Assessment of Mongolian Rangeland Condition and Trend
(1997-2009)

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Front Cover

The photo was taken in late May, 2011 in the Gobi-Altai region of Mongolia. The small shrub in late bloom is *Oxytropis*.. The area of the photo is a “wind funnel” for sand deflation, which causes the area in the foreground to have a “fuzzy” look. Deposits of sand are visible on west aspects of mountains in the background (Source: Dennis P. Sheehy 2011).

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ASSESSMENT OF MONGOLIAN RANGELAND CONDITION AND TREND

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Executive Summary

Mongolian pastureland is comprised of ecological zones that differ by weather patterns, land cover, and topo-edaphic characteristics. In 1997, ecological monitoring study areas were selected in each of the four ecological zones dominated by rangeland. Study areas were located in Forest Steppe (Zavkhan aimag, Bulnai suom), Dry Steppe (Zavkhan aimag, Tsetsen-Uul suom), Desert (Gobi-Altai aimag, Erdene suom), and Grass Steppe (Tov aimag, Altanbulag suom). Pastureland units of study were customary grazing areas used by groups of herders in bag administrative units. For these units, short term decision-making by the livestock herder usually has precedence over external decision-makers because of the need to direct day-to-day events in producing livestock.

A total of 114 pastureland monitoring sites were established in the four study areas to monitor status and trend of rangeland ecological condition. These changes in condition are set against a backdrop of increasing global temperature, changing precipitation patterns, and changes in the type and number of grazing livestock.

This document provides information on changes in rangeland ecological condition that occurred in the four ecological zones during the 11-12 year interval between surveys. Changes in ground surface attributes, vegetation cover, standing crop, and plant species composition of forage were evaluated at the four Bagh study areas.

In the four zonal study areas, rangeland was more degraded in 2008-09 compared to 1997. The primary causes of rangeland degradation were increased number of livestock with dominance of herd structure by goats, and increasingly arid rangeland pastures. We observed that aridity or overgrazing alone can affect pastureland condition; but a combination of factors has potential to exacerbate the rate at which rangeland condition changes, and the severity of the disturbance. This was especially true of Desert and Dry Steppe rangelands along elevation gradients where vegetation types typical of more mesic zones occurred. The higher elevation rangeland types were more affected by drought and overgrazing than the same vegetation types in Forest and Grass Steppe zones. Higher elevation Mountain Steppe pastures in the Desert zone were more degraded than lower elevation vegetation types receiving less rainfall but similar grazing pressure.

This information is intended as reference material for assessing rangeland ecological condition as it is affected by changes in the national livestock herd and weather during the past decade. The trend toward degradation of rangeland will continue or increase unless herd numbers and structure achieves a better balance between livestock species and carrying capacity of rangelands. Water source development and other improvements will increase available grazing area and animal feed, thus reducing overgrazing in some situations. Developing the capacity of the herders

and government staff to effectively manage and monitor grazing animal use of rangeland will play a crucial role.

Key Words: Mongolian rangeland, monitoring, ecozone, trend, forage, and precipitation

1. Introduction

Mongolia is situated in Central Asia with area comprising 1.566 thousand square kilometers. The territory extends 1259 kilometers from north to south, and 2392 kilometers from east to west (Tsegmid and Vorobiev, 1990). The country is located between 87º41′ and 119º56′ of east longitude, and 41º35′ and 52º09′ of north latitude (Jigjidsuren and Johnson, 2003). The greater part of the territory is more than 1500 m above sea level. Mongolia is surrounded by the Eastern and Western Alpine Ranges; Great Sayan, Buteel, and Khentii Mountains in the north; Great Khyangan highlands in the east; Mongolian Altai and Gobi-Altai Ranges in the south-east and south; Khan-khokhii and Khangai Mountains in the west; and the Gobi-desert to the south of the country (Gunin et al., 1999). Mongolia is known for long, cold winters and dry, hot summers. It has low precipitation levels, high temperature fluctuations with over 250 sunny days a year on average. The annual average temperature of Mongolia is 0.7ºC.

1.1 Ecological Units

Mongolia as a country is defined by juxtaposition of major east-west oriented ecological zones (Figure 1). From north to south, the major ecological zones include: 1) forest, which in the northern border area of Mongolia is classified as Mixed Forest and Needle leaf Forest, with southward extensions of Sparse Forest in the Khangai Mountains, 2) a grass or pasture steppe zone that has largest area in the eastern plains but stretches in a nearly contiguous belt across Mongolia, 3) a dry steppe or desert steppe that includes significant areas of shrub steppe and forms a precipitation and productivity ecotone between grass steppe and desert, and 4) desert or Gobi which comprises approximately 40 % of Mongolia's land area (Figure 1).

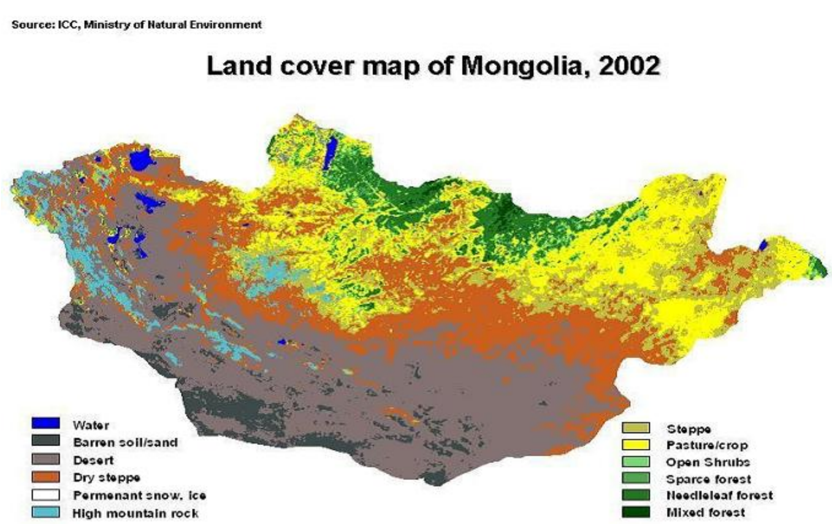


Figure 1. Map of Mongolian Ecological Zones.

1.2 Administrative Units

Mongolia is organized into administrative units that influence natural resource use in the different ecological zones (Figure 2). Provinces (aimags), county (suom), and districts (bag) are administratively defined units of land use, which often were established without consideration of the natural features of the landscape that influenced use. Although Mongolian pastoral herders are often referred to as "nomads" involved in "nomadic herding", and pastureland by constitutional mandate is "public" land administered by the state, most herders accept the concept of traditional rangeland use within bag, soum, and aimag administrative areas to which they have access and use rights. Although ingress and egress by herders from other areas is tolerated to a limited degree, ingress of substantial numbers of herders from other aimags or from other administrative units within the aimag can lead to grazing-related conflicts.

Figure 2. Location of soum Condition and Trend Monitoring Sites.

In this study, ecological monitoring study areas were selected in the four major ecological zones and within defined administrative units. The study areas were Erdene suom in Gobi-Altai aimag (Desert Zone), Tonsengel suom in Zavhan aimag (Forest Steppe Zone), Tsetsen-uul suom in Zavhan aimag (Dry or Desert Steppe Zone), and Altanbulag suom in Tov aimag (Grass Steppe Zone).

Study area *aimag*s were selected by representatives from Mongolian institutions involved in rangeland management and use. Specific suom and bag study areas were selected following discussion with local government leaders and livestock herders. Within each bag, sub-units comprised of seasonal pastures that were representative of zonal land cover and herder grazing strategies were selected for placement of monitoring sites.

1.3 Objectives

The Mongolian people have depended on livestock production for thousands of years and it remains a significant part of the country's economy. The use of rangeland by livestock has been mastered for generations, but the transition to capitalism and the market economy without adequate management and regulatory structures has caused unforeseen problems. Rangeland environments have also reportedly been impacted by climate change during the last 60 years, and climate change is predicted to continue (Batjargal, 1997). These changes together are the two most important factors impacting the condition of rangeland in Mongolia. In order to accurately gauge the impact of these changes on the Mongolian rangeland environment, it is necessary to verify environmental trends and impacts of livestock grazing. Revisiting past studies for comparative analysis will provide information useful for establishing current rangeland ecological condition and trends. This is especially important in the Desert Zone where significant changes are happening, and are likely to accelerate due to the development of major mineral resources. This will affect the densities of people in the area, people's lifestyles and livelihoods, and impact rangeland resources. The objective of this study is to document changes that have occurred on Mongolian rangelands in four Mongolian ecological zones.

2. Methods

2.1 Survey Areas

Administrative units in this study were three *aimag*s, four suom*s*, four *bag*s, and four resource areas (i.e., three *bag*s and one valley based *bag* sub-unit). User-defined units were seasonal pastures and vegetation types (Table 1). The number of these units is variable, depending on terrain, topography and associated vegetation and soils interacting with climate. The user-defined units link livestock herder groups/families with land, water and forage resources used for livestock production. These units also define the point at which markets, government decision-making, livestock production decisions by herder groups, and use of rangeland ecosystems intersect (Table 1). Information obtained in this study provides the basis for relating resource use and livestock management to rangeland ecological condition.

Selection of study area monitoring sites was based on juxtaposition and characteristics of plant communities. High livestock use of certain plant communities was linked to topo-edaphic characteristics (e.g., south aspects received heavy use during winter because of favorable temperature and exposure relationships prevailing at the site) while other plant communities received little livestock use for similar reasons (e.g.,understory of Larch communities on steep, northerly aspects received greater snow cover and had frozen soils making animal travel dangerous until soils thawed and firmed-up sufficiently to improve animal traction).

Survey areas were selected in each of the four major eco-zones of Mongolia (Gunin et al., 1999; Jigjidsuren and Johnson, 2003) in consultation with suom and bag governors and local herders. We also considered herders' mobility and camp locations on the resource area. We were able to cover all seasonal pastures including winter, transitional or spring/autumn, and summer. Initial rangeland survey results and monitoring site establishment techniques are available in the Asian Development Bank Final Project Report..

Table 1. Resource Characteristics of Study Areas

	I	II	III	IV
Aimag	Tov	Zavhan	Zavhan	Gobi-Altai
Case Study	Altanbulag	Bulnai	Tsetsen-uul	Tsegseg-nuur
Eco-Region	Grass Steppe	Forest Steppe	Dry Steppe	Desert
Vegetation Type	Mountain Steppe Mountain Rocky Steppe Grass Steppe Meadow River Valley	High Mountain Tundra High Mountain Meadow Mountain Meadow Steppe Mountain Steppe Mountain Rocky Steppe Mountain Dry Steppe Mountain Swampy Meadow Meadow Steppe Valley Steppe Sandy Steppe Dry Steppe Meadow River Valley	Mountain Tundra Mountain Meadow Steppe Mountain Steppe Mountain Rocky Steppe Meadow Steppe Valley Meadow Grass Steppe Sandy Steppe Alkali Meadow	High Mountain Meadow Mountain Rocky Steppe Mountain Steppe Mountain Desert Steppe Mountain Desert High Mountain Meadow Sandy Dry Steppe Valley Steppe Desert Steppe SandLand/Dune Steppe Desert Alkali Meadow Alkali Marsh Coulee Saxual
Yield (kg ha^{-1}) Winter/Spring Summer/Fall Average	 250 480 360	 240 490 350	 300 520 410	 160 200 190

2.2 Monitoring Sites

Monitoring sites in three study areas were located in clusters, with each cluster approximating a transect line across the watershed. In Erdene sum of Gobi-Altai, the desert valley winter pasture required more random placement of monitoring sites. Longitude and latitude coordinates of each monitoring site were recorded by GPS, which made it possible for investigators to relocate sites during the 2008/09 survey. Monitoring sites in each study area were:

- Fourteen Grass Steppe monitoring sites were established in the Second Bagh of Altanbulag suom, Tov aimag. Monitoring sites were selected in the Mountain Steppe and Typical Steppe vegetation types. Thirteen monitoring sites were re-measured during the 2008/09 survey.

