Climate change and sustainable livelihood of rural people in Mongolia

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1. Introduction

Mongolia is a vast, land-locked country bordering China and Russia. The average altitude is 1,580m above sea level. The country stretches from the Gobi desert in the south to the forest and forest steppes in the north and from the Altai Mountains in the west to the steppes and desert steppes in the centre and east. Mongolia has a harsh continental climate with four distinctive seasons, high annual and diurnal temperature fluctuations, and low rainfall. Because of the country's high altitude, it is generally colder than in other countries on the same latitude. Frequently, the country is hit by so-called *dzud* events, a succession of a very dry summer, an extremely cold autumn and a harsh winter which deprives livestock of grazing, often leading to high livestock mortality rates.

Many people in Mongolia depend on keeping livestock for their livelihoods (see box 1). Estimates indicate that almost four out of ten people in Mongolia hold livestock and in rural areas this figure can be as high as seven out of ten. A large part of the rural population has maintained the traditional lifestyle of moving around with their herds of cattle, goats, sheep, camels and horses.

The high dependency on keeping livestock makes the country and especially the poor rural people highly vulnerable to climate-related hazards. This was shown again in the period 1999 to 2002 when three consecutive *dzud* years killed nearly 30% of the livestock and many rural households were struggling to survive. Recurring drought events have also led to reduced pasture growth and limited water availability further aggravating the poor living conditions of rural households.

Realizing the sensitivity of the livestock sector to climate-related hazards, many people have started to express their concerns about the potential negative effects of climate change on the already vulnerable rural population and in recent years various studies have been undertaken to further investigate the issue.

A study carried out in the context of the AIACC project, for instance, has concluded that over the last 60 years the annual mean air temperature in Mongolia has increased by 1.66ºC. The warming has been most pronounced in winter with an increase of 3.61ºC. The spring and autumn temperatures have increased by 1.4 to 1.5ºC. No clear trend has been detected in summer temperatures. The study did not observe a significant change in mean annual precipitation during the same period. However, it was noted that changes in annual precipitation have a highly localized character and some areas in the country do show a significant increase whereas others show a decrease.

In terms of future climate projections, the results from a selected set of Global Circulation Models show a 3 to 10ºC increase in mean monthly temperature and a small increase in precipitation for the periods 2000 to 2040 and 2040 to 2070. All of the models predict that winter warming would be more pronounced than summer warming, especially after 2040.

According to various scientists, these changes in climate are having and will have a significant impact on natural resources such as water resources, natural rangeland, land use and snow cover.

In the next 40 to 50 years, many *soums* (sub-provinces) in the territory of the Bayan-Ulgii and Khovd provinces (in the western region of Mongolia) will increasingly be affected by desertification, because the amount of precipitation will decrease and average temperature will increase. Also, because of decreased permafrost, perpetual snows, glaciers, lakes, streams and rivers that have their origin in the Khangai Mountain range, will lose their headwater and will eventually dry up completely. They will only have seasonal and temporary flow dependent on precipitation levels. Furthermore, the decrease in permafrost in combination with changing rainfall patterns, will very likely result in an increase in the number of forest fires. Taken together, most of the studies conclude that climate change will negatively impact the natural resource base in Mongolia and will consequently further aggravate the precarious conditions in which rural communities are living[1].

In response to these and other observations, the government of Mongolia has started to formulate legislation and policy measures to prepare itself for the possible consequences of climate change. In 1993, the government ratified the United Nations Framework Convention on Climate Change (UNFCC) and in 2001 it approved a National Action Program on Climate Change. In addition, several policy documents have been put in place that are directly or indirectly related to climate change. These include:

- Laws on Nature and Environment; Laws on Meteorology, Hydrology and Environmental Monitoring; Laws on Land; Laws on Arable Farming; Laws on Disaster Prevention; Laws on Pasture;
- A program on sustainable development of Mongolia, 1999;
- A national program on preventing livestock from drought and *dzud* disasters, 2001;
- A food program on food supply, security and nutrition, 2001;
- A program on supporting development of intensive livestock-farming, 2003;
- A state policy on the development of food and agriculture; and
- Relevant annual reports on the natural and environmental review in Mongolia.

The government has also established an inter-disciplinary and inter-sectoral National Climate Committee (NCC), led by the Minister for Nature and the Environment, to coordinate and guide national activities and measures aimed at adapting to climate change. High-level officials such as Deputy Ministers, State Secretaries and Directors of the main departments of all related ministries and agencies are members of the NCC.

2. Objectives and rationale of activities undertaken

Even though much research has already taken place and certain policies measures have been proposed and adopted, it is recognized that a lot still needs to be done in order for Mongolia to be better prepared for the effects of climate change. In this respect, it has been noted that many people in Mongolia still consider climate change as something that will happen in the distant future and will have limited impact on their daily lives. Consequently there still exists a certain reluctance to start addressing the problem with clear and concrete policies and adaptation measures. In addition, the adaptation measures that have been proposed so far are often very general and sometimes even unrealistic with little reference to the actual situation on the ground. Finally, policies and adaptation measures largely exist on paper and are rarely implemented and enforced due to a lack of financial support and institutional capacity.

1 A database has been compiled by the NCAP project team in Mongolia containing information about climate change projects and publications in Mongolia.

Box 1: The agricultural sector in Mongolia

In recent years Mongolia has been experiencing strong and continuous economic growth. Its GDP grew by 5.6% in 2003 and by 10.6% in 2004. Growth in the agricultural sector turned around from -18.2% in 2001 and -12.4% in 2002 to +4.9% in 2003 and +19.9% in 2004. According to a World Bank report real GDP growth rate in 2007 was 9.9% and has been primarily driven by agriculture (which contributed 3.4% to economic growth), and services (which contributed 4.3%).

Agricultural sector activities predominantly consist of keeping livestock and animal husbandry. The 2007 annual livestock census reported an increase of 15% of livestock from 34.8 to 40.3 million livestock, with the number of goats, sheep and cattle increasing by 18, 15 and 14% respectively. All together, the livestock sector employs 364,000 people or almost 40% of Mongolia's working population.

Even though Mongolia has made notable progress in achieving macroeconomic stability and economic growth since its transition to democracy and shift to a market-based economy, it has also been noted that the social and environmental costs of this transition have been high. This is particularly so in the livestock sector, which has suffered from a decaying rural infrastructure because water wells, pasture irrigation systems and rural transport have not been maintained and have fallen into disrepair. Also the opening up of the Mongolian market has seen a shift from sheep keeping to goat keeping among herders who are trying to respond to the growing international demand for cashmere wool. Goats, however, are much more harmful to the environment than sheep because they disturb the pasture's regenerative capacities by feeding on roots and flowers. Consequently, the shift to goat keeping is putting increasing pressure on the pasturelands in Mongolia, threatening to accelerate pasture degradation and processes of desertification.

The NCAP project in Mongolia, which started in 2005 and ended in 2008, has tried to address some of these issues and has focused its activities on the following areas:

Firstly, the project has taken the support of the NCAP as an opportunity to further the understanding of baseline vulnerabilities in Mongolia. Rather than replicating past efforts, the project team has sought to further build on the existing knowledge and has carried out some more detailed studies in the field of climate science, pasture monitoring, water management and food security with the purpose of developing and formulating more detailed adaptation measures for herding communities in Mongolia.

Secondly, considerable efforts were made to increase public awareness of climate change in Mongolia through the publication of short articles in various newspapers and magazines and the broadcasting of television programs on climate change.

Finally, the project team has collaborated with key politicians and policymakers in Mongolia to further build legal and institutional foundations for implementing climate change adaptation policies in Mongolia and has developed a set of specific and feasible adaptation measures for rural herding communities in Mongolia.

In what follows, an overview is given of some of the key results of the project. Each chapter starts with a summary of the main results of the study reports. Next a summary is given of the activities that have taken place in relation to institution building and the formulation of adaptation measures. The chapter ends with some recommendations and lessons learned.

