently implemented or adopted policies and measures. The aggregated projections of GHG emissions by sectors are shown in Figure S.21 and Table S.4. Mongolia's total GHG emissions are expected to increase 3.25 times from 2006 to 2030.

Table S.4 Aggregated projections of GHG emissions by sector

Sectors	GHG emissions in Gg CO_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.

Energy consumption is expected to increase rapidly due to economic and population growth. Consumption particularly in the industrial sector is rapidly increasing due to the development of the quarry industry in mining sectors. GHG emissions in energy sectors in 2030 are expected to increase four times from that of 2006.

According to the Mongolia National Livestock programme, the total number of livestock should be 36 million heads in 2021, in order to remain within the pasture carrying capacity and to prevent further desertification. Currently, the livestock number already reached to 50 million heads. The total emissions of CO_2 and CH_4 also will significantly increase, in particular, the CO_2 emissions may increase several times (Figure S.22).

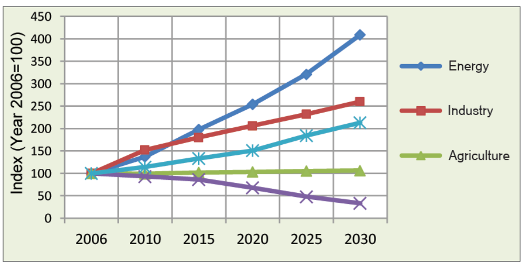


Figure S.21. Projections of GHG emissions and potential removals by sectors

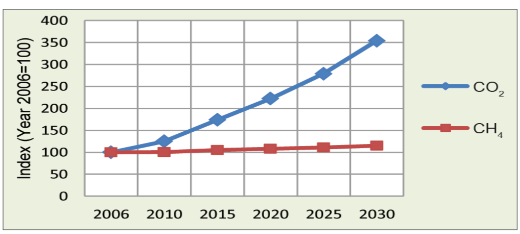


Figure S.22. GHG emission projections by gas types *Source: MNET,UNEP: Mongolia Second National Communication, Under the United Nations Framework Convention on Climate Change, 2010.*

Mitigating GHG emissions

Despite the fact that the total GHGs emissions of the country is relatively low, Mongolia has developed and is implementing GHG mitigation policies and strategies as in other countries. While these policies and measures are directed at reducing GHG emissions, efficient use of energy and heating and introduction of environmentally friendly technologies are promoted, as well. 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 alternative and low emission energy sources, as well as focusing on the efficient use of electrical and thermal energy produced from coal combustion. Use of energy efficient appliances is also important. In addition, a significant potential for reducing demand for fossil fuel through the use of renewable or other clean energy sources. GHG emissions can be mitigated through investment in large-scale hydropower plants, wind farms and solar power plants by using abundant resources of sun, wind and water of Mongolia. Several studies were conducted on projected GHG emissions and mitigation possibilities in Mongolia's energy sector with support from international organizations (GGGI 2014; Dorjpurev J. 2013; ADB 2013).

In order to conduct GHG's mitigation assessment, a detailed analysis on innovative technologies and practical measures to reduce GHG emissions is necessary. In this regard, several scenarios for economic development trend of the country was developed for a comparative analysis. A Baseline scenario of the development is compared and analyzed with GHGs mitigation scenario. The Baseline scenario of the economic development indicates further increase of GHG emissions under the business-as-usual scenario.

There are several policy documents including laws and programmes that are being implemented to mitigate GHGs.