- Thirty-three monitoring sites were established in the “Deed Khargan” pastureland area of Orgih bag in Tosontsengel suom of Zavkhan aimag. The seven vegetation types in which monitoring sites were randomly selected were Larch Forest, Shrub Meadow, Mountain Steppe, Shrub Steppe, Riparian Meadow, and Grass Steppe.

- Twenty-six monitoring sites were established in the Dry Steppe study area. In 2009, 24 monitoring sites in seven vegetation types were re-measured. The seven vegetation types in which monitoring sites were randomly selected were Desert Steppe, Mountain Steppe, Sand Land, Typical Steppe, Mountain Meadow, Riparian Meadow, and Larch Forest.

- Thirty-one Desert Zone monitoring sites were established in Tsetseg-nuur bagh of Erdene suom, Gobi-Altai aimag. Monitoring sites were randomly selected along a transect line in Desert Shrub, Saline Marsh, Shrub Steppe, Desert Steppe, Mountain Steppe, and Meadow vegetation types. In 2008, seven sites in Desert Shrub, and one site in Saline Marsh were re-measured on the winter range. Thirteen sites in Shrub Steppe, Desert Steppe, and Mountain Steppe were re-measured on the spring-fall transitional range. Six sites in Mountain Steppe and Meadow were re-measured on summer range.

2.3 Condition Survey

The cluster of monitoring sites in each zone was arranged along three replicated transects in a representative area zone. At each monitoring site, three sampling plots were oriented to cardinal directions from the center of the monitoring point (plot #1 was 15 meter-paces due North on the 0 degree axis, plot #2 was 15 meter-paces due Southeast on the 120 degree axis, and plot #3 was 15 meter-paces due Southwest on 240 degrees). The three plots were used to measure vegetation cover, plant presence, and productivity of herbaceous vegetation (i.e., graminoids which included grasses and sedges), forbs, and small half shrubs). Plot size was 0.5 m^2 in sparsely vegetated Desert and Dry Steppe vegetation types and 0.25 m^2 in Forest and Grass Steppe vegetation types.

Herbaceous plant cover (%) was determined by estimating basal cover of graminoid and forb species in the plot (VCOV). Non-vegetative cover in the plot was determined by estimating surface cover of bare ground (BARE), litter (LITT), rock and gravel (ROCK), and cryptogam (CRYP) in each plot

2.3.1 Standing Crop

Standing crop at the monitoring site was determined by harvesting vegetation within each plot. All clipped samples were separated by live and dead materials, with the latter discarded. Live material (standing crop) was further separated by growth form, oven dried at 60°C for 48 h, weighed, and expressed in kg ha^{-1}. Total standing crop at a monitoring site was determined by summing the aboveground biomass of all growth forms removed from each plot. Nomenclature of plant species and growth form of plants follows Ulziikhutag (1984) and Gubanov (1996).

2.3.2 Palatability

Plant palatability and selection of indicator species of disturbed rangelands follows was determined according to Damiran (2005). Field investigators were the same in both the 1997 and 2008/09 vegetation surveys; therefore, human bias was assumed to be only a minor source of variation in survey results.

2.3.3 Pasture productivity

Pasture productivity is a secondary measure of pasture condition because yield is influenced by a number of factors including plant growth form, plant palatability, timing and duration of grazing, annual precipitation, and stocking rate. Annual variability in precipitation and temperature are primary factors influencing short-term, annual pasture productivity. Intensity of animal grazing over time, combined with precipitation and temperature, have longer-term effect on rangeland productivity. We compared productivity (kg ha^{-1}) of seasonal pastures in the Desert and Forest Steppe zones.

2.3.4 Trend and Condition

Results of the above parameters and observation of ground surface characteristics were used to determine current ecological condition and trend of change at each monitoring site.. Condition classes were excellent, good, fair, poor, and very poor.

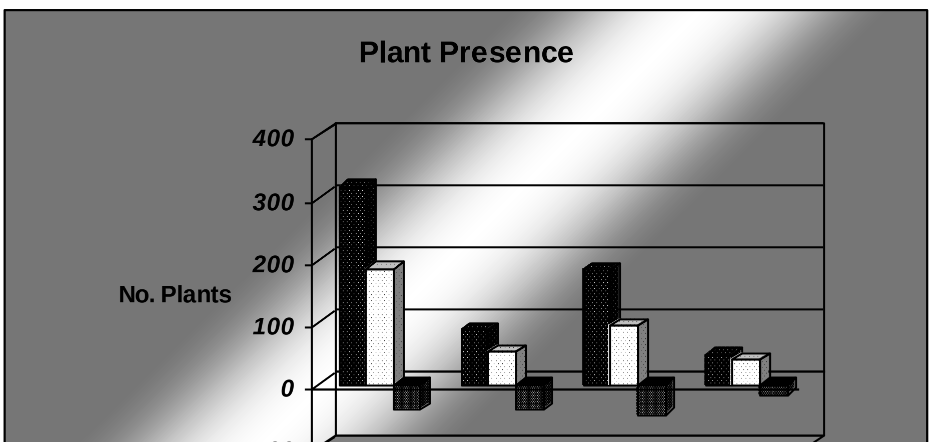
3. Results

3.1 Condition survey

3.1.1 Desert Zone

Change in Plant Presence. During the 1997 survey, we identified 112 plant species, of which 25 were graminoids (i.e., grass or grasslike plants), 72 were forbs, and 15 were shrubs (Figure 3). During our 2008 survey, only 76 plant species were identified. Of these, 17 were graminoids, 47 were forbs, and 15 were shrubs

More than 41 % (131) of the species encountered during the 1997 survey were not found in 2008 (Figure 3). There appeared to be a shift in plant growth-form composition towards the shrub (6.4 %) growth-form and a relative decline in graminoid (-7.7 %) and forb (-7.4 %) growth forms during the 11 year interval.



	Total	Grass	Forb	Shrub
1997	316	88	184	48
2008	185	52	94	40
% Change	-41	-41	-49	-17

Figure 3. Change in plant presence on the Desert study area between 1997 and 2008.

Vegetation Types. The Desert study area contained six distinct vegetation types (Table 2). Vegetation types in the winter range were Desert Shrub, which dominated the intermountain desert valley and had the highest number of monitoring sites, and Salt Marsh, which was an inclusion in the Desert Shrub vegetation type. Vegetation types in the spring-fall transitional range, which was a canyon connecting summer range and winter range, were Shrub Steppe, Desert Steppe, and Mountain Steppe. The Mountain Steppe vegetation type occurred at higher elevation of the canyon (T1) and on north aspects of the canyon at lower elevations (T2). Both Shrub Steppe and Desert Steppe vegetation types occurred along the canyon floor or on south aspects of the canyon at lower elevation. The Mountain Steppe vegetation type dominated the higher elevation summer range while the Riparian Meadow vegetation type had limited area along the major stream draining the summer range.

Table 2. Plant presence in Desert study area seasonal pastures and vegetation types.

Items	Total		Growth Form					
			Grass		Forb		Shrub	
Year	97	08	97	08	97	08	97	08
Winter (n=8)	**57**	**19**	**10**	**4**	**31**	**4**	**16**	**11**
Desert Shrub (*n*=7)	52	15	9	3	29	3	14	9
Salt Marsh (*n*=1)	5	4	1	1	2	1	2	2
% Change	*-67*		*-60*		*-87*		*-31*	
Transitional (n=13)	**148**	**100**	**45**	**32**	**82**	**38**	**21**	**19**
Shrub Steppe (*n*=3)	18	14	3	3	9	6	6	5
Desert Steppe (*n*=2)	21	16	9	5	11	8	1	3
Mountain Steppe (*n*=8)	109	70	33	24	62	24	14	11
% Change	*-32*		*-29*		*-54*		*-10*	
Summer (6)	**115**	**66**	**33**	**16**	**71**	**40**	**11**	**10**
Mountain Steppe (*n*=5)	96	54	27	11	59	33	10	10
Meadow (*n*=1)	19	12	6	5	12	7	1	0
% Change	*-43*		*-52*		*-44*		*-9*	

Eight monitoring sites in two vegetation types were re-measured on the winter pasture. During the 11-year interval between surveys, total plant presence declined 67 %, graminoid presence declined 60 %, forb presence declined 87 %, and shrub presence 32 %. In the dominant Desert Shrub vegetation type, total plant presence declined 71 %, graminoid presence declined 67 %, forb presence declined 89 %, and shrub presence declined 35 %. The Salt Marsh vegetation type had few species present when measured in 1997 or 2008. In this vegetation type, forb presence declined 50 %.

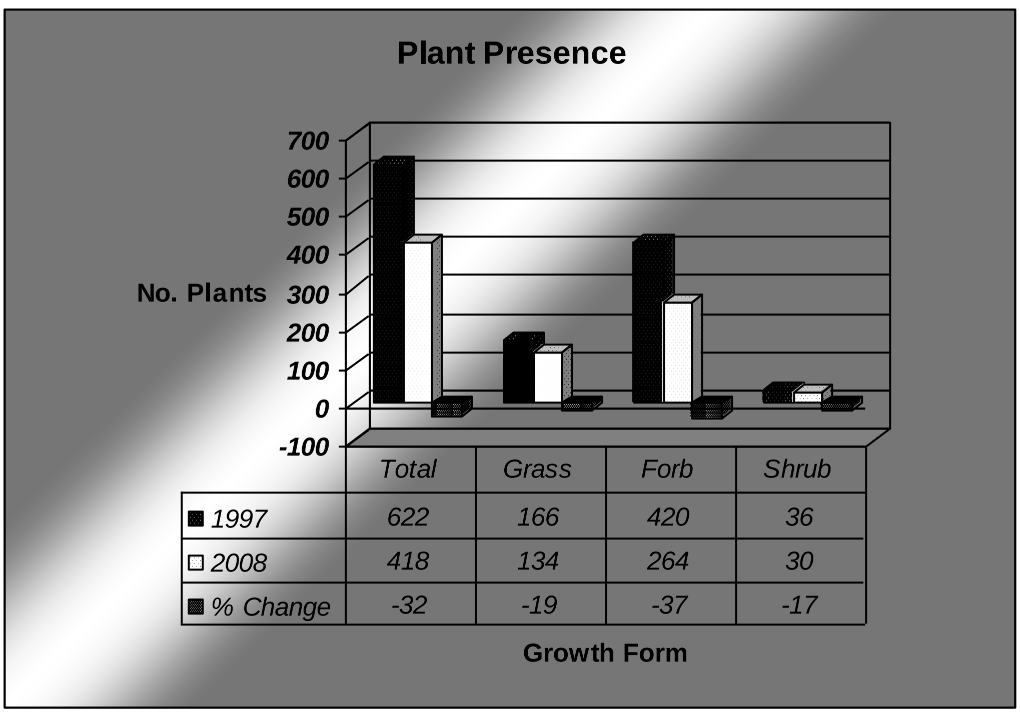
Thirteen monitoring sites in three vegetation types were re-measured on the spring-fall transitional pasture. During the 11-year interval between measurements, total plant, graminoid, forb and shrub presence all declined 32 %, 60 %, 54 %, and 10 % respectively. The higher elevation Mountain Steppe vegetation type had higher decline in plant presence than the lower elevation Shrub Steppe and Desert Steppe vegetation types. In this vegetation type, total plant presence declined 35 %, with highest decline among graminoid and forb growth-forms.

Six monitoring sites in two vegetation types were re-measured on the summer pasture. During the 11-year interval between measurements, total plant presence declined 43 %, graminoid presence declined 52 %, forb presence declined 44 %, and shrub presence declined 9 %. In the dominant Mountain Steppe vegetation type, total plant presence declined almost 44 %, with highest decline occurring among graminoid plant presence (59 %). In the Riparian Meadow vegetation type, total plant presence declined 36 % with highest decline in forb (-41.7 %) and shrub (-100 %) growth forms.