3. Key results and findings from the studies

In the context of the NCAP project, four interrelated studies were carried out to further develop the understanding of climate change vulnerabilities in Mongolia, with a special focus on rural herding communities. The studies cover different areas related to the livelihood activities of rural communities including exposure to (extreme) climate events, pasture resources, water resources, and food security. The results from the studies have served as a basis for discussing and formulating more specific adaptation measures which are presented in section 5.

3.1 Climate change exposure and extreme events

The study on climate change exposure and extreme events further builds on existing climate science work in Mongolia in three respects. Firstly, whereas previous studies have mainly focused on climate averages, this study has dealt with extreme climate events such as prolonged droughts and harsh winters (*dzud*). Secondly, the study provides an update on the historic trend analysis up to the year 2007. Finally, the PRECIS Regional Climate Model was used to downscale GCM data for key climate parameters and identify vulnerability hotspots in Mongolia.

Trend analysis

According to a linear trend estimation of temperature changes over the period from 1940 to 2007 annual *temperature* has increased by 2.1ºC (figure 1). Most of the increase is taking place in winter (3.6ºC). Spring and autumn temperatures have increased by 1.8 and 1.9ºC respectively and summer temperature by 1.1ºC. Interestingly, the observed increase in annual temperature is higher than the one detected in a previous study which used data from 1940 to 2001 and showed an increase of 1.66ºC in mean annual temperature. This indicates that the years since 2001 are further adding to the warming trend. Also, whereas the previous study did not show a significant increase of summer temperature, the current study reveals a summer warming trend of 1.1ºC.

Annual precipitation has not significantly changed, but it has decreased by 7% in terms of the country's spatial average (figure 2). The direction and magnitude of change differs from place to place and a small increase in precipitation is detected in the east, southeast and the Altai Mountain region whereas the southern part of the Khangai Mountains and the central region of Mongolia show a decrease. These observations are in line with the results from the previous study. It is also noted that convective precipitation is becoming more dominant, particularly in the transition zone between semi-desert and desert areas.

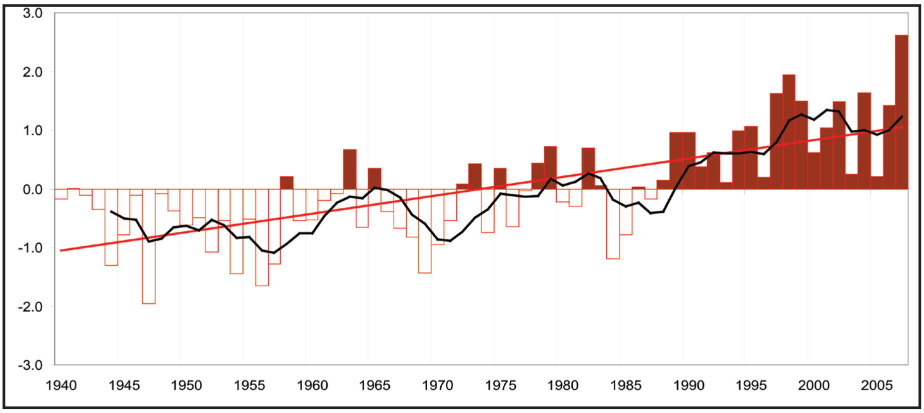

Figure 1: Annual mean temperature anomaly time series over Mongolia, ºC

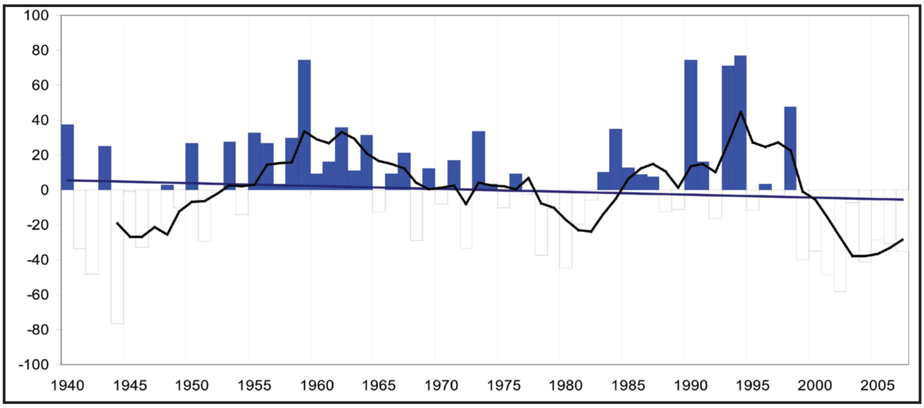

Figure 2: Annual total precipitation anomaly time series over Mongolia, mm

In order to understand changes in extreme events, the study defined a set of *climate extreme indices* as recommended by the CCl/CLIVAR Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI). An overview of the trends in climate extreme indices is given in table 1.

Table 1: Extreme indices trends based on results from 24 meteorological stations over Mongolia, 1950 to 2006

Index	Definition	Units	Trends
Max Temp (TX)	Monthly maximum value of daily maximum temp	ºC	2.9
Min Temp (TN)	Monthly minimum value of daily minimum temp	ºC	5.2
Cool nights	Percentage of days when TN<10th percentile	Days	-7.1
Cool days	Percentage of days when TX<10th percentile	Days	8.4
Warm nights	Percentage of days when TN>90th percentile	Days	-12.8
Warm days	Percentage of days when TX>90th percentile	Days	12.1
Diurnal temperature range	Monthly mean difference between TX and TN	ºC	-0.9
Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm	-0.4
Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm	-3.7
Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	mm/day	-0.2
Number of heavy precipitation days	Annual count of days when PRCP>=10mm	Days	-0.5
Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days	-0.2
Very wet days	Annual total PRCP when RR>95th percentile	mm	-4.2
Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm	-15.0

Extreme temperature indices show an increase in both daily maximum and minimum temperature. However, the warming trend of the minimum temperature is higher than for the maximum temperature. These observations are also consistent with a decrease of the diurnal temperature range over Mongolia.

Concerning the trend in precipitation, a decreasing trend is observed all over the country except in the southwestern region. A relatively high decrease is observed in the central region of the country. This also corresponds to indices of extreme wet conditions. However, more studies need to be done on the type of precipitation and the percentage of heavy precipitation compared to the total amount, especially in terms of areas where severe land degradation is going on. In short, the trend analysis shows that extreme temperature indices are changing towards warming, and extreme precipitation is showing that dryness is becoming more dominant in the country.

Downscaling climate data using PRECIS

Previous studies on climate change in Mongolia have mainly focused on Global Circulation Model (GCM) outputs for assessing the impacts and vulnerability of ecosystems and socio-economic sectors. However, the resolution of a GCM is typically in the range of 250 to 300km which is often not detailed enough to support decision-making processes at a local level. Moreover, local topography and land cover influences on the regional climate are not adequately represented in GCMs. Therefore, this study has used the PRECIS (Providing Regional Climate for Impacts Studies) Regional Climate Model to downscale global model output to the regional scale (50 to 60km).

Even though it is acknowledged that multi-model approaches are essential for understanding and appreciating uncertainties in individual model results, running a Regional Climate Model is in itself very expensive and needs considerable computer capacity, time and experience. Consequently, in the context of this study it was only possible to run one Regional Climate Model and choices needed to be made on which emission scenario to use (A2) and which GCM would be used to set out the boundary conditions for the model (HadCM3). Therefore it is suggested that the results from this study are read with care and are best interpreted in conjunction with results from similar modeling efforts in the region.

Two model runs were performed: the first one to simulate the historic climate for the period 1961 to 1990 and the second one to project future climate conditions for the period 2071 to 2100 using the A2 emission scenario.