The goals of the National Action Programme on Climate Change (MNET 2011b) 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. The strategic objective 3 of the programme aims at mitigating GHG emissions and establishing a low carbon economy through the introduction of environmentally friendly technologies and an improvement in energy efficiency. In June 2005, the Parliament of Mongolia approved the National Renewable Energy

Programme to promote use of renewable energy in Mongolia. The programme aims at creating enabling conditions for ensuring ecological balance, reduction of unemployment and poverty, and sustaining social and economic development by increasing the renewable energy share in the total energy supply of Mongolia, by improving the structure of energy supply, and by widely applying renewable energy sources in rural areas. The goal envisioned in the programme is to increase the current 3%-5% share of the renewable energy in the total generation to 20%-25% by 2020. In order to ensure policy environment for implementation of the goals, the Parliament of Mongolia passed the Renewable Energy Law in January, 2007. The primary stipulation of the Renewable Energy Law and the National Renewable Energy Programme provide for a feed-in tariff for the grid and the independent power generation from renewable energy. Any price difference for electricity generated by a renewable energy source, which is connected to a transmission network, shall be absorbed by the selling price from other power plants connected to the same transmission network. The Mongolia Green Development Policy, recently approved by the State Great Khural (Parliament) provides clear strategic objectives in establishing low-carbon and climate resilient societies.

In order to achieve the GHG mitigation goals and targets, high potential GHG mitigation activities and measures to be implemented in the energy sector were identified.

Livestock is a main methane emission source in Mongolia. Potential options for reducing methane emission from livestock sector will be to limit the increase of the total number of livestock; and to increase the animal productivity, especially cattle (Dagvadorj et al. 2010).

The forest is an economically, socially and environmentally multi-beneficial complex ecosystem. The Mongolian forest is economically beneficial, and it is essential for biodiversity conservation and maintenance of carbon balance in the region. Carbon is absorbed and stored in the forest; therefore, the emissions from forest fires, decomposition and logging will have an impact on accumulation of atmospheric carbon. Potential options for GHGs mitigation and sequestration in the forest sector (Dagvadorj et al. 2010) include measures for natural restoration; afforestation and reforestation; implementation of Green Belt programmes; and use of bio-energy.

In terms of land use, waste related issues causing serious problem for the cities and settlements, particularly for Ulaanbaatar. Methane emission from waste is comparatively low; however, the measures such as capturing methane from the waste; improving waste management; and waste recycling can be undertaken in the waste sector.

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 the 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 Mechanism. 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. 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.

Joint Crediting Mechanism (JCM). In 2009, the Parties to the UNFCCC agreed to limit the rise in the global average temperature to 2°C at the Copenhagen Conference of Parties. Mitigation targets announced by developed countries and mitigation measures of developing countries are insufficient to avoid exceeding the global limit (State of negotiations. Doha 2012. UNFCCC. COP18 and CMP8). Moreover, Parties agreed that market mechanisms under Kyoto protocol are still insufficient 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 a Joint Crediting Mechanism (JCM) that 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.

Japan and Mongolia signed the bilateral agreement on the “Low carbon development partnership” to implement the JCM on January 8, 2013. Mongolia can be engaged, through implementation of JCM, to directly support the achievement of 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” of NAPCC, and the promotion of actions listed in Mongolian NAMA, which were submitted to UNFCCC secretariat in January, 2010 according to the Copenhagen Accord. Under the JCM implementation, two model and demonstration projects, several JCM Planning Studies and MRV Methodology Demonstration Studies and Feasibility Studies (JCM FS) were conducted in Mongolia in FY 2013 with the technical and financial support of Japan.

Enhanced Carbon Sequestration by Land Ecosystems

Carbon Dioxide Removal Methods (CDR)

To slow down or perhaps reverse the projected increases in atmospheric CO2, several methods have been proposed to increase the removal of atmospheric CO2 and enhance the storage of carbon in land, ocean and geological reservoirs. The CO2 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 will have to be stored for at least hundreds of years for Carbon Dioxide Removal (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 CO2 emissions to the atmosphere but they do not involve a net removal of CO2 that is already in the atmosphere.