3.1.2 Forest-Steppe Zone

Change in Plant Presence. The seven vegetation types found in forest steppe had a high diversity of communities and plant species compared to the other zonal study areas. In the 1997 survey, we identified 157 plant species, of which 33 were graminoids, 115 were forbs, and nine were shrubs. In the 2008 survey, we identified only 101 plant species, of which 24 were graminoids, 72 were forbs and five were shrubs.

During the 11 year interval between measurements, total plant presence at all monitoring sites declined almost 33 %, graminoids 19 %, forbs 37 %, and shrubs 17 % (Figure 4). All growth-forms of plants declined on the Forest Steppe study area in the 11-year interval between measurements. Graminoid plants declined more than 18 %, forb plants more than 36 %, and shrub plants more than 16 %. There appeared to be a shift in plant growth-form composition towards graminoid (20.6 %) and shrub (24.5 %) growth-forms, and a decline in the forb (-6.5 %) growth-form.



	Total	Grass	Forb	Shrub
1997	622	166	420	36
2008	418	134	264	30
% Change	-32	-19	-37	-17

Figure 4. Change in plant presence on the Forest Steppe study area between 1997 and 2008.

Vegetation Types. The Forest Steppe study area contained seven distinct vegetation types (Table 3). Vegetation types in the higher elevation winter range included Larch Forest on north and west aspects, Shrub-Meadow associated with stream drainages, and Mountain Steppe on stream terraces and south and east aspects. The highest number of monitoring sites was located in Mountain Steppe, and Mountain Steppe was the predominant vegetation type in the three seasonal pastures. Mountain Steppe and Sedge Meadow vegetation types dominated the mid-elevation transitional pasture. Mountain steppe communities occurred on upland aspects and broad stream terraces while Sedge Meadows were associated with stream drainages. Summer pasture vegetation types included Shrub Steppe on east aspects of upland terrain, Mountain Steppe on north and west aspects of upland terrain, Grass Steppe on lower elevation terrain, and Meadow vegetation type associated on stream and river floodplains.

Table 3. Plant presence in Forest Steppe study area seasonal pastures and vegetation types.

Items	Total		Growth Form					
			Grass		Forb		Shrub	
Year	1997	2008	1997	2008	1997	2008	1997	2008
Winter (17)	**337**	**230**	**90**	**70**	**227**	**157**	**20**	**14**
Larch Forest (n=3)	40	30	11	13	23	16	5	1
Shrub-Meadow (n=6)	138	99	43	38	90	58	6	6
Mountain Steppe (n=8)	159	101	36	19	114	83	9	7
% Change		*-32*		*-22*		*-31*		*-30*
Transitional (8)	**156**	**97**	**37**	**31**	**111**	**57**	**8**	**8**
Mountain Steppe (n=7)	143	89	31	29	104	51	8	8
Sedge Meadow (n=1)	13	8	6	2	7	6	0	0
% Change		*-38*		*-16*		*-49*		*0*
Summer (8)	**129**	**91**	**39**	**33**	**82**	**50**	**8**	**8**
Shrub Steppe (n=3)	58	37	16	14	38	19	4	4
Stream Meadow (n=1)	20	16	5	7	14	8	1	1
Mountain Steppe (n=2)	36	22	12	7	22	13	2	2
Grass Steppe (n=2)	15	16	6	5	8	10	1	1
% Change		*-29*		*-15*		*-39*		*0*

Seventeen monitoring sites in three vegetation types were re-measured in the winter range. During the 11-year interval between measurements, total plant presence declined 32 %, graminoid presence declined 22 %, forb presence declined 31 %, and shrub presence declined 30 %. Among vegetation types, Mountain Steppe had the highest decline in total plant presence (-36.4 %) with graminoids having highest decline in plant presence. The Larch Forest vegetation type had highest decline in shrub presence (-80 %) while the Shrub Meadow vegetation type had highest decline in forb presence (-35 %).

Eight monitoring sites were re-measured on spring-fall transitional range. During the 11-year interval between measurements, total plant presence declined 38 %, graminoids declined 16 %, and forbs declined 49 %. There was no decline in shrub presence. In the Mountain Steppe vegetation type, total plant presence declined almost 38 % and forbs declined almost 51 % while in the Sedge Meadow vegetation type, graminoid plant presence declined almost 67 %.

Eight monitoring sites were re-measured on summer range. During the 11-year interval between measurements, total plant presence declined 29 %, graminoid presence declined 15 %, forb presence declined 39 %, and no change occurred in shrub presence. Among vegetation types, decline in total plant presence was high in both Shrub Steppe (-36 %) and Mountain Steppe (-39 %) vegetation types, and moderate in the Shrub Meadow (-20 %) vegetation type. Graminoid plant presence declined in all vegetation types except Shrub Meadow (+ 40 %) while forb plant presence declined in all vegetation types except Grass Steppe (+ 25 %). There was no change in shrub presence among the four vegetation types.

3.1.3 Grass Steppe Zone

There is little vegetation differentiation on the Grass Steppe study area but the Mountain Steppe vegetation type usually occurs on higher elevation ridges. Typical Steppe vegetation types in the study area are generally found in valleys between low elevation ridges and on south aspects of lower elevation ridges.

Change in Plant Presence. In the 1997 survey, we identified 88 plant species, of which 17 were graminoids, 65 were forbs, and 6 were shrubs. In the 2009 survey, we were able to identify only 41 plant species, of which 8 were graminoids, 30 were forbs and 3 were shrubs. More than 53 % of plant species identified in the initial survey were not found in 2009.

The most substantial change in the 11 year interval between measurements occurred in total plant presence which declined 37 % (Figure 5). There appeared to be a shift in plant growth-form composition on the study area towards graminoid (17.9 %) and shrub (60.0 %) growth-forms, and a decline in the forb growth-form (-18.2 %).

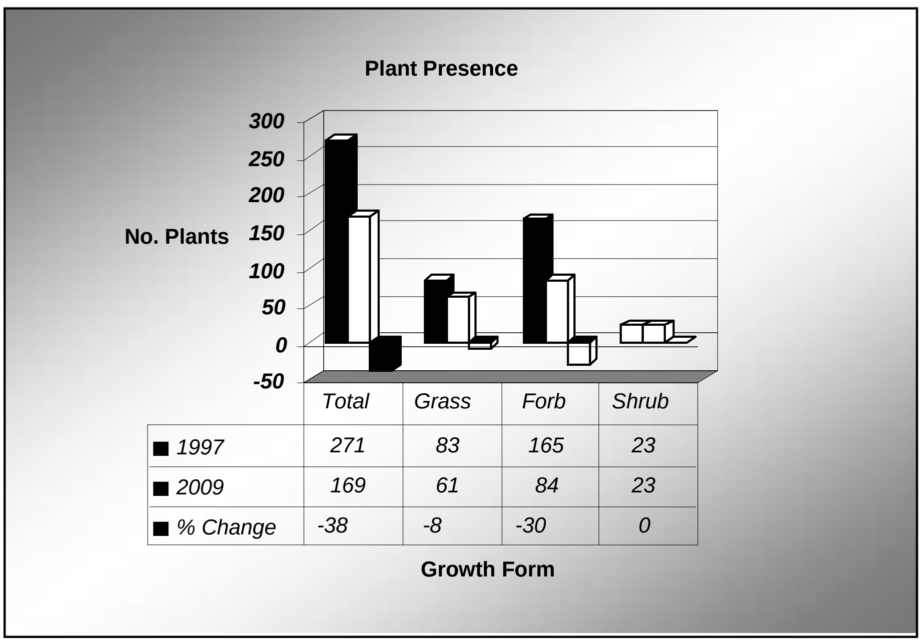


Figure 5. Change in plant presence on the Grass Steppe study area between 1997 and 2009.

Vegetation Types. The Grass Steppe study area contained two distinct vegetation types. Two monitoring sites in Mountain Steppe and five monitoring sites in Typical Steppe were re-measured on winter range. Two monitoring sites in Mountain Steppe and four monitoring sites in Typical Steppe were re-measured on summer range. Vegetation types in the Grass Steppe study area were similar on both winter and summer rangeland (Table 4). Both seasonal ranges were comprised of Mountain and Typical steppe vegetation types, and reflected the more-rolling topography found in the Grass Steppe ecozone. Nine of the 13 monitoring sites occurred in the

Typical Grass Steppe vegetation type which dominated valley-floor vegetation. The four monitoring sites occurring in the Mountain Steppe vegetation type occurred on north aspects of higher elevation ridges.

Table 4. Plant species presence by seasonal pasture and vegetation type in the second bagh of Altanbulag soum.

Items	Total		Growth Form					
			Grass		Forb		Shrub	
Year	1997	2008	1997	2008	1997	2008	1997	2008
Winter (7)	**44**	**39**	**14**	**11**	**26**	**23**	**4**	**5**
Mountain Steppe (n=2)	26	17	8	6	16	8	2	3
Typical Steppe (n=5)	18	22	6	5	10	15	2	2
% Change		*-11*		*-21*		*-11*		*25*
Summer (n=6)	**65**	**36**	**18**	**11**	**43**	**22**	**4**	**3**
Mountain Steppe (n=2)	25	16	5	5	18	9	2	2
Typical Steppe (n=3)	19	12	7	4	11	7	1	1
Typical Steppe (I) (n=1)	21	8	6	2	14	6	1	0
% Change		*-45*		*-39*		*-48*		*-25*

Seven monitoring sites were re-measured on winter range. During the 12-year interval between measurements, total plant presence declined 11 %, graminoid presence declined 21 %, forb presence declined 11 %, and shrub presence increased 25 %. Among vegetation types, total plant presence declined almost 35 % in the Mountain Steppe vegetation type but increased 33 % in the Typical Steppe vegetation type. In both vegetation types, highest change occurred in forb presence. Forb presence declined in Mountain Steppe (-50 %) and increased in Typical Steppe (+ 50 %).

Six monitoring sites were re-measured in the summer range. During the 12-year interval between measurements, total plant presence declined 45 %, graminoid presence declined 39 %, forb presence declined 48 %, and shrub presence declined 25 %. Among vegetation types, total plant presence had highest decline in the *Achnatherum splendens* inclusion in the Typical Steppe vegetation type. In the inclusion, total plant presence declined 61 % and all plant growth-forms declined more than 50 %. The Mountain Steppe vegetation type had no decline in graminoid presence but forb presence declined 50 %. Both graminoid and forb presence had high decline in the Typical Steppe vegetation type.

3.1.4 Dry Steppe Zone

Change in Plant Presence. In the 1997 survey, we identified 109 plant species, of which 26 were graminoids, 79 were forbs, and 4 were shrubs. In the 2009 survey, we identified only 96 plant species, of which 24 were graminoids, 67 were forbs and 5 were shrubs. Almost 12 % of the plant species found in 1997 were no longer found at monitoring sites in the 2009 survey.

The most substantial change in the 12 year interval between measurements occurred in total plant presence which declined by 21 %, and total forb presence which declined by 29 % (Figure 6). Graminoid presence declined 10 % while shrub presence increased 9 %. Changes in plant growth-form indicated a shift towards grass (4.7 %) and shrub (2.4 %) growth-forms on the Dry Steppe study area.