Figure 2 shows the observed mean temperature for the period 1961 to 1990, a PRECIS simulation of mean temperature for the period 1961 to 1990 and a projection of future temperature for the 2071 to 2100 period. As can be seen from this figure, the PRECIS simulation results of the 1961-1990 period give a reasonable presentation of the observed temperature in Mongolia in the same period (figure 3 a, b). This gives some confidence about the model's capability to project the future climate of Mongolia although, as was mentioned before, it will be important to interpret the model results in conjunction with results from other modeling efforts. Figure 3c also shows a general increase in temperature in Mongolia for 2070 to 2100 compared to the 1961 to 1990 baseline.

In terms of *precipitation*, figure 4 shows the observed mean precipitation for the period 1961 to 1990, a PRECIS simulation for the period 1961 to 1990 and a projection of future precipitation for the period 2071 to 2100. Again the simulation of the 1961 to 1990 period gives a reasonable representation of the observed precipitation in Mongolia in the same period.

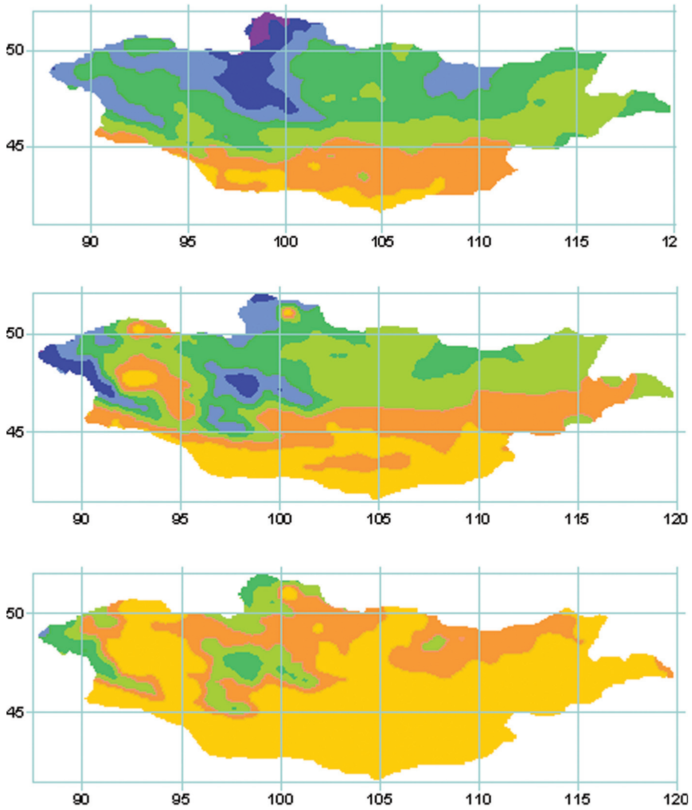

Figure 3: Annual temperature, ºC (from top down) a) Observed climate of 1961 to 1990, b) Simulated climate of 1961 to 1990, c) Projected climate of 2071 to 2100

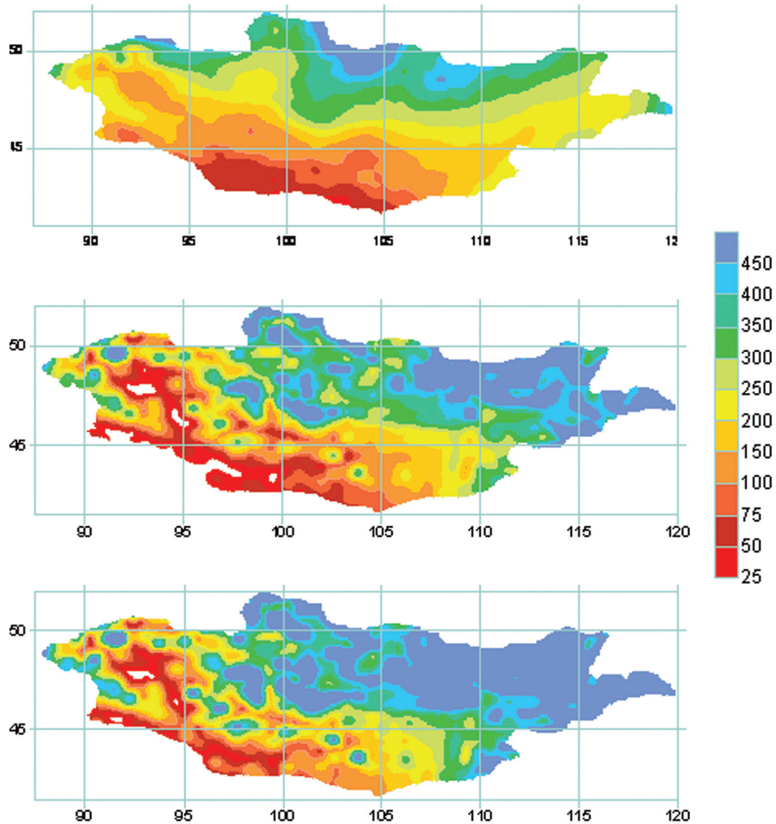

Figure 4: Simulated mean annual precipitation, mm (from top down) a) Observed climate of 1961 to 1990, b) Simulated climate of 1961 to 1990, c) Projected climate of 2071 to 2100

More important than changes in average annual climate, however, are changes in seasonal climates and extreme events. In order to understand changes in seasonal temperature and precipitation, the study has considered differences between the baseline climate and the future climate projections.

Contrary to the trends observed in historical temperature, the PRECIS modeling results for the period 2070 to 2100 show a high temperature increase of 5 to 7˚C during the summer season. Temperature increases for the other seasons are estimated at 4.5 to 5.5˚C in winter, 3.5 to 5˚C in spring and 3.5 to 4.5˚C in autumn. There are also geographical differences with the western and northwestern parts of Mongolia showing the highest increase.

According to the PRECIS model results, summer precipitation will increase by 40 to 60mm in the mountainous region of central Mongolia, and the small areas in the northeast and southeast of the country. The rest of the country shows an increase of 20 to 40mm except for the northwestern part of Mongolia where the model shows a decrease of 20 to 40mm. This is also the area where many glaciers are situated and most rivers are being charged by the permafrost. In autumn, there is a 0 to 20mm increasing in the west and 20 to 40mm in the east of Mongolia. In spring, a 0 to 20mm increase is projected in central and western Mongolia and 20 to 40mm in the east. In winter, there is a 0 to 20mm decrease across the whole territory of the country. If precipitation change is defined and expressed as a percentage of the baseline climate value, then the summer increase is not particularly high, but the winter increase is. The area where precipitation levels are decreasing is the northwestern part of Mongolia.

The above mentioned research results show a significant climate change during the summer season compared to other seasons. If one considers the geographical distribution of the changes, it appears that the western and northwestern parts of Mongolia will be especially affected by global warming.

In terms of future changes in the occurrence of extreme events, the study has diagnostically estimated drought, *dzud* and dryness indices at model grid points using PRECIS model outputs. The frequency is defined for both the periods 1961 to 90 and 2071 to 2100 and expressed as a percentage (e.g. 20% meaning that the event occurs once every five years, and 50% meaning that the event occurs every 2 years). During the 1961 to 1990 period, the occurrence of drought events was relatively equally distributed across the country with a slightly higher frequency in the western and central parts of Mongolia. The future distribution of drought frequencies looks different with a very high incidence of drought events in the northwestern part of the country and a reduced frequency of drought events in the southwestern part.

Finally, based on the PRECIS model results, the study also calculated a dryness index which was defined as the ratio between precipitation and potential evaporation (P/Eo). To summarize, the analysis shows that extreme events like *dzuds* and droughts are expected to become more frequent, especially in the northwest of the country and dry conditions are expected to increase over the whole territory.

Vulnerability of aimags *(provinces) to extreme climate events*

In order to assess the vulnerability of different *aimags* to extreme climate events, the study has developed an index of vulnerability based on both current and future exposures. Because the most important season for herding is summer, the study focused on summer precipitation trends and drought frequency projections in order to assess the relative vulnerabilities of different *aimags*. The results from the assessment are given in table 2. The table shows that 12 out of 18 *aimags* in Mongolia are highly exposed to climate change and climate variability.