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. The principle of these CDR methods is to increase a net primary productivity and/or store a larger fraction of the biomass produced in the ecosystem carbon pools with long turnover times, for example, under the form of wood or refractory organic matter in soils. Few studies have been conducted recently on grassland soil carbon sequestration potential in Mongolia. For this assessment, 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 entire territory of Mongolia. The resulting estimate of a national technical mitigation potential through improved grassland management is very large, at around 29 million tCO_2-eq.p.a. This is one-third of the energy sector technical potential and 18 times larger than the industry sector potential. However, there are significant barriers to adoption in grassland management. The spatial distribution of technical mitigation potential is quite uneven (Figure S.23) with some aimags (Provinces) having a much higher technical mitigation potential than the others. This big difference is mainly caused by soil features and geographical zones. For instance, soil carbon sequestration potentials are much higher in Dornod and Tuv aimags (5,293,481-5,655,995 tCO_2-eq.p.a.) where dominant soil types is dark chestnut than in Khentii and Selenge aimags (9650 - 43,237 tCO_2-eq.p.a.). Overall, there is a very limited carbon sequestration potentials in Gobi desert areas with low quality sandy and stony soils.

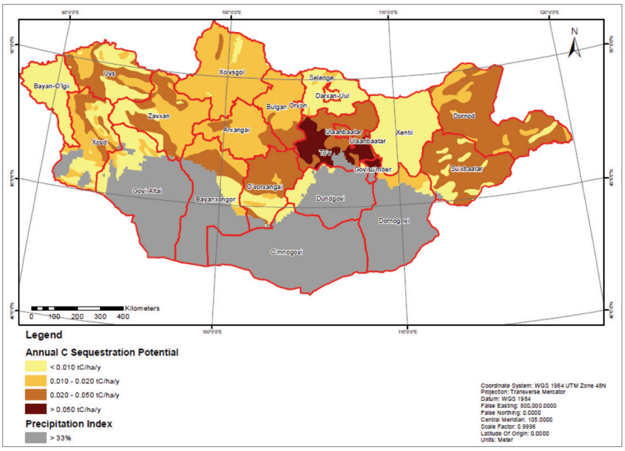


Figure S.23 Distribution of technical potentials for soil carbon sequestration in Mongolia

Biochar Preliminary Studies

A 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 the last two decades around the world. Activities related to biochar in Mongolia have started since the establishment of the Ulaanbaatar Biochar Initiative (UBI) in 2008. The Mongolian Biochar Initiative (MoBI), one of the sub 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. The initial studies on biochar properties, its effect on soil and plant, and production technology are being conducted in Mongolia by the initiative (Agricultural EngTech Journal, 2014).

Further research is necessary to clarify the sequestration potentials of biochar made by various feedstocks in different soil types in Mongolia. Moreover, studies on the potentials for cooperative marketing of carbon credits generated from the individual and community units are important to promote production and sequestration of biochar from thinly distributed sources of biomass by small-scale primary producers.

Carbon Capture and Storage

Carbon Capture and Storage (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 processes. Carbon dioxide is then transported by either pipeline or a ship, for a safe and permanent underground storage, preventing from entering the atmosphere and contributing to anthropogenic climate change. CCS 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. 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, A Policy Strategy for Carbon Capture and Storage). Mongolia meets these criteria and has an opportunity to implement CCS through NAMAs or other mechanisms. Preliminary study on CCS in Mongolia was initiated with some international research institutes such as BGR, Germany. However, it is too early to present outcomes of these studies.

Technology Needs Assessment

Mitigation Technology Assessment

Researchers worldwide agree that the anthropogenic GHG emissions can be reduced by using advanced and environmentally-friendly technologies. The Mongolian Government adopted important policies to develop and introduce environmentally-friendly technologies. Advanced technologies are essential to a successful implementation of these policies. The mitigation TNA suggests options for the most important technologies, feasible for introducing to Mongolia in near future to reduce the GHG emissions. Assessments of currently applied technologies and needs for each of the sectors are identified: Energy, Industry, Livestock, Land Use and Wastes.