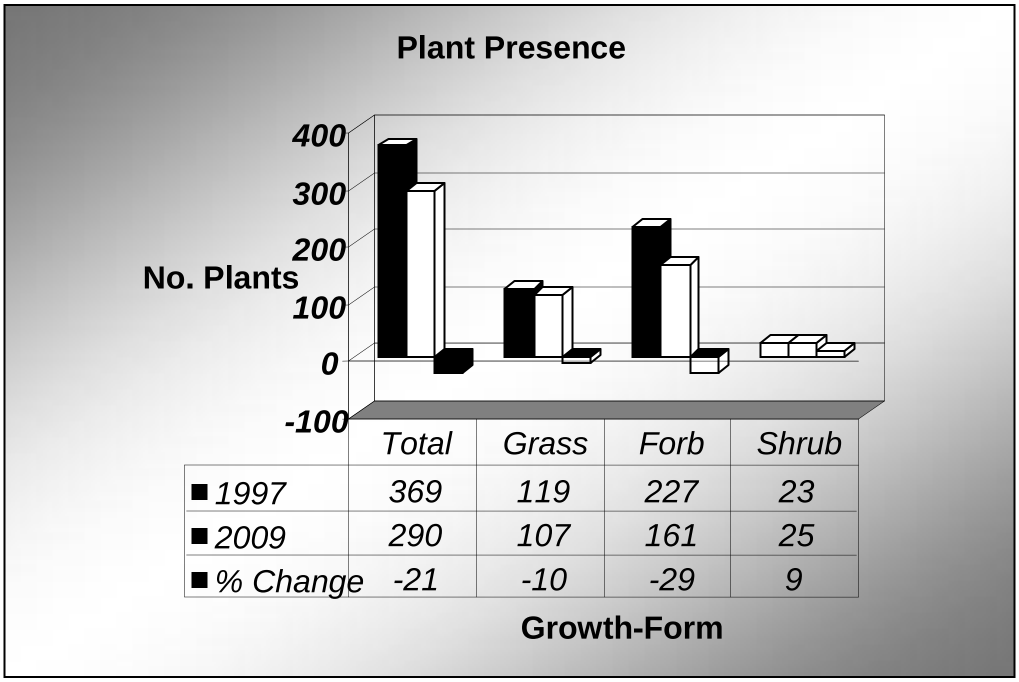


Figure 6. Change in plant presence on the Dry Steppe study area between 1997 and 2009.

Vegetation Types. Twenty-four monitoring sites were re-measured on the Dry Steppe study area. Nine winter range monitoring sites, which is a moderate elevation basin surrounded by dunes, were re-measured in Desert Steppe, Mountain Steppe, Sandland and Typical Steppe vegetation types. Six monitoring sites on spring-fall transitional range, which is located along a major stream, were re-measured in Mountain Steppe and Riparian Meadow vegetation types. On summer range, nine monitoring sites were re-measured in Mountain Steppe, Mountain Meadow, Sandland, and Larch Forest vegetation types. Slope and aspect were highly variable in the three seasonal range types.

Nine monitoring sites were re-measured on winter range. Total plant presence in the four vegetation types declined 20 %, graminoid presence declined 17 %, forb presence declined 23 %, and no change occurred in shrub presence. Among vegetation types, Desert Steppe and Mountain Steppe vegetation types had less total plant presence while Sandland and Typical Steppe vegetation types had increased total plant presence. Desert Steppe gained graminoids and shrubs presence but lost forb presence. Mountain Steppe lost presence of graminoids, forbs, and shrubs. Sandland lost graminoid presence, gained forb presence, and had no change in shrub presence. Typical Steppe gained graminoid presence and had no change in forb or shrub presence.

Six monitoring sites were re-measured on spring-fall transitional range. Total plant presence in the two vegetation types comprising transitional range declined 18 %, graminoid presence declined 17 %, forb presence declined 19 %, and shrub presence increased 17 %. Among the vegetation types, Mountain Steppe had less total plant presence while Riparian Meadow remained unchanged. Mountain Steppe had declining graminoid and forb presence but increased shrub presence. Riparian Meadow had no change in total plant presence, graminoid presence declined 28 %, forb presence increased 22 %, and shrub presence had no change.

Table 5. Plant presence in Dry Steppe seasonal pasture and vegetation types

Items	Total		Growth Form					
			Grass		Forb		Shrub	
Year	1997	2008	1997	2008	1997	2008	1997	2008
Winter (9)	**96**	**77**	**36**	**30**	**51**	**39**	**9**	**9**
Desert Steppe (n=4)	55	47	18	17	30	23	7	8
Mountain Steppe (n=1)	20	7	8	3	11	4	1	0
Sandland (n=2)	8	9	4	3	4	6	0	0
Typical Steppe (n=2)	13	14	6	7	6	6	1	1
% Change		*-20*		*-17*		*-23*		*0*
Transitional (6)	**121**	**99**	**36**	**30**	**79**	**64**	**6**	**7**
Mountain Steppe (n=4)	87	65	22	20	61	42	4	5
Riparian Meadow(n=4)	34	34	14	10	18	22	2	2
% Change		*-18*		*-17*		*-19*		*17*
Summer (9)	**152**	**114**	**47**	**47**	**97**	**58**	**8**	**9**
Mountain Steppe (n=5)	107	71	31	28	69	35	7	8
Mountain Meadow (n=1)	12	10	7	5	5	5	0	0
Sandland (n=2)	8	13	3	5	5	7	0	1
Larch Forest (n=1)	25	20	6	9	18	11	1	0
% Change		*-25*		*0*		*-40*		*13*

Nine monitoring sites were re-measured on summer range. Total plant presence in the four vegetation types comprising summer range declined 25 %, graminoid presence had no change, forb presence declined 40 %, and shrub presence increased 13 %. Among vegetation types, Mountain Steppe had declining plant presence in all categories except shrub, which had increased presence. Mountain Meadow had declining total and graminoid plant presence but no change in forb or shrub presence. Sandland had increased plant presence in all categories. Larch Forest had declining total plant presence, increased graminoid presence, and declining forb and shrub presence.

3.1.5 Change in Site Cover

Cover of five site attributes was re-measured in 2008 to assess longer-term trends occurring in the Desert Zone ranges (Table 6).

Desert. Bare ground, surface rock and gravel, and cryptogam cover increased on the Desert study area while vegetation litter and vegetation basal cover decreased. Among seasonal ranges, a negative trend in ecological condition of summer range was indicated by higher cover of bare ground and surface rock/gravel. Summer range in the Desert study area is located at higher elevation in the desert mountains; thus the limited availability of summer range in the Desert study area ensures high livestock grazing intensity. The increase in cover of bare ground and surface rock/gravel and the decrease in vegetation litter and cover was most apparent in the Mountain Steppe vegetation type.

The negative trend in site cover was least apparent on the lower elevation transitional range. The transitional range had less grazing pressure because livestock water sources were not available during the measurement interval. In this seasonal range, vegetation litter and basal cover had improved, especially on the lower elevation portion of transitional range dominated by Desert Steppe vegetation types. Winter range in the Desert study area has greater area than either summer or transitional range. Consequently, cover of site attributes had little change in the interval between measurements.

Table 6. Change in cover of study area site attributes

Zone	Year	% Cover of Site Attributes				
		BARE	LITT	ROCK	CRYP	VCOV
Desert	1997	28	10	33	1	28
	2008	27	4	45	1	23
	% Change	-4	-60	27	0	-18
Dry Steppe	1997	30	17	11	10	32
	2008	38	9	13	3	36
	% Change	27	-47	18	-70	-13
Forest Steppe	1997	18	11	17	9	45
	2008	26	6	24	8	36
	% Change	44	-45	41	-11	-20
Grass Steppe	1997	29	18	15	8	32
	2008	55	8	10	1	26
	% Change	90	-56	-33	-88	-19

Dry Steppe. Cover of bare ground and surface rock/gravel increased on Dry Steppe seasonal ranges while vegetation litter, cryptogams, and vegetation basal cover decreased. Among seasonal ranges, high bare ground and low basal cover of vegetation on spring-fall transitional range indicated degradation was occurring. The transitional range had high livestock grazing pressure in the interval between measurements, especially on the Mountain Steppe vegetation type which dominates transitional range. Summer range site attributes, especially bare ground caused by sand deflation, indicates that degradation is occurring as livestock grazing intensity increases on the remaining uncovered rangeland. Winter range appeared to have least change in site attributes indicating degradation is not a major factor.

Forest Steppe. Cover of bare ground and surface rock/gravel increased while cryptogams, vegetation litter and basal cover decreased on the Forest Steppe study area. Among seasonal ranges, a negative trend in ecological condition of spring-fall transition range was indicated by increased cover of bare ground and surface rock/gravel, and less cover of cryptogams, vegetation litter and basal cover. This was especially characteristic of the Mountain Steppe vegetation type which dominates spring-fall transition range. A negative trend in ecological condition of summer range was also apparent. Upland vegetation types had increased bare ground cover and reduced cover of vegetation litter and basal cover.

Grass Steppe. Cover of bare ground substantially increased while other site attributes decreased on the Grass Steppe study area. Although surface rock/gravel decreased on Grass Steppe monitoring sites, the high cover of bare ground indicated that valley monitoring sites were being covered by wind-blown sediments. Among seasonal ranges, changes in cover of site attributes indicated a negative trend in ecological condition of both summer and winter range. The negative trend was most apparent in the Typical Steppe vegetation type which dominates summer range, and in the Mountain Steppe vegetation type on winter range.

3.2 Change in Plant Composition

Composition of vegetation standing crop in different zones is variable. Although herbaceous graminoids and forbs comprise the majority of forage vegetation, shrubs, and occasionally trees, provide an additional forage component to standing crop. Mongolian livestock and large wild herbivores generally demonstrate preference for different plant species, although preference for the same or similar plant species may differ by season and vegetation zone (Table 7). A primary factor influencing animal selection of different plants is palatability of the plant to the animal. Highly palatable plants are preferred by animal grazers, less palatable plants are considered desirable by animals, and least palatable plants, even though considered forage, are undesirable to grazing animals.

Table 7. Livestock grazing impacts on study area plant composition.

Vegetation Zone	Interval	Forage Plant Preference		
		Preferred	Desirable	Undesirable
Desert	1997	63	93	97
	2008	37	57	34
	% Change	-41	-39	-34
Dry Steppe	1997	16	141	182
	2009	15	115	152
	% Change	-6	-18	-16
Forest Steppe	1997	78	293	403
	2008	45	166	189
	% Change	-42	-43	-53
Grass Steppe	1997	11	104	150
	2009	7	71	91
	% Change	-36	-38	-39

Desert. In 1997, 253 forage plants were identified in standing crop vegetation found at Desert Zone monitoring sites. By 2008, total forage plants identified were 128, which indicated a 50 % average decrease in forage plants on the study area. Among plants comprising forage standing crop, preferred plant species declined by 41 %, desirable plant species by 39 %, and undesirable plant species by 34 %. The substantial decline in all categories of forage plants, especially livestock preferred plants, indicated high grazing pressure by livestock.

Dry Steppe. In 1997, 339 forage plants were identified at Dry Steppe zone monitoring sites. By 2009, total forage plants identified were 282, which indicated a 16 % decrease in forage plants on the study area. Among plants comprising forage standing crop, preferred forage plants decreased 6 %, desirable forage plants decreased 18 %, and undesirable forage plants decreased 16 %. Although all preference categories of forage plants declined, the lower decrease in forage plants indicated that livestock grazing pressure, while high, had less impact in the Dry Steppe study area relative to animal selection of plants based on palatability.

Forest Steppe. In 1997, 774 forage plants were identified at Forest Steppe zone monitoring sites. In 2008, only 400 forage plants were identified, which indicated a 48 % decrease in forage plants on the study area. Among plants comprising forage standing crop, livestock preferred forage plants, desirable forage plants and undesirable forage plants decreased 42 %, 43 %, and53 % respectively. The high loss in forage plants of all preference categories indicates the high livestock grazing pressure on seasonal ranges, upland vegetation types, and specific plant communities receiving high use by sheep and goats.

Grass Steppe. In 1997, 265 forage plants were identified at Grass Steppe zone monitoring sites. In 2009, only 169 forage plants were identified, which indicated a 36 % decrease in forage plants on the study area. Among plants comprising forage standing crop, livestock preferred forage plants decreased 36 %, desirable forage plants decreased 38 %, and undesirable forage plants decreased 39 %. The high loss of all categories of forage plants indicated high livestock grazing pressure on the Grass Steppe study area. The Grass Steppe zone surrounding Ulaanbaatar has been impacted by livestock herds awaiting abattoir dates during the Negdel period and by the movement of herders and livestock into the peri-urban area during the transition period. In addition, the Grass Steppe zone naturally has lower plant species number, and when disturbed by high livestock grazing pressure, replaces forage plants with non-livestock used plants.