Table 2: Extreme climate vulnerability based on the exposure level

Aimag Name	Current	Future	Exposure level
Arkhangai	High	High	High
Bayankhongor	High	Low	High
Bayanulgii	Low	High	High
Bulgan	High	Low	High
Dornod	Weak	Low	Weak
Dorno-govi	Weak	Low	Weak
Dundgovi	High	Low	High
Govi-altai	Low	Low	Low
Khentii	Low	Low	Low
Khovd	Weak	High	High
Khuvsgul	Weak	Weak	Weak
Selenge	High	Low	High
Sukhbaatar	Weak	Low	Weak
Tuv	High	Low	High
Umnugobi	High	Low	High
Uvs	Low	High	High
Uvurkhangai	High	Low	High
Zavkhan	High	High	High

3.2 Pasture resources

Pasturelands constitute one of the key resources for the livestock based economy in Mongolia. According to the 2005 Land Inventory Report, 116 million ha or 73.9% of the total land surface of Mongolia can be considered as pastureland. Being one of the key resources in the Mongolian economy, this study has looked into historic changes in pasture resources and has sought to understand how these changes can be related to changes in climate and other socio-economic developments.

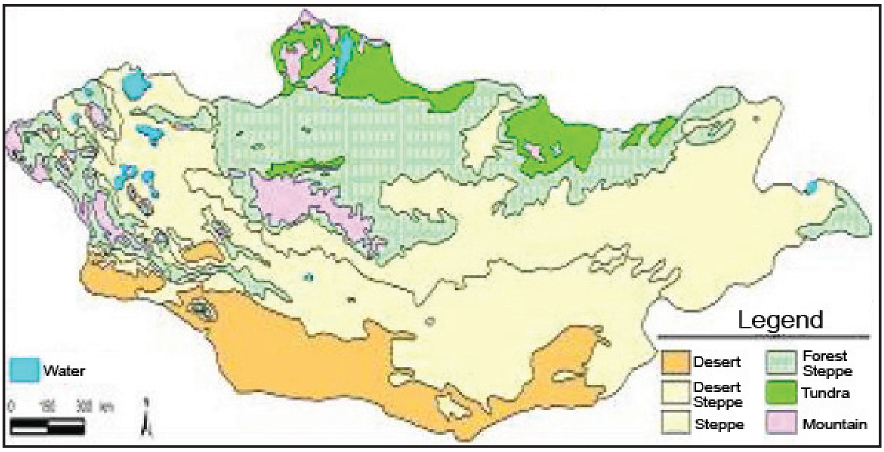

Figure 5: Natural zones of Mongolia

Mongolia is divided into 6 natural zones: tundra; high mountain; forest steppe; typical steppe; desert steppe; and desert (see figure 5). The pasture productivity, dominant species and type, length of growing season and phenology are different for each of these natural zones. The pasture productivity, for instance, ranges between 150 and 1500 kg/ha increasing from the deserts in the south to the forests and forest steppes in the north.

Historic trends in pasture resources

In order to analyze the historic trends in pasture resources, the study has examined the Normalized Difference Vegetation Index (NDVI) using NOAA-AVHRR data. Figure 6 shows the annual NDVI dynamics of the different natural zones of Mongolia. As can be seen from this figure, the NDVI ranges are spatially and temporally different. Tundra, high mountain and steppe zones have a clear seasonal cycle whereas in desert steppe and desert zones such annual dynamics cannot be observed. The figure also shows that the height of the growing season is concentrated during the months of July and August. Consequently, the remainder of the study has focused on these two months.

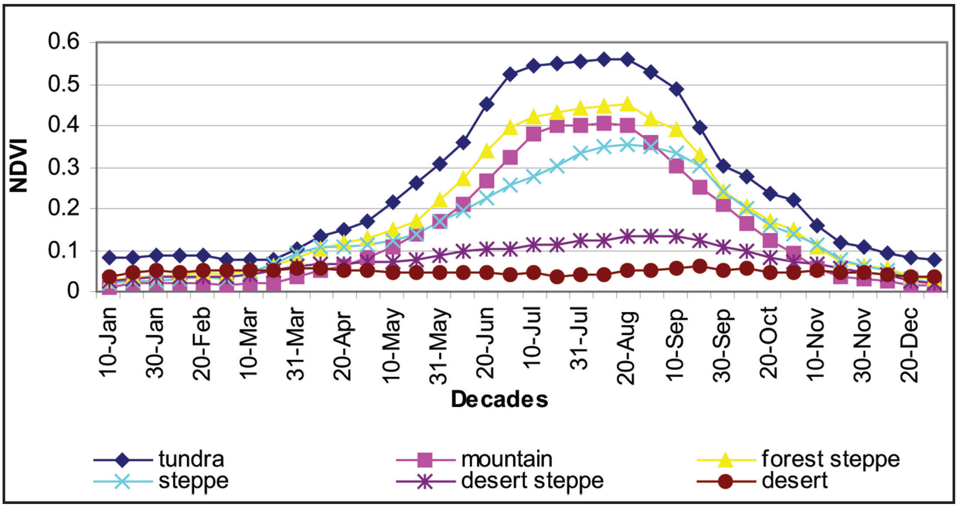

Figure 6: Average NDVI values for the different natural zones in Mongolia

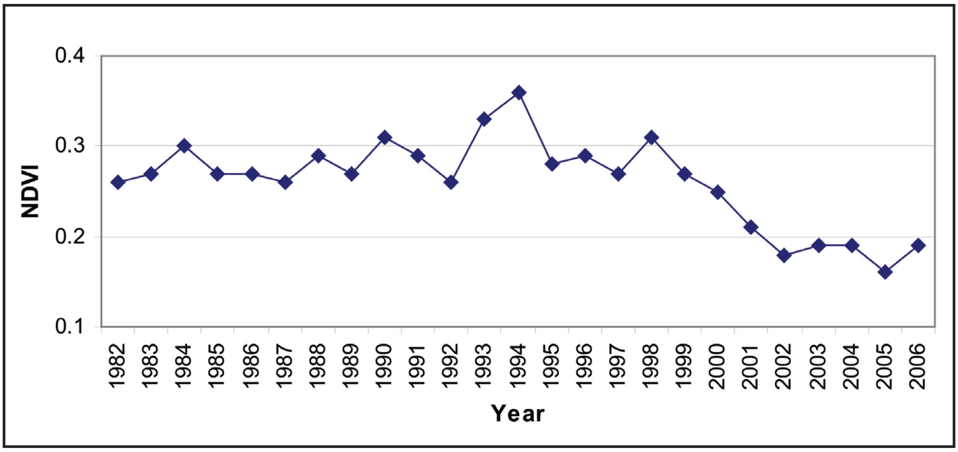

Figure 7: Annual NDVI values averaged across Mongolia

The NDVI changes over the last 24 years for July and August are depicted in figure 7. The NDVI values don't show a significant trend up to 1994. However, from 1994 onwards, a decreasing trend can be observed. This trend can be observed in all natural zones and, in desert steppe and desert zones, the NDVI values are even dropping below the 0.06 threshold of no vegetation (i.e. bare soil).