Energy systems. Mongolian energy sector consists of three inter-connected regional 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 throughout the country.

Suggested technology options to be introduced in near future are summarized below. New large-scale thermal power plants will be constructed at the 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, a 220 MW Hydro power plant is planned for construction at either the Eg or Selenge Rivers, and a 50 MW wind park is planned for Sainshand city. Completion of these projects will greatly contribute to increasing the efficiency of the integrated energy system and further GHG reduction. Large-scale hydro power plants can reduce 897 thousand tons of CO_2 from one billion kW.h electrical power generated.

Suggested technology options for heating supply systems to be introduced in near future are: 1) Apply technologies suggested for energy efficiency and saving of the CES and its GHG emission reduction, and 2) Increase efficiency of the small-capacity and low pressure heating boilers to reduce the GHG emissions. Thus, relevant technologies, and also barriers and constraints to introduce these clean and environmentally-friendly technologies were identified in this report.

Adaptation Technology Assessment

The Adaptation Technology Needs Assessment was conducted for the first time in Mongolia in 2012, which was an opportunity to determine the highest priority sectors and technologies for adaptation. High ranking technologies scored relatively high with their benefits for economic asset, environment, biodiversity and people’s livelihood.

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 at intensifying vegetable production through a set of water saving measures such as drip irrigation, and low cost green house or mulch.

Potato seed production system (PSPS): This comprises 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 land area unit. 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 pastoral system, and herder families’ livelihoods are highly dependent on and influenced by weather and climate. SPLEWS integrates main components such as risk knowledge, monitoring and predicting, disseminating information and response. Precise seasonal prediction and proper preparation to dzud would result in saving almost 80% of the animal losses every winter.

High quality livestock (HQL): Improving animal quality rather than quantity is the best method to ensure high production and livestock development in Mongolia. HQL technology aims at improving the quality of animals based on a selective breeding using these core herds as well as improved animal health services. Diffusion of innovative technology would enable Mongolia to control livestock numbers within its pasture carrying capacity and to reduce overgrazing and desertification.

Sustainable Pasture Management (SPM): Healthy 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 that are combinations of hard and soft techniques. Example is early warning systems that combine hard measuring devices with soft knowledge and skills that can raise awareness and stimulate appropriate actions.

According to the guideline, 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.

The technology action plan (TAP) compiled through a process of analyzing how the development and transfer of prioritized technologies can be accelerated to meet the major milestones. In the analysis of the gap between the existing situation of the country's technology development and transfer and the desired situation were explored and barriers and system inefficiencies were identified. This was followed by the determining measures to fulfill the gap, which was briefly described in the above section. In the action plan, measures were recommended to transfer technologies in different stages of development e.g., how to accelerate technology research, development and diffusion (RD&D) in the country; how to manage technology deployment; and how to accelerate technology diffusion.

Legal Framework and Institutional Arrangements for Climate Change Actions

Legal Framework. The United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol is the main international treaty through which Parties are committed to take action to mitigate GHG emissions and to adapt to the adverse impacts of climate change. This will be accomplished by promoting national policies and strategies including the provision of financial and technological supports to countries, cooperating in preparing for adaptation to the impacts of climate change, and by reducing greenhouse gas emissions.

Currently, Mongolia does not have a specific law on climate change that concerns the regulation of climate change related activities, but a number of existing laws and amendments reflect climate change concerns and challenges and promote activities addressing climate change. Yet, these issues are not well coordinated in the relevant laws. In the key national development policy documents which include the basic concepts, principles and legal framework of climate change have been reflected. In 2012, amendment of the Law on Air reflects objectives to address climate change concerns such as establishing the Task Force Office of Climate Change responsible for the management and implementation of action plans under the international conventions and national programmes, as well as regulation, assessments, and reporting on the project activities implemented under the climate change adaptation fund and clean development mechanisms.