3.3 Change in Pasture Productivity

***Desert Zone*.** Total pasture productivity declined 78.8% on the Desert winter pasture (Table 8). Monitoring sites in the Shrub Steppe vegetation type, which dominated the winter pasture, had a productivity decline of 95.4% compared to 1997. However, productivity of three vegetation types in the transitional pasture had an average increase in productivity of 182.6 % while two vegetation types in the summer pasture had a 145.2% increase in average productivity in the 11 year period. Salt Marsh in winter pasture had the highest productivity in both 1997 and 2008 while Mountain Steppe in the summer pasture had the lowest productivity in 1997 but had an almost 60 % increase in production in 2008. Shrub Steppe in winter pasture experienced both the greatest decrease in productivity and the lowest rate of productivity in 2008.

Non-use by livestock of the transitional pasture, which limited livestock access to drinking water may account for improved study area productivity in 2008. On summer pastureland, improvement in productivity during the measurement interval period, while high, did not reflect the relatively low productivity at the monitored sites during measurement in either 1997 or 2008.

Forest Steppe Zone. Forage standing crop on Forest Steppe pastures averaged 544.6 kg ha^{-1} in 1997 and 443.1 kg ha^{-1}in 2008 (Table 9). The decline in forage productivity by 20 % may indicate only that heavy livestock grazing occurred in 2008. Winter pasture at higher elevations had highest productivity among seasonal pastures in both 1997 and 2008. Average productivity of the three vegetation types was 639.4 kg ha^{-1}in 1997 and 479.9 kg ha^{-1}in 2008. The winter pasture had highest decline in productivity over the 11 year interval. The transitional pastures had average yield of 550.0 kg ha^{-1}in 1997 and 413.0 kg ha^{-1}in 2008. The decline in forage productivity of transitional range vegetation types was similar to the decline in forage productivity of the winter pastures. The transitional Meadow vegetation type had highest decline in forage productivity (-57.8 %) among all vegetation types. Summer pasture vegetation types had relatively low productivity compared to vegetation types in winter and transitional pastures. However, average productivity in 2008 was higher (394.9 kg ha^{-1}) than in 1997 (337.8 kg ha^{-1}). Average productivity in 2008 was higher in three of the four vegetation types. Only the Meadow vegetation type had decreased yield in 2008 compared to yield in 1997 (390.7 kg ha^{-1}vs. 404.0 kg ha^{-1}, respectively).

Table 8. Productivity (kg ha^{-1}) changes of vegetation types in the Desert zone study area between 1997 and 2008.

Items	1997	2008	% change 1997 vs.2008
Winter	**645.7**	**136.8**	**-78.8**
Shrub Steppe (n=7)	514.0	23.7	-95.4
Salt Marsh (n=1)	1567.5	928.6	-40.8
Transitional	**145.2**	**265.1**	**+82.6**
Shrub Steppe (n=3)	186.7	438.4	+134.8
Desert Steppe (n=2)	343.0	368.0	+7.3
Mountain Steppe (n=8)	80.1	174.3	+117.6
Summer	**71.0**	**103.1**	**+45.2**
Mountain Steppe (n=5)	66.4	105.3	+58.6
Meadow (n=1)	94.0	92.0	-2.1

Table 9. Productivity (kg ha^{-1}) changes of vegetation types in the Forest Steppe study area between 1997 and 2008.

Productivity (kg ha^{-1})	*1997*	*2008*	*% change 1997 vs.2008*
Winter	**639.4**	**479.9**	**-24.9**
Larch Forest (3)	337.5	289.8	-11.4
Meadow (6)	842.7	645.8	-23.4
Mountain Steppe (8)	600.2	426.8	-28.9
Transitional	**550.0**	**413.0**	**-24.9**
Meadow (1)	487.0	205.3	-57.8
Mountain Steppe (7)	559.0	442.7	-20.8
Summer	**337.8**	**394.9**	**+16.9**
Grass Steppe (3)	313.7	365.3	+16.4
Meadow (1)	404.0	390.7	-3.3
Mountain. Steppe (2)	330.6	435.4	+31.7
Shrub Steppe (2)	345.0	400.7	+16.1

3.4. External Factors Affecting Ecological Condition

Livestock grazing intensity and weather conditions (temperature and precipitation) were evaluated at Desert and Forest Steppe zone study areas. Either of these factors alone can influence trend in ecological condition; grazing intensity (i.e., density, timing, and duration of livestock grazing) relative to forage production and animal preference. Increasing aridity (drought caused by higher temperature and lower precipitation) can interact to influence trend in ecological condition. In Mongolia, the major impact of climate devolves from weather, especially temperature and precipitation. Precipitation and temperature are the major factors affecting vegetation growth. Inadequate precipitation, given optimal temperature needed for growth, is the primary factor inducing drought.

3.4.1 Change in Livestock Numbers

Desert Zone. The trend in livestock numbers on the Desert zone study area during the 11-year interval between measurements was similar to Erdene suom and national livestock trends (Figure 7). Comparison of total livestock numbers indicated that suom livestock had increased from 100,122 animals in 1996(or 1997?) to 170,000 animals in 2008. Total livestock numbers on the study area trended upward each year except in 2002 when substantial numbers of livestock died during a drought followed by severe winter conditions. Composition of the study area herd also changed substantially during this period.

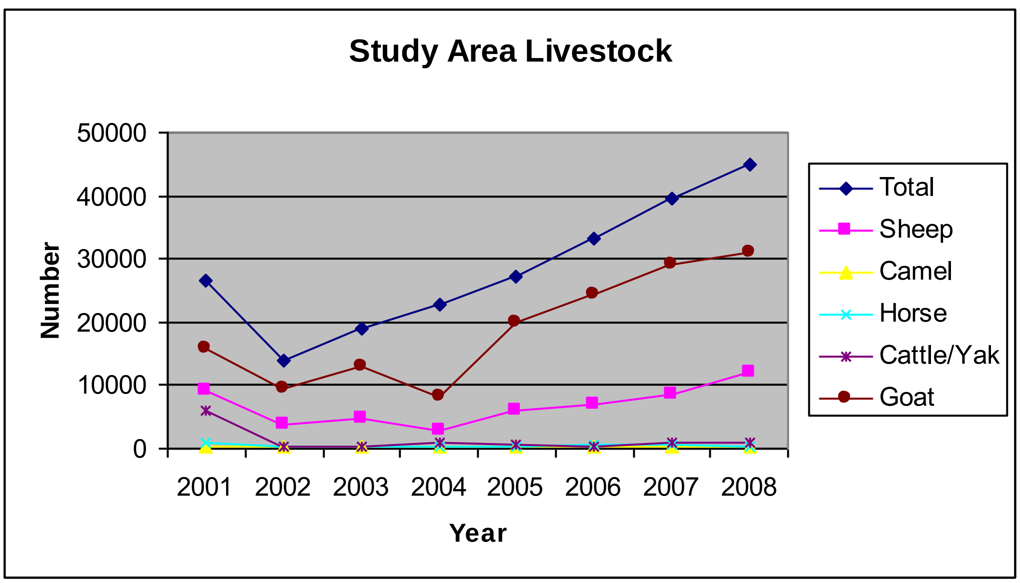


Figure 7. Change in livestock numbers and composition in the Desert study area.

Goat numbers had highest increase during the 11-year interval between measurements. Total goat numbers almost doubled between 2001 and 2008, and followed the national trend. Relative to Sheep Equivalent Units (SEU), animal numbers had decreased by 26.5 % between 2001 and 2008 (i.e., 1 camel=6 sheep, 1 horse = 6 sheep, 1 cow/yak = 5 sheep, and 1 goat = .8 sheep). However, the decrease in SEU's reflected a reduction in cattle/yak numbers and an increase in goat numbers.

Forest Steppe. Change in livestock numbers on the Forest Steppe study area in the 11-year interval between measurements approximated the national trend (Figure 8). Prior to the 2000/02 drought/dzud event, the trend in livestock numbers was higher for all livestock species except camel. Between 1997 and 1999, total livestock numbers increased from approximately 29,000 head to 34,000 head. During the severe drought/dzud of 2000/02, approximately 8500 head of livestock were lost from the suom herd. Suom livestock loses during the drought/dzud included 4000 sheep, 2000 goats, 900 horses, and 1700 cattle.

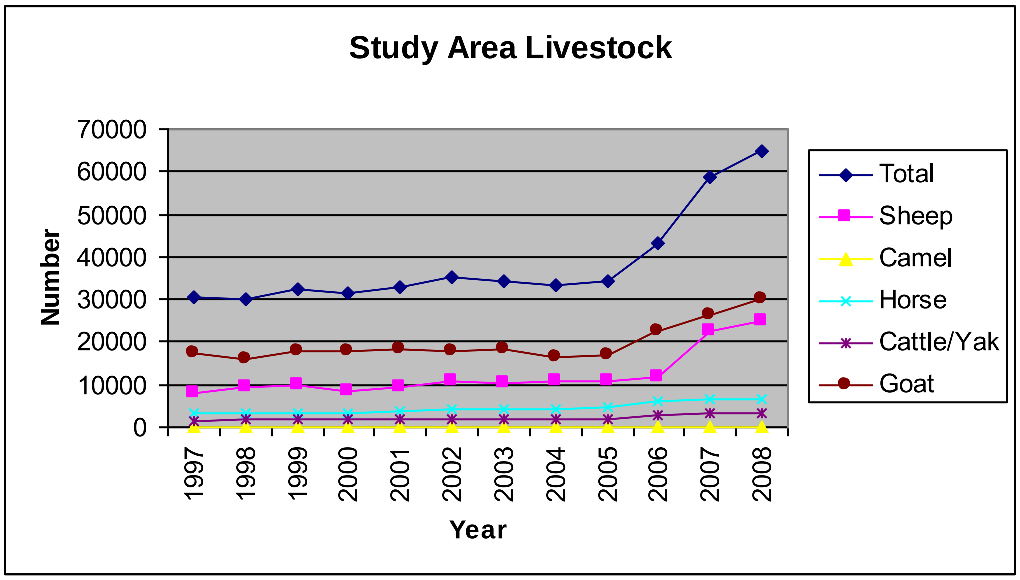


Figure 8. Change in livestock numbers and composition in the Forest Steppe study area.

Livestock in the Forest Steppe study area had little increase in numbers between 1997 and 2005. However, in 2006 all livestock numbers began increasing, especially goats and sheep. Goat numbers increased 18,000 head between 2005 and 2008, while sheep numbers increased 15, 000 head during the same time. In 2008, sheep and goats comprised 85 % of the study area herd, and had a sheep to goat ratio similar to the soum herd. Large stock comprised the remaining 15 % of the study area herd. Camels, which appeared to be relatively unaffected by the drought/dzud, continued to decline in relative numbers. The apparent trend towards herd domination by goats that existed in the national herd in 2008 was also occurring in the Forest Steppe study area.

3.4.2 Influence of Precipitation

The impact of climate change on study area vegetation was evaluated using precipitation as the primary indicator (Figure 9). Annual cumulative precipitation in three of the zonal study areas was erratic among years in the interval between measurements. However, cumulative precipitation had a similar pattern among study areas. The Desert study area consistently had lower precipitation compared to the other study areas but had more consistent cumulative precipitation among years. Since 2006, Desert zone cumulative precipitation has been around 60 mm which is substantially lower than the 125 to >200 mm received annually between 1997 and 2005. Annual cumulative precipitation on the Forest Steppe study area tended to decline between 1997 and 2000, increased substantially between 2000 and 2003, and declined to < 150 mm between 2003 and 2008. Cumulative precipitation in the Grass Steppe study area was erratic but trended downward in the interval between measurements.