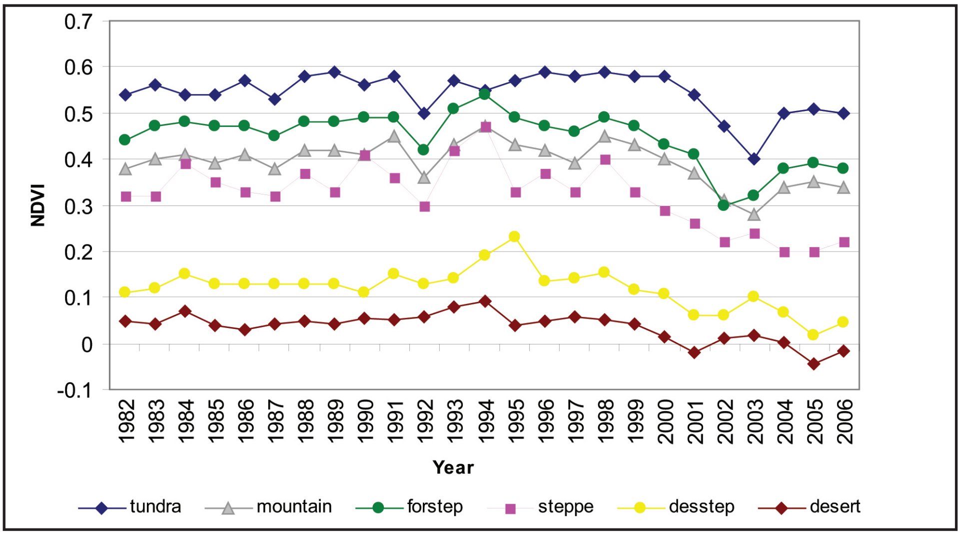

Figure 8: Annual NDVI values averaged across the different natural zones

To further understand trends in pasture resources, the normalized value of NDVI, ZNDVI, was calculated. This also allows comparison of the trends in pasture resources between different areas and regions in the country. ZNDVI is expressed as follows:

$$Z_{NDVI} = \frac{NDVI_k - \overline{NDVI_i}}{\sigma_{k\ NDVI}} \times 100$$

where, NDVI ik and σ ik represent the NDVI value and its standard deviation at point i, of year k[2]. The slope of Z NDVI values for July and August were negative in all sums (figure 9). The lowest values were detected in the *aimags* of Uvs, Arkhangai, Bulgan, Khuvsgul, Tuv, Selenge, Dornod and Omnogobi. This clearly indicates that serious pasture degradation is taking place in many parts of the country.

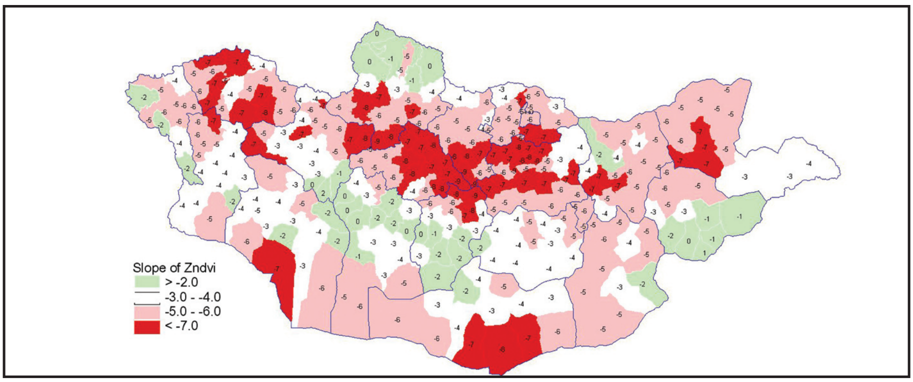

Figure 9: Slope of ZNDVI value, 1982 to 2003

2 $\overline{NDVI}$ i represents the long term average value of NDVI at point i.

Apart from looking at trends in the amount of pasture resources, the study has also looked at changes in phenology. As can be seen from the summary in table 3, the growing season is getting longer in almost all natural zones.

Table 3: Pasture vegetation (fenced) phenology phases dates change, days/1 year.

Natural zones	Vegetation species	onset	heading	flowering	maturing	senes-cence
Desert	Leymus	-0.77	0.73	-0.75	-0.36	-0.7
Desert	Stipa	-0.03	1.05	-0.32	-0.6	0.3
Desert steppe	Agropyron	-0.38	1.9	1.46	2.58	1.73
Desert steppe	Cleistogenus	0.75	0.46	0.02	-0.93	-0.52
Desert steppe	Leymus	-0.13	-0.94	-1.29	3.92	1.59
Desert steppe	Stipa	0.13	0.49	0.57	0.24	-0.1
Forest steppe	Agropyron	-0.57	0.16	0.31	0.39	0.43
Forest steppe	Festuca	-0.32	-0.04	0.26	0.15	-0.32
Forest steppe	Leymus	-0.53	-0.39	-0.78	-0.59	0.21
Forest steppe	Stipa	-0.51	0.78	0.4	0.12	-0.11
Steppe	Agropyron	-0.16	0.24	0.07	0.07	0.09
Steppe	Cleistogenus	0.16	0.33	0.46	-0.12	0.14
Steppe	Leymus	-0.18	0.04	-0.77	-0.68	0
Steppe	Stipa	-0.41	0.78	-0.22	-0.23	-0.08

Factors influencing pasture resources

Typically, the causes of land and pasture degradation are various. The Agency of Land Affairs, Geodesy and Cartography carried out a study on the state and quality of pasturelands in Mongolia and found that more than half of the pasture area was degraded to some extent (table 4). The table also shows the different reasons for the degradation and as can be seen from the table the main factor causing pasture degradation is overgrazing.

Table 4: Land degradation and its causes in Mongolia

Causes of degradation	Size of area, ha	Percentage of total surveyed area
Total pasture area conducted in survey, of which affected by:	58,282,362	
• autogenetic	279,516	0.5
• technological	130,328	0.2
• distribution of rodents	186,860	0.4
• overgrazing	15,985,413	30.1
• sand movement	1,934,894	3.6
• water erosion	181,724	0.3
• ravines	178,027	0.3
• polluted	2,085,454	3.9
Not used because of:		
• Over use	6,586,531	12.4
• Lack of water supply	1,288,708	2.4
Normal or not degradated	24,233,683	45.7

There are strong indications that the growing number of goats is rapidly adding to this problem. Goats are especially destructive to grassland vegetation as they frequently destroy the roots of plants. Over the past couple of years, the number of goats has increased significantly by 10 million. Currently, goats make up 47% of the total number of livestock in Mongolia.

These observations are further supported by the results from a study carried out within the NCAP project, which shows that, every year, the number of livestock is exceeding the carrying capacity of the pastureland in 135 to 180 *soums* (figure 10).

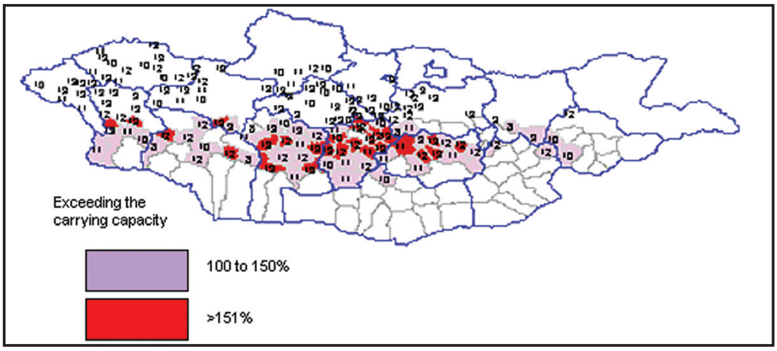

Figure 10: The exceeding of carrying capacity averaged for 1986 to 2003

Apart from overgrazing, it is recognized that other climate factors also play an important role in the quantity and quality of pasture resources. A study carried out examined the relationship between climate, soil moisture and vegetation and found, among other things, a strong correlation between July rainfall and vegetation growth. In addition, they also concluded that few but heavy rainfall events lead to less vegetation growth than more frequent rainfall events with less rainfall per event.

In a similar way, this study has calculated the differences in vegetation growth (using the NDVI as an indicator) between very wet, normal and very dry years. The analysis indicates that, in the case of a severe drought, the NDVI values decrease by 19% in Taiga, 30 to 55% in the forest steppe area, 55 to 78% in the steppe area and more than 64% in the desert steppe area compared to very wet years (figure 11). The results from this analysis show the important effect of rainfall amounts on vegetation growth with less rainfall leading to less vegetation and in certain cases no vegetation at all (NDVI<0.06).