In order to address challenges associated with climate change, Mongolia developed its National Action Programme on Climate Change (NAPCC) that 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 sectoral development plans and programmes. NAPCC includes a set of measures, actions and strategies that enable vulnerable sectors to adapt to potential climate change and to mitigate GHG emissions. The implementation of these goals will support Mongolia in achieving sustainable socio-economic development. In NAPCC, five strategic objectives, under which 96 activities were included, were proposed for implementation in two phases over the periods 2011-2016 and 2017-2021. Implementation plan for the first phase (2011-2016) of the NAPCC was approved by the Government on November 9, 2011. Measures to create enabling conditions for NAPCC's five strategic objectives will result in accomplishment of the first phase of the proposed measures. These include establishment of the proper legal environment, structure and improvement in the cooperation between related institutions.

The Millennium Development Goals-based Comprehensive National Development Strategy (MDG-based CNDS) of Mongolia approved by State Great Khural (Parliament) on February 12, 2008, comprehensively defines the development policy of

Mongolia. 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."

Institutional arrangements. Climate change adaptation and mitigation efforts should be managed as a shared responsibility rather than sectorial. In other words, the responsibilities should be clarified and made explicit to all institutes and authorities involved. In 2012, amendment of the Law on Air addresses coordination and collaboration. As per amended Law, a Climate Change Coordination Office (CCCO), under the supervision of the Minister for Environment and Green Development, was established with responsibilities to carry out day to day activities related to fulfillment of Mongolia's commitments under the UNFCCC and Kyoto Protocol, to manage the nationwide activities, and to realize integration of climate change related problems in various sectors. The CCCO includes Clean Development Mechanism National Bureau of the Kyoto Protocol, 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 approved by Parliament in 2012.

International Cooperation on Climate Change

The major development partners of Mongolia on climate change related interventions are the Global Environmental Facility (GEF), the Governments of Japan and Germany, Asian Development Bank (ADB), World Bank (WB), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP) and others. In addition, cooperation with groups 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 supports are essential for Mongolia. It should also be noted the support from Governments of Australia, The Netherlands, Luxembourg, USA and Switzerland have contributed to the climate change adaptation and mitigation efforts in the past.

Mongolia needs to increase its international climate profile to attract increased financing on climate change actions. As a small country in terms of population, and a lower-middle income country, Mongolia is not seen as a country in need of priority support or as a powerful emerging economies such as China, India, Brazil, South Africa and others. Yet, climate vulnerability and change is extremely high in both rural and semi-urban populations of Mongolia. Currently, Mongolia receives a low level of international climate financing.

UN-REDD. Mongolia joined the UN-REDD Programme (UNDP, FAO and UNEP) in June, 2011. Guided by a Multi-stakeholder taskforce, development of a national REDD+ Readiness Roadmap is now completed through assistance of the UN-REDD programme. Meanwhile, UN-REDD has 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. In April 2014, Mongolia was invited to present its National UN-REDD Programme at the 12th UN-REDD Programmeme Policy Board meeting, which took place in Lima, Peru on July 7-9, 2014. Financial support for implementation of the National REDD+ Programme is confirmed at the meeting.

Global Green Growth Institute (GGGI). Mongolia became a member to the GGGI in 2013. The GGGI and MEGD signed a Memorandum of Understanding (MOU) in November 2011 for the cooperation in programmes and joint activities that foster 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 the green growth planning should be focused. 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 Green Development Policy.

Bilateral cooperation established in 2013 with the Government of Japan on Joint Crediting Mechanism (JCM) is a good example of the successful north-south collaboration in the field of climate change. Under the partnership, joint studies have been undertaken in energy supply to improve Combined Heat and Power (CHP) Plant to identify Business as Usual (BAU) and Nationally Appropriate Mitigation Actions (NAMA) scenarios in energy supply. A total of nine projects were undertaken during the 2013 fiscal year with contributions from the Japan's Ministry of Environment and Ministry of Economy, Trade and Industry(METI) . These include five feasibility studies, two demonstration projects, one model project, and one project planning study. Also, the Ministry of Energy of Mongolia and METI of Japan signed a MOU in 2013 on JCM to promote effective implementation of JCM projects and exchange information in the energy sector of Mongolia.