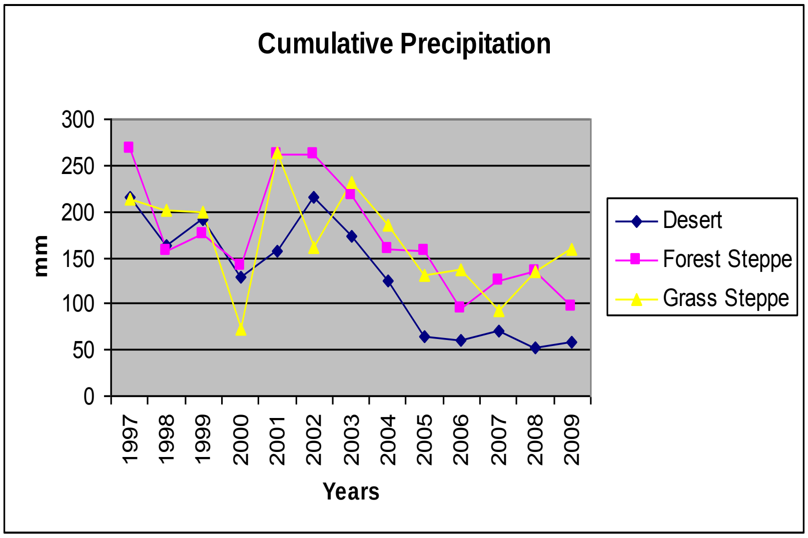


Figure 9. Cumulative precipitation occurring on three study areas between 1997 and 2008/09.

3.4.3 Forage Growth

The impact of precipitation on zonal forage growth is obvious (Figure 10). The Desert zone study area had decreasing annual forage growth between 1997 and 2004. Since 2004, annual forage growth had decreased to <100 kg ha^{-1} growing annually between 2006 and 2008. Forest Steppe annual forage growth was higher than Desert forage growth but followed the same general trend between 1997 and 2009. Grass Steppe had highest annual forage growth among the three study areas but forage growth was erratic on the study area. Forage growth on the three study areas had a general negative trend throughout the interval between measurements.

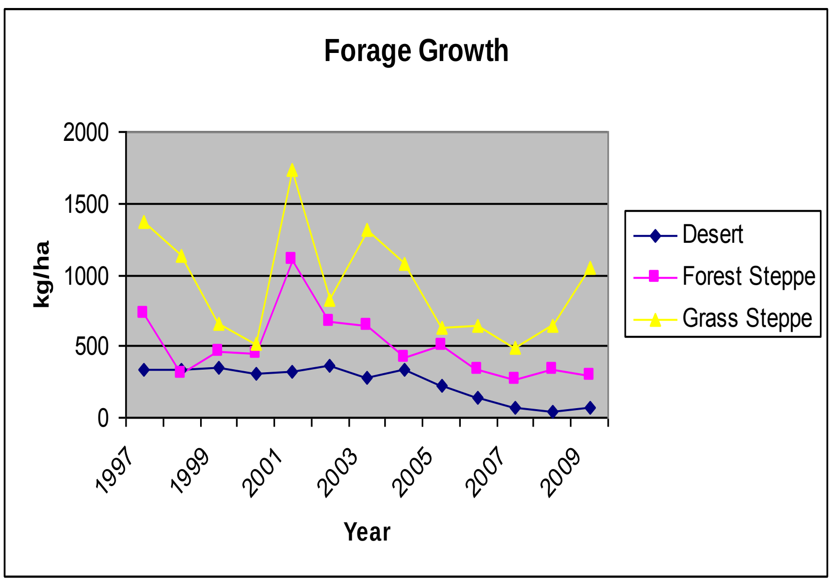


Figure 10. Annual forage growth on three zonal study areas between 1997 and 2009.

4. DISCUSSION

We surveyed rangeland Condition and Trend monitoring sites that had been established during an earlier study in 1997. Monitoring sites had been established in four ecological zones to determine changes in a number of site factors. Specific site factors re-measured included plant species, plant presence by growth form, cover of site attributes, palatability rating of plant species at the site, productivity of the site, livestock numbers, and weather factors influencing plant growth. Since rangeland comprises about three quarters of the land area in Mongolia, we felt that it was extremely important to know how the current changes in land use and climate in Mongolia are affecting these areas. Even more importantly these results may help provide information to local livestock herders to help them adapt to the many changes occurring in Mongolia.

Our results indicated that rangeland ecological condition had trended lower in the interval between measurements. In general, rangeland condition had decreased and trend at the four zonal study areas was negative. Since all four zonal rangelands indicated a negative trend in ecological condition, it is probable that rangelands across the zone are degrading if similar change factors are present in other areas. Information obtained from the four eco-zone study areas indicated:

- The total number of plant species comprising standing crop forage on study areas had declined;
- The presence of plants at monitoring sites had declined in the interval between measurements. Graminoid and forb plant growth forms had highest loss of presence on summer and transitional pastures.
- Ground surface cover of bare soil and rock increased while basal vegetation, cryptogams, and plant litter cover decreased.
- Livestock preferred and desirable plant species had loss of presence on seasonal ranges of the four study areas
- Seasonal ranges were less productive when re-measured compared to initial measurements in 1997, except on seasonal ranges that had less livestock grazing pressure during the interval between measurements.
- Numbers of livestock grazing the four study areas increased, and composition of livestock changed with large stock, especially cattle, being replaced by goats.
- Annual cumulative precipitation on the four zonal study areas was erratic, and declining.
- The forage component of standing crop vegetation was declining on the four study areas.

4.1 Rangeland Condition

In the Desert zone, ecological condition of winter and summer pastures had deteriorated or did not improve in the interval between measurements if heavily grazed by livestock (Table 10). On winter seasonal range, rangeland communities in the Shrub Steppe vegetation type had deteriorated from good ecological condition to poor ecological condition while the Salt Marsh vegetation type remained in poor ecological condition. The Mountain Steppe vegetation type on transitional range had deteriorated from good to poor ecological condition. However, Shrub and Desert Steppe vegetation types in transitional range had improved from fair to good ecological condition. On summer seasonal rangeland, the Mountain Steppe vegetation type had deteriorated from good to poor ecological condition while the Meadow vegetation type had deteriorated from poor to very poor ecological condition. Our conclusion is that Mountain Steppe and Desert Shrub vegetation types were most affected by change during the interval between measurements.

Table 10. Changes in Desert Zone site ecological condition

Year	*1997*	*2008*
Winter	**Good**	**Poor**
Shrub Steppe (7)	Good	Poor
Salt Marsh (1)	Poor	Poor
Transitional	**Fair**	**Fair**
Shrub Steppe (3)	Fair	Good
Desert Steppe (2)	Fair	Good
Mountain Steppe (8)	Fair	Poor
Summer	**Good**	**Poor**
Mountain Steppe (5)	Good	Poor
Meadow (1)	Poor	V.Poor

Overgrazing by livestock, along with increased aridity and higher goat numbers, are most likely the primary factors affecting ecological change in the Desert zone. The lower, canyon portion of the transitional pasture lacks water sources for livestock and human consumption; consequently it received less grazing use by livestock in the interval between monitoring surveys. Lack of livestock access to spring-fall transitional pastures, especially with the build-up in total livestock numbers and the change in herd structure to dominance by goats, has substantially increased grazing pressure on winter and summer pastures. Condition of lower elevation canyon transitional pastures improved primarily because of less livestock grazing pressure.

The overall ecological condition of Forest Steppe Zone pastureland shifted from fair to poor in the 11 year interval between surveys (Table 11). While winter pastures remained in fair ecological condition or have improved, transitional pastures shifted from poor to very poor ecological condition, and summer pastures shifted from fair to poor ecological condition.

Table 11. Changes in Forest Steppe Zone ecological condition between 1997 and 2008.

Year	*1997*	*2008*
Winter (n=17)	**Fair**	**Fair**
Larch Forest (3)	Fair	Fair
Shrub Meadow (6)	Fair	Good
Mountain Steppe (8)	Fair	Fair
Transitional (n=8)	**Poor**	**Very Poor**
Mountain Steppe (7)	Fair	Poor
Meadow (1)	Poor	Very Poor
Summer (n=8)	**Fair**	**Poor**
Shrub Steppe (2)	Good	Poor
Stream Meadow (1)	Fair	Very Poor
Mountain Steppe (2)	Fair	Very Poor
Grass Steppe (3)	Fair	Fair

We concluded that winter pastures were subjected to less grazing pressure than transitional or summer pastures because of time of use by livestock. Normal grazing-induced plant stress is less severe on Forest Steppe winter pastures because plant species comprising forage were in senescence at that time, covered with snow or ice, or were not selectively grazed. During the winter, livestock readily consume most available biomass, including plant material that would be toxic during other seasons. Mountain Steppe plant communities have highest livestock grazing use during the winter because of their location relative to aspect and elevation. Conversely, spring grazing use of transitional pastures occurs when many forest steppe plant species are most susceptible to grazing induced stress. Sheep and goat capacity to select specific plant parts places considerable stress on preferred and desirable plants during this vulnerable time.

On Dry Steppe rangeland, we concluded that little change in rangeland ecological condition occurred on winter range (Table 12); however, transitional and summer range had lower condition compared to condition during the initial survey. All vegetation types except Larch Forest had lower condition.

Table 12. Changes in Dry Steppe Zone ecological condition between 1997 and 2009.

Year	*1997*	*2008*
Winter (9)	**Good**	**Good**
Desert Steppe (n=4)	Good	Good
Mountain Steppe (n=1)	Good	Good
Sandland (n=2)	Good	Good
Typical Steppe (n=2)	Good	Good
Transitional (6)	**Fair**	**Poor**
Mountain Steppe (n=4)	Fair	Poor
Riparian Meadow(n=4)	Fair	Poor
Summer (9)	**Fair**	**Poor**
Mountain Steppe (n=5)	Poor	Poor
Mountain Meadow (n=1)	Good	Poor
Sandland (n=2)	Fair	Poor
Larch Forest (n=1)	Good	Good

We observed that overgrazing and increasing aridity affected trend on transitional and summer range, but that a negative impact on condition was accelerated by deflation of wind-blown sand that was occurring throughout much of Zavkhan aimag. Stream drainages in which summer range were located are natural wind-funnels for wind-driven sand. Major sand deposits in these river valleys decrease area of summer range, and decrease productivity of remaining critical summer range.

On Grass Steppe rangeland, we concluded that ecological condition of both winter and summer seasonal ranges has declined. All vegetation types found on both ranges had declining condition. In this ecozone overgrazing by livestock seems to be the major factor causing declining pasture condition.

Grass Steppe rangeland around Ulaanbaatar has been overgrazed for several generations; first by collective herds from throughout Mongolia awaiting slaughter dates at the abattoir, and secondly by the general movement of rural people and livestock to Ulaanbaatar since the 1990s. Overgrazing and increasing aridity have caused loss of preferred and desirable plants, and has facilitated their replacement with unpalatable or noxious "increaser" plants such as *Atremisia adamsii*.

Table 12. Changes in Grass Steppe Zone ecological condition

Year	*1997*	*2008*
Winter (7)	**Fair**	**Poor**
Mountain Steppe (n=2)	Fair	Poor
Typical Steppe (n=5)	Fair	Poor
Summer (6)	**Good**	**Poor**
Mountain Steppe (n=2)	Good	Poor
Typical Steppe (n=3)	Fair	Poor
Typical Steppe (I) (n=1)	Good	Fair

4.2 Trend Changes

The general trend of rangeland ecological condition in the four zonal study areas was negative (Table 13). The major drivers of the downward trend were overgrazing, especially by goats which had increased substantially during the interim period between surveys. Declining annual precipitation was causing increased aridity throughout Mongolia, but especially in the Desert and Dry Steppe Zones. While overgrazing is the main driver of change in Forest Steppe and Grass Steppe zone, increasing aridity combined with overgrazing will accelerate ecological degradation in more xeric vegetation types. In Desert and Dry Steppe, lack of optimal precipitation is the main driver of change. However, overgrazing can negatively impact more mesic vegetation types in Desert and Dry Steppe rangelands such as Mountain Steppe vegetation type occurring at higher elevations.