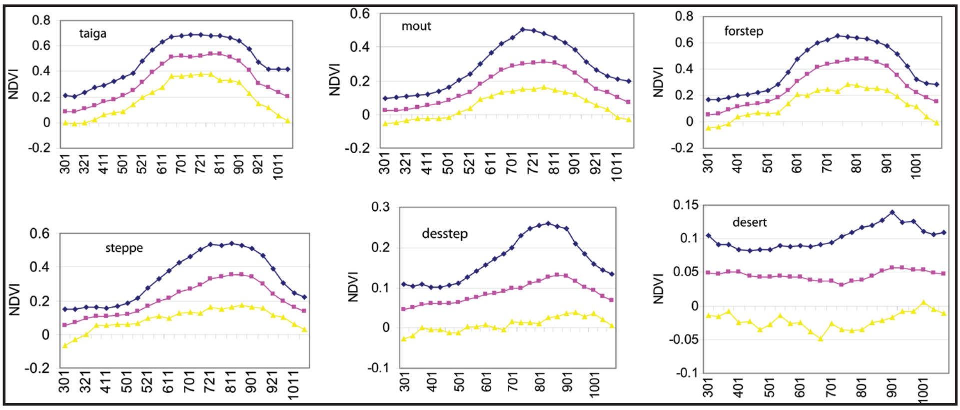

Figure 11: NDVI values for very dry (yellow), normal (pink) and very wet years (blue) in different natural zones in Mongolia

Also an analysis of the distribution of bare soil areas (i.e. no vegetation, NDVI<0.06) during dry and wet years clearly shows the effects of rainfall on vegetation. Figure 12 compares the bare soil area distribution during a wet year (1993 to 1994) and a very dry year (2001 to 2002). As can be clearly seen from this figure, the bare soil area is much larger during a very dry year.

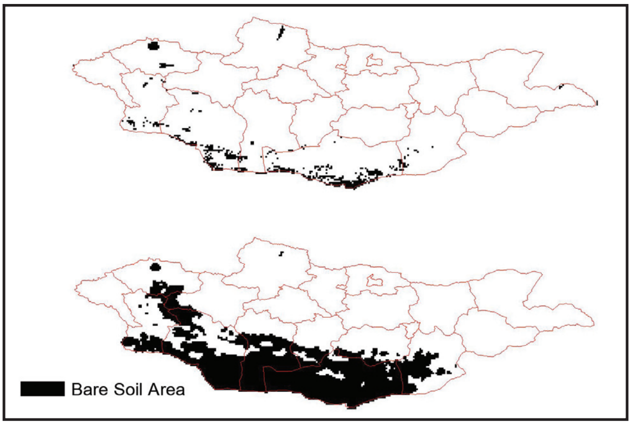

Figure 12: Bare soil area distribution in wet and dry years

Figure 13 gives the bare soil area as a percentage of the total pasture area in Mongolia and shows that in a very dry year like 2002, 25% of the total pasture area in Mongolia was bare. This situation severely reduces the availability of pasture resources for herding communities in the south of Mongolia and in certain cases this has forced herding families to abandon their herding lifestyle all together.

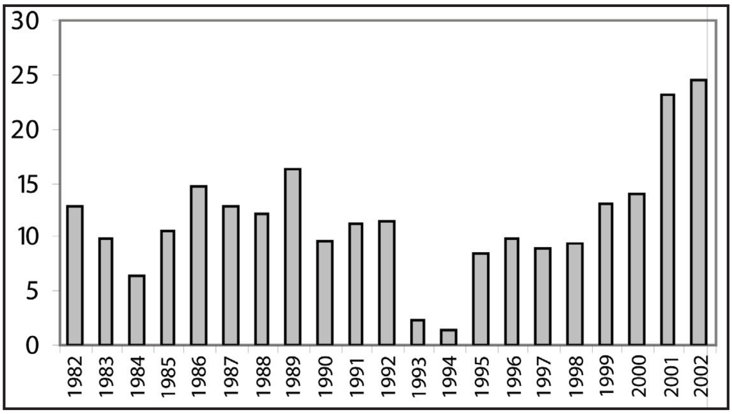

Figure 13: Bare soil area as a percentage of total pasture area

Impacts of climate change on pasture resources

Based on a detailed analysis of the relationship between the vegetation and climate conditions in the different natural zones, a vegetation growth index was developed. The vegetation growth index is expressed as:

$$Q_z = \frac{3}{8}\left(f_1(R) + \frac{3}{f_1(T)^2} \right)\left(f_1(T) - \frac{1}{3} \right)$$

Where R is rainfall and T is temperature.

Using this formula, threshold values of Qz were identified marking the point at which a shift of vegetation or natural zone is likely to occur. Future projections of temperature and rainfall in Mongolia were then used in combination with the threshold values to map the shifting boundaries of the different natural zones. The results are depicted in figure 14.

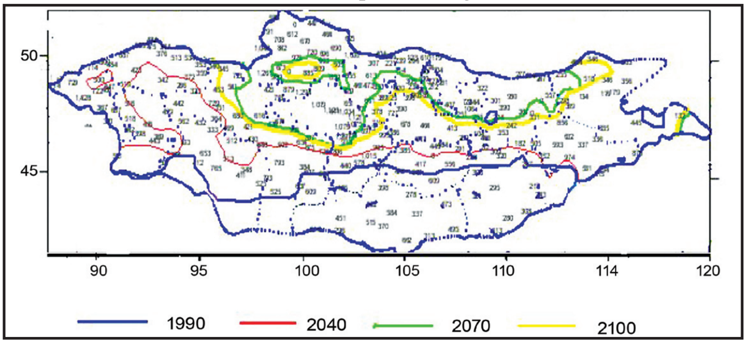

Figure 14: The shifts in the northen boundary of the desert based on threshold values of Qz. (The black figures represent the number of households).

Figure 14 shows that by the year 2070 northern boundaries of desert and steppe zones will move by 350 to 450km. This means that, over the next 60 years or so, the boundary of the desert is expected to move north at an average of 6 to 7km a year. It is clear that this will potentially have dramatic effects on the availability of pasture resources in the future.

3.3 Water resources

The total water resources of Mongolia are estimated at 599km^3 composed mainly of water stored in lakes (500km^3) and glaciers (62.9km^3). Annual river runoff and its groundwater contribution is estimated to be 34.6 km^3. Mongolia ranks 56th in the world in terms of water/capita/year and is defined as a country with limited or little water resources. Water resources are unequally distributed over the country: in the northern part of the country the available water per capita is 4 to 5 times more than the world average, in the southern part of the country; the available water per capita is 10 times less than the world average.

Historic trends in water resources

The latest state water inventory resulted in a count of 5,138 rivers in Mongolia of which 884 or 17.2 % had dried up. Similarly, in 2007 Mongolia had 3,747 lakes of which 1,189 were dry (31.6%). On average, surface water bodies in Mongolia had reduced by 25% in recent years.

Glaciers in Mongolia have been reduced by 30% since mid-1940. If this trend continues it is expected that glaciers with a depth of up to 50m will disappear by 2040, and glaciers with a depth of up to 100m will melt by 2050 to 2060. The largest glaciers with a depth of between 200m and 300m could completely disappear by 2070/2080 and 2090 respectively.

Several studies have been carried out that have tried to identify the reasons for the observed decline in water resources in Mongolia. For instance, the decline in river runoff has been explained by various factors, including a change in precipitation patterns with heavy rainfall events becoming more common (short and heavy showers are not contributing significantly to the soil moisture and consequently to the groundwater recharge), land cover changes due to human activities (land loses its runoff regulating capacity, there is less infiltration thus less recharge to the groundwater), loss of hydraulic connection between surface and groundwater, and finally change of river runoff and regime (direct flow has increased, while low flow period becomes longer).