Green Climate Fund (GCF) and Adaptation Fund (AF). There are already a vast number of national and international funds, with different access modalities and a diversity of funded projects. This in turn, may make climate finance complex and difficult to understand. Mongolia has already benefitted from some of them, including the Ecosystem-based adaptation project as funded and supported by AF through UNDP Mongolia. Recently (2010), there have been important new developments in the international institutional architecture with the establishment of the Green Climate Fund (GCF). The GCF aims at pursuing a country driven approach and to strengthen engagement through the effective involvement of the relevant institutions and stakeholders at the country level.

Climate Change Education, Public Information and Knowledge

It is crucial to raise awareness on climate change related issues among the public and individuals, to give them a correct 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 sustainable development education. Activities towards climate change mitigation and adaptation are not only the environmentalists' duty, it needs everyone's effort and participation. In other words, climate change directly or indirectly affects everybody's daily livelihood. Therefore, being knowledgeable about climate change will help people to choose how best to adapt.

In order to to raise public awareness for effective climate change adaptation and reduction of its negative impacts, the aim is to implement training programmes for general education school students, teachers, herders and farmers.

The country is implementing the following public awareness activities on climate change:

- General trainings and seminars, including discussions
- Themed trainings and activities within the certain sectors
- Organizing regional seminars for domestic/local areas
- Organizing topic-specific integrated trainings to prepare and train teachers from local areas
- Distributing publications, newsletters and maintaining and operating a web page

One of the main objectives of the NAPCC is to raise public awareness and educational issues. The strategic objective 5 of this programme is defined as "Conduct public awareness campaigns and support citizen and community participation in actions against climate change."

Cooperation between the MEGD CCCO and United Nations Educational, Scientific and Cultural Organization (UNESCO) helps provide citizens with information on climate change concerns, their roles in global climate and adaptation to changed climate conditions by raising their knowledge, and optimal ways to mitigate and adapt climate change. Therefore, a "climate change education" programme is being implemented under the framework of the United Nation's sustainable development supports with UNESCO initiative (UNESCO, 2010). Mongolia's future depends on our actions today. The majority of citizens consider that climate change issues are relevant to the politics, decision makers and environmental specialists who work in the field. Research shows that merely 1% of the Mongolian population has a deep knowledge about climate change or those involved in the climate change initiatives and environmental sector. Even if the 3,000 people work in this sector, it is insufficient to significantly mitigate GHGs and to prepare 3 million other people for climate change adaptation. Therefore, providing climate change education and sustainable development knowledge to public is one way to tackle this issue. Everyone should be obliged to learn about the climate change mitigation results and negative impacts. 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 practice those in their daily lifestyles.

Climate change, ecosystem adaptation educational training programme. There are many ongoing activities that promote awareness on climate change and educational training programmes onecosystem-based adaptation. These include promoting educational needs on climate change, system level assessment with inter-sectoral researchers and scientists, developing educational curriculums, defining new professional indexes and classifications in different levels of education and reflecting these in university programmes and developing guidebook and textbooks (2014). Especially, it is imperative to develop educational curriculums and define new professional indexes and classifications related to the fields of environment and climate change.

Educational programme in primary schools and universities. The Mongolian Government has coordinated with the Swiss Development Cooperation Agency and has initiated a project to include the climate change and sustainable development education issue in every level of education programmes (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.

GOVERNMENT OF MONGOLIA

MINISTRY OF ENVIRONMENT AND GREEN DEVELOPMENT

Address: Government Building-2, United Nations Street-5/2, Ulaanbaatar-15160, Mongolia
Tel: +976-11-326595, +976-11-311173. Fax: +976-51-264711