Table 13. Trend in rangeland condition in four zonal study areas.

Ecozone	Year	Good	Fair	Poor	V. Poor
Desert	1997	12	13	2	0
	2008	5	0	21	1
	% Change	-58.3	0	950	-100
Forest Steppe	1997	14	15	5	0
	2008	5	10	12	6
	% Change	-64.2	-33.3	140	600
Dry Steppe	1997	11	10	5	0
	2008	10	0	16	0
	% Change	-9.0	-100	180	0
Grass Steppe	1997	3	10	0	0
	2008	0	1	12	0
	% Change	-100	-90.0	1200	0

Based on our assessment of trend, we concluded that zonal rangelands have degraded during the interval between measurements. Desert and Grass Steppe rangelands appeared to be most degraded, followed by Forest Steppe rangeland and Dry Steppe rangeland. Degradation of rangeland was most apparent on upland vegetation types, especially Mountain Steppe, and lowland Meadow vegetation types. Both vegetation types were subjected to heavy grazing pressure by livestock and have plant growth characteristics that make them susceptible to grazing induced degradation.

Mountain Steppe vegetation offered highly palatable plants for both small and large livestock grazers. Topo-edaphic locations also facilitated livestock grazing during all seasons of the year. Livestock preferred grasses in Mountain Steppe tended towards plants with caespitose growth-habit which caused the plant to be less resistant to grazing. The Meadow vegetation types had high livestock grazing pressure during more temperate parts of each annual cycle. Meadows were preferred grazing areas by all livestock during the summer and early fall because of the high nutrition available from grasses and sedges that comprise meadow vegetation. Most meadow forage plants can withstand moderate to heavy grazing pressure, but continuous heavy grazing pressure without rest will negatively affect ecological condition of meadows.

4.3 Change Factors

In our opinion, there were two primary change factors causing rangeland degradation in the four zonal study areas 1997 and 2008. One factor was the increase in total livestock numbers and dominance of herd structure by goats. Discussions with livestock herders and local government officials indicated that study areas were severely affected by the 2001/02 drought/dzud in part because of overstocking and overgrazing of key vegetation types. In addition to the direct impacts of drought and dzud, increasing aridity is affecting rangeland condition and productivity. Impacts include: i) insufficient precipitation or precipitation at inappropriate times, ii) lack of adequate precipitation causing streams, lakes and springs to dry-up, and iii) annual productivity of vegetation was declining. There has been a gradual but persistent increase in aridity from insufficient precipitation during the 11 year interval between measurements.

The primary impact of climate change relative to pastureland degradation in both the Desert and Forest Steppe study areas was increasing aridity. Angerer et al. (2008) reviewed potential impacts of climate change on Mongolian pastureland. They suggest:

- Movement of current ecological zones northward due to higher temperatures and increased aridity with mountain taiga and forest steppe replaced by steppe vegetation and steppe; desert steppe and desert increasing in size and shifting northward,
- A reduction of Net Primary Productivity (NPP) by 5-30% in forest steppe and steppe zones and 25-75% higher NPP in high mountain and desert steppe zones due to higher mountain temperatures and higher desert precipitation;
- Water deficiencies in areas with temperature increase and precipitation decrease but better water use efficiency in areas of both temperature and precipitation increase;
- Reduced soil cover as aridity increases could exacerbate an already serious soil loss problem;
- Increased soil disturbance and reduced ground cover could increase the invasion of non-native species;
- Increased drought frequency and intensity coupled with increased human and animal population will increase pastureland degradation.

Our data collected from the four zonal study areas supports Angerer et al. (2008). We found there was: i) a reduction in NPP, ii) water deficiencies in the Desert Zone, iii) reduced ground cover and expansion of native increaser plants such as fringed sagebrush (*Artemisia frigida*), and iv) less resiliency of pastureland to withstand drought (Annex 2). Although our data does not specifically verify that the drought/dzud of 2001/02 accelerated pastureland degradation, we think the severity of the drought/dzud, combined with increasing aridity and overgrazing, was sufficient to suppress the natural resilience of pastureland vegetation communities and induce accelerated degradation.

The interaction between forage growth and precipitation and temperature is most obvious during droughts and dzud. Spring is almost always a cold drought characterized by low moisture, cold drying winds, and little forage growth. Depending on location, forage growth generally begins in late spring as ambient air temperature increases and precipitation events occur. Forage growth is usually initiated during late spring and summer with maximum forage growth completed by late summer throughout Mongolia. However, the amount of annual forage growth is dependent on amount and timing of precipitation during the growing season. Insufficient precipitation causes drought and reduces livestock access to forage and nutrients necessary to sustain livestock during the next winter and spring. Severe summer droughts followed by a severe winter often cause high winter and spring livestock mortalities, and affect ecological condition of Mongolian rangeland.

5. Conclusions

Our conclusions regarding current ecological condition of rangeland in the four zonal study area are:

1. Ecological condition as determined by comparing vegetation and physical attributes had changed in the 11 year interval between measurements. Although weather patterns, vegetation, and topo-edaphic characteristics are different in each zone, the trend in ecological condition was similar. In general, ecological condition during the 11 year interval between measurements had shifted from fair to poor condition (Annex 2).

2. One factor causing the decline in ecological condition was livestock grazing. Total livestock numbers in the four zones increased between 1997 and 2008 but total livestock Sheep Equivalent Units (SEU) decreased. In all zones, goats followed the national trend towards domination of herd structure. Our conclusion is that goats, because of their dietary plasticity and capacity to access preferred and desirable plant species, were a dominant factor causing rangeland degradation.

3. Climate change has affected pastureland resiliency, and has contributed to rangeland degradation. The severe drought/dzud that occurred between 2000/02, combined with the higher goat stocking rate, created conditions causing accelerated loss of ecological condition and rangeland degradation in the four zones (Annex 3).

4. It is important to consider both administrative units and natural ecological units in monitoring ecological condition of rangeland (Asian Development Bank 1997). Generally, decisions about land use at the national, *aimag*, *sum*, and *bag*, can be considered a function of government decision-making over long-term planning and management horizons. Conversely, seasonal pastures and vegetation types reflect natural attributes of the landscape that directly affect use by livestock. For these units, short term decision-making by the livestock herder usually has precedence over external decision-makers because of the need to direct day-to-day events in producing livestock. At this level, both the herder and the livestock make decisions about use. The herder can direct livestock towards vegetation by actually herding them to specific plant communities (e.g., otar) or by restricting livestock access to a certain season (e.g., winter season grazing), but the livestock will actually decide the level of use that occurs in these units. Livestock grazing strategies should be a function of plant community species composition,

animal preference and selectivity, and short-term external influences (i.e., snow depth, wind direction, aspect and temperature, etc). Future efforts to reverse or stabilize rangeland condition should be implemented as a cooperative program involving both users and administrators.

5. A primary predisposing factor to rangeland degradation was the buildup in goat numbers and the decline in cattle/yak numbers as a percentage of the study area herd. Goats have the capacity to more efficiently utilize different plant growth forms and have higher dietary plasticity. Our conclusion is supported by the decline in preferred, desirable and undesirable plant species throughout rangeland even though bagh livestock numbers on a Sheep Equivalent Unit (SEU) basis have substantially declined despite the increase in total livestock numbers. A continued shift of the herd to goats and an increasing total number of livestock, along with increasing aridity, will continue to predispose rangeland and the livestock herd to a more severe crash when the next drought/dzud occurs.

6. Increasing aridity as a result of climate change will affect annual species more severely than perennial species. Most grass and shrub species are deep-rooted perennials. Although many of the forb species are also perennial species, a much higher proportion of forbs are annuals or bi-annuals. During periods of stress such as drought, annual forbs may be impacted more than grasses or shrubs because of moisture requirements for seed germination and the lack of deep root systems needed to access moisture in the soil profile. The decline in presence of grass and shrub species indicates long-term insufficient moisture and/or other stresses such as over-grazing.

7. Although total yield of rangeland vegetation is an indicator of forage resources, it does not indicate the food value of particular ranges to different animal users. Growth-form, individual plant species, plant palatability, and availability of nutrients are more important in determining the value of plants as food to different animal users (Damiran, 2005). The number of palatable forage species in a particular pasture should be regarded as an indicator of ecological condition. Therefore palatability of plants should be taken into account in monitoring forage resources. More palatable plants are assumed to be more consumable by an animal while less palatable plants are assumed to be less consumable by a grazing animal. .

In summary, rangeland in all zonal study areas has become increasingly degraded and, unless changes in management relative to herd structure and stocking rate are implemented, we think the rate at which rangeland degrades will accelerate. The trend toward degradation of rangeland will continue unless herd structure achieves a better balance between livestock species. Partial solutions exist such as i) change herd structure back to a more balanced herd structure with reduced goat numbers, ii) develop additional water sources so that livestock can optimally utilize and access available resources, iii) improve capacity of government staff at the suom to manage rangelands through application of pasture improvement and livestock grazing management strategies.

ANNEXES

Annex 1. Regional Differences Affecting Mongolian Livestock Production.

Eco-Region	Environmental Factors	Livestock Production Risk Factors	Livestock Suitability	Livestock Production Strengths	Suggestions to Improve Regional Livestock Production and Mitigate Risk
1.Hangai-Hovsgol.Region (Aimags of Arhangai, Hovsgol, Bulgan and Zavhan). Mountainous region of high elevation and deep valleys with some forest and arid steppe;	i) elevation between 2000 and 3000 m; ii) mean annual temperature between -2.5°C and 7.5°C with low temperature in January of -24°C and high temperature in July of 19°C ; iii) between 60 and 100 frost-free days; annual precipitation between 200 and >400 mm; iv) average wind speed between 2-4 m/sec; v) snow cover often > 15 mm in depth.	i) winter cold and deep snow limit animal access to forage and nutrients and reduce efficient use of available nutrients. ii) lack of access to water during cold periods can be major factor limiting animal production iii) equilibrium ecosystem function whereby over stocking of livestock can change species composition and induce soil, vegetation, and water degradation	i) Native yak, native cattle, sheep and reindeer, ii) hybridization with English breeds if winter and spring supplemental nutrients provided.	i) forage production on natural rangelands during summer and fall is high, ii) harvesting forage with grazing animals during summer and fall is optimal, iii) hay, fodder and grain production potential are relatively high.	i) Increase animal access to nutrients during winter and spring by growing hay and fodder crops on abandoned or marginal cereal grain land. ii) Reduce animal stocking rate by shifting marginal livestock producers to alternative forms of livelihood including producing hay, fodder, and supplements for sale locally or to other nutrient deficient regions. iii) Change pastoral livestock production system from yearlong forage dependence to greater dependency on nutrient input during the winter and spring seasons. iv) Regulate animal numbers according to seasonal access to nutrients v) Limit goat and camel numbers in the livestock herd. vi) Improve herd genetics to meet developing market demand for quality meat by crossing native cattle with English breeds. vii) Improve livestock producer access to animal production inputs and competitive markets for offtake..