Impacts of future climate change on water resources

In terms of the effects of future climate change on water resources in Mongolia, several studies have been carried out over the past years. These studies have already indicated that the water resources in Mongolia are very sensitive to even small changes in temperature and precipitation. Some of the main findings of these studies are briefly summarized here.

One study concluded that runoff in Mongolia will increase up to 2040 and will then start to decrease again. The study further suggests that the runoff peak flow will be about a month earlier in 2040 compared to the current situation. The appearance of ice phenomena in rivers is expected to be delayed by 3 to 10 days, while in spring period the ice cover breaking process is expected to start 5 to 15 days earlier than in the current situation. Equally, spring floods due to snow and ice melting are expected to start occurring.

Using the HadCM3 climate projection data, another study concluded that, by 2040, the permafrost area in Mongolia will be reduced by 30% and by 2070 to 2099 the permafrost area will have disappeared completely. As a consequence, the marsh areas will expand and start damaging settlements and infrastructure.

The latest studies on changes in evaporation, evapotranspiration, and runoff based on the A2 emission scenario show a significant increase in evapotranspiration during the 2020 to 2080 period and even the increase of runoff can not compensate such for this unbalance in the water cycle of the river basin. For instance, in Uvs lake basin in western Mongolia, the increase of river runoff is projected to be 10 times less than the expected increases in evapotranspiration. This again indicates that river basins will be much drier in the future.

The use of water resources by rural herding communities

Main sources of water for rural herders are different types of surface water as well as groundwater resources which are accessed through different types of wells. In a survey carried out among several herding families, it appeared that wells are becoming increasingly important due to the drying of surface water bodies. The herding families also identified wells as the best way to improve access to water in rural areas. The number of wells in rural Mongolia has varied over time. During the early years of the transition from a socialist system to a market-based system, many wells fell into disrepair and were left without an owner. Since early 2000, the situation has changed a little bit and about 2,000 wells have been repaired, 43 new wells have been drilled and by 2008 it is expected that 800 new wells will be built and several other wells are planned to be repaired.

Even though groundwater is playing an important role in the livelihoods of many herding communities, there is relatively little known about groundwater resources in Mongolia. The available data and information is scarce and certainly insufficient to support sound groundwater policies and the design of a well network for assisting rural herding communities. This study has looked at the groundwater resources on one site in the center of Uberkhangai province.

From the study, it appears that the groundwater table has significantly dropped between 1997 and 2006, probably due to changes in precipitation patterns and lack of recharge. Between 1997 and 2006, the groundwater table dropped 2m and according to this projection, the level may drop 5 to 6m by 2040. These are significant observations and further studies will be needed in order to better understand groundwater dynamics and availability.

3.4 Socio-economic indicators for climate change vulnerability

Vulnerability to climate change is not only a biophysical process, but also depends on socio-economic conditions and developments. This study has, therefore, also considered socio-economic indicators in order to understand the vulnerability of rural communities to the potential impacts of climate change.

Socio-economic conditions in Mongolia: understanding the baseline vulnerabilities

In Mongolia research of the livelihoods of the population has mostly been connected to the purpose of learning and understanding poverty levels at the national level. The results of these surveys divide the population into four groups: rich-middle, middle-medium, middle- poor and poor. According to 2006 census data, there are 170.7 thousand herding households in Mongolia of which 40% live below of the poverty line. Since 1996 the poverty of herding households has not decreased.

A more detailed survey, examined the livelihood conditions of rural herding households by examining five types of household characteristics:

X_1 – *income characteristics* (monthly income per person of household, monthly monetary income distribution, monthly monetary income & expenses)

X_2 – *immovable characteristics* (assets relevant to land and real estate such as a dwelling, its condition, livestock fences, water resources, wells, ownership of other immovable assets, and their value)

X_3 – *movable characteristics* (number of livestock, transport vehicles, valuable personal items, movable assets for use in the household)

X_4 – *characteristics of social indicators* (education and expenditure on education of herdsmen and other household members; social care (pension and health care); public services (health, education, cultural); infrastructure (distance from cultural services, health services and markets; electricity provision; veterinary services; communication provision; per capita daily caloric intake; access to credit; the environment of the living area)

X_5 – *characteristics' ability to adapt to external impacts* (socio-economic & climate change) (this is based on people's perceptions of their lifestyle, quality of life, opinions on unemployment and poverty in the area, and perception of the threats they face and the actions that need to be taken to reduce these)

Based on the analysis of these characteristics, households were grouped into four different categories: poor, lower-middle, middle and upper-middle. The results of the survey show that 60.7% of herding households live in poor conditions (see table 4).

Table 4: Livelihood conditions of rural herding households

	Total	**Of which**			
		Poor	**Lower-middle**	**Middle**	**Upper-middle**
Households	255	155	86	14	0
%	100	60.7	33.7	5.4	0

Table 5 also shows, for each of the household characteristics, the number of households per category of poor, lower-middle, middle and upper-middle. As can be seen from the table, 73.3% of the households are poor in terms of social position and none of the households can be considered upper-middle in terms of immovable assets or adaptation ability.

Table 5: Livelihood conditions of rural herding households according to different characteristics

Classification	Characteristics											
	Income (X1)		Immovable assets (X2)		Movable assets (X3)		Social position (X4)		Adaptation ability (X5)		Concentration of characteristics	
	households	%	households	%	households	%	households	%	households	%	households	%
Poor	151	59.2	175	68.6	151	59.2	187	73.3	120	47.1	155	60.8
Lower-middle	72	28.2	57	22.4	58	22.7	38	14.9	83	32.5	100	39.2
Middle	27	10.6	23	9.0	37	14.5	28	11.0	52	20.4		
Upper-middle	5	2.0	0	0.0	9	3.5	2	0.8	0			
Total	255	100	255	100	255	100	255	100	255	100	255	100

Table 6: Herdsmen's Livelihood Dynamic, 1990 to 2006, by thousand households

	1991-1990	1992-1991	1993-1992	1994-1993	1995-1994	1997-1996	1999-1998	2000-1999	2001-2000	2002-2001	2003-2002	2004-2003	2005-2004	2006-2005
<10	-11.4	-6.1	-10.5	-1.6	-3.1	-4.2	-3	2.7	2.4	-0.6	-3.3	-1.9	-3.7	-2.6
11-30	-16.4	-2.4	-12.2	-3.2	-3.2	-6.1	-0.9	4.5	2.6	-0.3	-3.4	-5.1	-2.1	-4.4
31-50	8.2	-0.7	-6.5	-1.7	-1.8	-2.7	-1.8	3.2	1	0.1	-3.8	-3.5	-2	-2.7
51-100	21.3	2.4	-2.9	-0.4	-1.9	2.3	-1.6	1.7	-2.9	-4.3	-3	-4	-2.7	-2.5
101-200	21.2	10.9	8.6	1.8	0.4	9.9	0.4	-8	-8.4	-5.3	1.3	0.5	1.6	2.9
201-500	5.2	8	10.9	3.7	3.1	1.6	1.4	-4.2	-5.5	-2.6	4.4	5.3	3.3	6.5
501-999	0	0.38	0.89	0.85	0.97	0.46	0.33	-0.85	-1.19	-0.25	0.7	1.5	1.2	1.9
1000-1499	0	0.01	0.04	0.09	0.14	0.09	0.2	-0.17	-0.25	0.04	0.1	0.3	0.4	0.7
1500-2000	0	0	0	0	0.01	0.02	0.01	-0.03	-0.01	0	0.02	0.04	0	0
2001<	0	0	0	0	0.01	0	0.01	0	-0.01	-0.01	0	0.0.2	0	0.1
less than 100 animals	1.7	-6.8	-32.1	-6.9	-10	-10.7	-7.3	12.1	3.1	-5.1	-13.5	-14.5	-10.5	-12.2

Climate conditions affecting baseline vulnerability
Herders are living under direct risk of weather and climate. Local officials and 97.6% of the herders consider climate change and environmental change a reality in their area[3]. When asked which aspects of their environment and climate had changed most significantly they named various elements including heavy snowfall, reduction of drinking water, frequent drought and *dzud* events, drying up of rivers and springs, reduction in hay making yield, reduction of feeding value of pasture land, sand movement and intensification of desertification. The herders also noted a decrease in the number of forage plant species, animal fatness and bodyweight, and consequently a reduction in the production of meat and milk as well as wool, cashmere and molt hair.

The importance of climate related events for rural herding households can be easily explained by the fact that herding households depend directly on their natural environment. For instance, when looking at the food intake by herding households, one realizes that livestock constitutes the main source of food in the form of meat and milk. Climate conditions that affect the survival of the livestock will therefore directly affect the food intake of the herding households.

Similarly, an analysis of the number of livestock per household during periods of favorable climate conditions compared to periods of less favorable climate conditions clearly shows the relationship between climate and household conditions. As can be seen from table 6, between 1990 and 1999, the number of households with small herds decreased for 8 consecutive years whereas the number of households with larger herds increased year by year. These developments can be partly explained by the introduction of private livestock ownership, but also by the favorable weather conditions during this period. During the *dzud* years of 1999 to 2001 many livestock died and immediately there was an increase in the number of households with small herds and a decrease in the number of households with larger herds.

4. Towards adaptation in Mongolia

Based on the results and findings from the studies and reports, it is recognized that urgent actions are needed to prepare Mongolia for the potential consequences of climate change. This project has, therefore, carried out two interrelated activities in order to move Mongolia towards adaptation. The activities that were carried out are:

- Activities in relation to building an institutional environment for adaptation; and
- Activities in relation to the formulation of concrete and specific adaptation measures.

Building an institutional environment for adaptation

Having realized that adaptation measures will be hard to implement without a strong and committed institutional framework, the project team has sought to contribute to the process of institution building and has actively engaged with policymakers at different levels to bring up the issue of climate change adaptation.

Developing a strong institution for adaptation was considered to be a necessary step because experiences from the past have shown that policy measures often only exist on paper and are rarely implemented because of the lack of institutional capacity, vague mandates and lack of financial resources. The National Action Plan for Climate Change in Mongolia, for instance, which was already approved in 1999, has not yet been implemented due to lack of financial resources and political commitment. This and other documents will need to be updated in order to make them compact, easy, executable and measurable.

3 Risk and development of Livestock sector, "Risk Study" working group, JEMP co., Ltd., February 2002

Therefore, the project has suggested the development of a permanent unit within the government, which will be responsible for climate change adaptation and will receive secured funding from the government budget. To this end, the project team has worked closely together with representatives from the Mongolian Parliament to put together a draft resolution for establishing a Permanent Sub-Committee on Climate Change Adaptation. The draft has been introduced to the Permanent Standing Committee for Food, Agriculture and Nature and Environment of the Mongolian Parliament.

Apart from formulating a draft resolution for establishing a Permanent Sub-Committee on Climate Change Adaptation, the project team has also worked with the office of the President to include climate change adaptation into the 'MDG-based Comprehensive National Development Strategy', which was ratified by Parliament on the 31st of January 2008. Due to these efforts, chapter six of the strategy now has a very strong focus on climate change and climate change adaptation.

Formulating adaptation measures

Many of the adaptation measures that have been formulated in the past, are often characterized by their generic approach and in many cases little thought went into how they can be financed and implemented. Furthermore, adaptation measures are often formulated without taking into consideration other drivers of change. The discussions about climate change vulnerability, for instance, have caused a lot of discussions in Mongolia about whether or not the government should stimulate a shift from traditional livestock activities towards an economy based on farming. However, traditional livestock activities are not only under pressure from climate change but are also influenced by other socio-economic developments, such as the increased demand for cashmere. Without understanding these broader developments, it is hard to develop appropriate policies for dealing with the problems that people are facing.

Having recognized these issues, the project team has tried to formulate a set of adaptation measures that are specific, realistic and clear in terms of space and time, and most importantly, they are executable and measurable. The formulation of adaptation measures was further guided by a couple of principles. Firstly, the project team is convinced that traditional livelihoods based on livestock herding will continue to exist in the coming decades. Consequently, the starting point for the formulation of adaptation options is the traditional herding communities. Secondly, rather than focusing on livestock as a point of departure for developing adaptation measures the project team has sought to bring the herders to the centre of the discussion and has tried to design adaptation measures that can support their communities.

To support and complement the list of adaptation measures, the project team also developed a climate change adaptation model for herders. Core ideas of the model include:

- designing comfortable mobile accommodation for herders with secured water, energy and communication supplies and which meets basic sanitation requirements;
- creating a network of "water filling stations" similar to the network of petrol stations in other parts of the world;
- cultivating fodder for animals in areas with favorable climate conditions and developing a forage distribution system, possibly linked to the "water filling station" network; and
- increasing and supporting education, awareness and information exchange capacities of herders.

5. Conclusion recommendations

Studies carried out under the second phase of the NCAP in Mongolia, have convincingly shown that climate change impacts will have significant effects on the natural resource base of rural households in Mongolia. Changes in temperature and rainfall patterns combined with an increase of extreme events are projected to have negative impacts on both pasture and water resources in Mongolia. This is expected to further add to the economic hardships that many of the rural households are already experiencing. The studies have also calculated that, by 2070, the northern boundaries of the desert zone will have moved north by 350 to 450km, making economic livestock keeping nearly impossible in large areas of the country.

Based on the results and other experiences from the NCAP project in Mongolia, the following strategic recommendations and suggestions for further research were developed.

Policy recommendations

One of the main lessons learned from this project was that, without a strong institutional environment, it is very hard to implement any adaptation policy or measure. Consequently, this project has sought to contribute to the establishment of a Permanent Sub-Committee on Climate Change Adaptation as part of the Standing Committee on Food, Agriculture and Environment of the Mongolian Parliament. At the time of writing, the proposed sub-committee had not yet been approved. Hence, it is recommended that further efforts are taken to realize this aim.

In addition, and based on the observation that there are already a significant amount of policy documents relevant to the issue of climate change adaptation available, it is also recommended to revise and update existing policy documents and to start enforcing existing laws and regulations.

Finally, more efforts need be made to create a more favorable financial and economic environment for herding households so that some necessary investments can be made for coping with the adverse impacts of climate-related hazards. Possible ways of improving the financial and economic environment include:

- the establishment of favorable long term loan conditions;
- the creation of clear rules for property and ownership;
- facilitating the establishment of small enterprises; and
- the development of insurance packages for climate related risks.

Suggestions for further research

One of the key outcomes of this project has been the development of downscaled climate data using the PRECIS model. As was mentioned before, one should, however, be careful in interpreting the results from only one climate model because of the uncertainties that are inherent in all the existing climate models. Recently, many authors have started to argue for the use of multi-model approaches which combine the results from many different climate models and, as such, proved a better basis for decision-making. More downscaling work needs to be done in Mongolia in order to start using the multi-model approach and to provide better climate information to decision-makers.

The studies carried out under the NCAP project in Mongolia include both biophysical and socio-economic studies. In the end, however, it proved difficult to combine both the biophysical and socio-economic information in order to better understand the vulnerability of rural households to climate change. Further research is needed to better understand these dynamic interactions between biophysical and socio-economic systems and to link both systems.

One of the key areas that has received insufficient attention so far in the climate change community is the impacts of climate change on the availability and distribution of groundwater resources in Mongolia. As many rivers are drying up, more and more rural households are starting to depend on groundwater resources. A better understanding of the availability and distribution of groundwater resources will be necessary in order to improve the management and use of these valuable resources by rural herding communities.