Eco-Region	Environmental Factors	Livestock Production Risk Factors	Livestock Suitability	Livestock Production Strengths	Suggestions to Improve Regional Livestock Production and Mitigate Risk
2. Selenge-Onon Region (Aimags of Tov, Selenge and Bulgan). The region is a basin with drainage to the north.	i) elevation between 1500 and 2000 m; ii) mean annual temperature between 0.0°C and 2.5°C with coldest temperature in January (-20°C) and warmest temperature in July (19°C) ; iii) between 70 and 120 frost free days, iv) annual precipitation between 250 and 400 mm; v) Snow cover averages 5 to 10 mm in depth; vi) wind speed averages between 4 to 6 m/sec.	i) winter cold and deep snow can limit animal access to forage and nutrients and reduce efficient use of available nutrients. ii) lack of access to water during cold periods can be a major factor limiting animal production; iii) equilibrium ecosystem function whereby over stocking of livestock can change species composition and induce soil, vegetation, and water degradation	Native or hybrid cattle and sheep.	i) principle agricultural cropping area for Mongolia; ii) rainfed & irrigated cultivation of cereal grains (wheat, barley, rye, oats) and hay is possible and creates opportunities to produce livestock feed grains and silage; iii) forage production on natural rangelands during summer and fall is high, iv) harvesting forage with grazing animals during summer and fall is optimal for rangeland use.	i) Increase animal access to nutrients during winter and spring by growing hay and fodder crops on abandoned or marginal cereal grain land and improved hayland[1/] ii) Reduce animal stocking rate by shifting marginal livestock producers to alternative forms of livelihood including producing hay, fodder, and supplements for sale locally or to other nutrient deficient regions. iii) Regulate animal numbers according to seasonal access to nutrients iv) Limit goat and camel numbers in the livestock herd, v) Change pastoral livestock production model primarily dependent on forage yearlong to "nutrient supply" model dependent on harvested feeds during winter and spring and forage during summer and fall. vi) Primary region suited to development of an integrated, semi-extensive livestock production system

Eco-Region	**Environmental Factors**	**Livestock Production Risk Factors**	**Livestock Suitability**	**Livestock Production Strengths**	**Suggestions to Improve Regional Livestock Production and Mitigate Risk**
3. Altai Region (Aimags of Uvs, Bayan-olgii, Hovd, Zavhan and Gobi-Altai). High mountain and desert valley region in western Mongolia.	i) elevation between 1500 and 4000 m; ii) mean annual temperature between -2.5°C and 5.0°C with low temperature of -24°C in January and high temperature of 22°C in July; iii) between 60 - 120 frost free days; precipitation between 400 and 500 mm. iv) snow depth ranges between 5 to >15 mm v) wind speed can occur between 2 and 6 m/sec.	i) winter cold and deep snow limit animal access to forage and nutrients and reduce efficient use of available nutrients. ii) forage and browse production potential on natural shrub rangelands is low; iii) lack of access to water during cold periods can be major factor limiting animal production iv) equilibrium ecosystem function in the north whereby over stocking of livestock can change species composition and induce soil, vegetation, and water degradation, non-equilibrium ecosystem in south whereby environmental influences such as drought and/or dzud in combination overstocking can change "steady state" conditions very quickly as well as decimate large herbivore populations	cattle, sheep, goats and horses in the north, sheep, goat, and camel in the south.	i) shrub dominated rangeland are optimal winter and spring season rangelands for adapted livestock; ii) harvesting forage and browse with adapted grazing animals during all seasons is optimal, iii) hay, fodder and grain production potential is low except in a few oasis and developed irrigated areas.	i) Increase animal access to nutrients during winter and spring by growing hay and fodder crops in oases, by rehabilitating abandoned irrigation developments as irrigated hayland (i.e., especially legumes such as alfalfa), and by importing animal feed from more efficient feed producing regions. ii) Reduce animal stocking rate by shifting marginal livestock producers to alternative forms of livelihood, by rationalizing livestock numbers and kind, and by obtaining higher annual livestock turnover. iii) Regulate animal numbers according to seasonal access to nutrients Limit Cashmere goat, cattle, and horse numbers as a proportion of herd. iv) Improve application of the pastoral, extensively managed livestock production model by developing and rehabilitating wells and by facilitating distribution of livestock and livestock producers.

Eco-Region	Environmental Factors	Livestock Production Risk Factors	Livestock Suitability	Livestock Production Strengths	Suggestions to Improve Regional Livestock Production and Mitigate Risk
4. Central and Eastern Steppe Region. (Aimags of Dornod, Hentii, Sukhebaatar, Dorngobi and Dundgobi).Broad, essentially treeless grass steppe region in central and eastern Mongolia.	i) elevation between 900 and 2000 m; ii) mean annual temperature between 0.0°C and 2.5°C with low temperature in January of -20°C and high temperature of 22°C in July; iii) between 110 and 140 frost free days, precipitation between 150 and 250 mm. iv) Snow depth ranges between 5 to 10 mm v) wind speed can occur between 4 and 8 m/sec.	i) winter cold and deep snow can limit animal access to forage and nutrients and reduce efficient use of available nutrients. ii) lack of access to water during all seasons except along major rivers is a major factor limiting animal production; iii) equilibrium ecosystem function whereby over stocking of livestock can change species composition and induce soil, vegetation, and water degradation iv) High winds during spring and lack of topographic animal shelter can limit livestock production efficiencies; v) Difficulty of access to major markets and low human population is a major constraint except in the western portion of the region and along the rail corridor.	sheep, goat, horse, and cattle	i) Has potential as an area to produce hay and other livestock feeds (i.e., during the collective era, there were 20 state hay farms in the region). ii) Considerable unused rangeland exists in the eastern and northern part of the region, iii) Has potential to become an export region for livestock offtake because of close proximity to railroads, water transportation, and large population areas in China, iv) forage production on natural rangelands during summer and fall is high, harvesting forage with grazing animals during summer and fall is optimal for rangeland use.	i) Increase animal access to nutrients during winter and spring by developing improved hay and animal feed grains capacity on abandoned hay and crop farms for sale locally or to other nutrient deficient regions.[1/] ii) Improve livestock production potential of the region by developing wells and livestock shelters iii) Regulate animal numbers according to seasonal access to nutrients iv) Limit goat and camel numbers in the livestock herd. v) Change pastoral livestock production model primarily dependent on forage yearlong to "nutrient supply" model dependent on harvested feeds during winter and spring and forage during summer and fall. vi) Develop regional value-added facilities to improve export potential.

Eco-Region	Environmental Factors	Livestock Production Risk Factors	Livestock Suitability	Livestock Production Strengths	Suggestions to Improve Regional Livestock Production and Mitigate Risk
5. Gobi Region (Aimags of Gob-altai, Bayan-hongor, Ovor-hangai, Dundgobi, Omnogobi, Gobi-Sumbaer, and Dorngobi). Semi-arid and arid southern section of Mongolia	i) elevation between 700 and 1400 m; ii) mean annual temperature between 0.0°C and >2.5°C with a low January temperature of -20°C and high temperature of 23°C in July; iii) between 90 to > 130 frost free days, variable precipitation of 100 mm. iv) wind speed between 2 and 8 m/sec occurs.	i) lack of water for grazing animals is a major factor limiting livestock distribution and production in the Gobi Region. ii) non-equilibrium ecosystem whereby environmental influences such as drought and/or dzud in combination with overstocking can change "steady state" conditions very quickly and as well as decimate large herbivore populations. iii) Difficulty of access to major markets and low human population is a major constraint to sustainable livelihoods. iv) Overbrowsing of shrubs which dominate vegetation communities can not be easily mitigated. v) hay,fodder and grain production potential is low except in a few oasis and developed irrigated areas. vi) Arid ecosystems are prone to both environmental and anthropromorphic desertification	native sheep, goat, and camel	i) shrub dominated rangeland are optimal winter and spring season rangelands for adapted livestock; ii) harvesting forage and browse with adapted grazing animals during all seasons is optimal, iii) region has highest potential to support Cashmere goat production.	i) Increase animal access to nutrients during winter and spring by importing supplemental feeds. Improve livestock distribution and production potential of the region by developing wells and livestock shelters ii) Regulate animal numbers according to seasonal access to nutrients iii) Limit horse and cattle numbers in the livestock herd and maintain correct proportions of goat and sheep. iv) Maintain and improve pastoral livestock production model primarily dependent on forage/browse yearlong by improving animal distribution capabilities of the livestock herder (i.e., access to water, transportation and supplemental feed). v) Develop regional value-added facilities to improve export potential. Develop cross border marketing linkages. vi) Encourage faster livestock turnover and initiate annual "severe culling" at the end of the fall grazing season. vii) Focus livestock production to take advantage of local, national, and international markets developing along the rail and road corridor.

Annex 3. Potential Effect of Climate Change on Mongolian Rangeland

Potential Impacts of Climate Change on Livestock Production

A. Economic

Global market fluctuations mask variations caused by climate change at regional scales (Schnieder 2007). However, the market economy that was introduced to Mongolia in 1990 is focused primarily in the capital city of Ulaanbaatar (Batima, 2008). Herders in Dundgov, Omnogov, and Dornogov provinces must respond primarily to variables found in nature rather than market incentives. The largest impact on livelihoods is the drying up of water sources and declining forage resources for livestock (Natsagdorj, 2005).

Vulnerability is a function of the expected rate of climate change relative to the resilience of the system. However, vulnerability of natural systems are also a function of human developments that block migration routes, fragment habitats, reduce animal populations, introduce invasive alien species, and pollution (Schnieder, 2007). Any changes in the natural systems will greatly affect the human populations that are dependant on them.

Herders could benefit economically from mild winters. However, some researchers believe that rapid warming in winter can create problems. For example, if there is sudden snow melt followed by freezing, then large ice sheets will interfere with pasture grazing (Natsagdorj, 2005). In general, climate change compounded with poverty could be a devastating arrangement. Gobi herders may have a very low adaptive capacity because of limited access to information, technology, capital, forage, and other agronomic inputs that will allow them to adjust their production strategy to match changing conditions (Cruz et. al 2007).

Fortunately, it is evident that current climate variability falls largely within the coping range of fodder production and it is not expected to be exceeded significantly because of predicted climate changes (Schnieder, 2007). This makes hay production, especially winter time forage, an important tool for any herder transitioning into predicted climate change scenarios and the very real emerging economy.

B. Pastureland

Pasture in the Gobi regions of Dundgov, Omnogov, and Dornogov are controlled primarily by abiotic factors of temperature and precipitation, and the biotic factor of animal grazing. Sensitivity analysis of plant biomass examines the abiotic variables and shows that a plant aboveground biomass decreases with increased temperature. However, plant biomass increases with additional precipitation, and this effect dwarfs the temperature effect as can be seen in figure 1 (Batima, 2008).

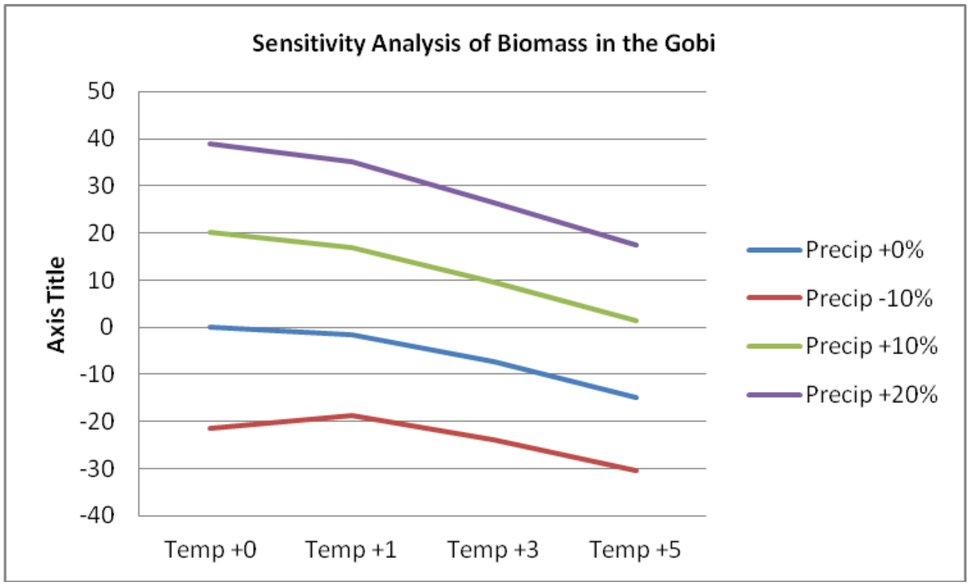


Figure 1. In 2008, Batima shows that precipitation is a greater effect on above ground biomass than temperature.

Relative to predictions of computer models, the HADCM3 and CSERO models agree that biomass will increase for the desert steppe region in both the A2 and B2 scenarios. The ECHAM model shows no change in biomass for the A2 scenario and decreasing biomass in the B2 scenario (Figure 2).

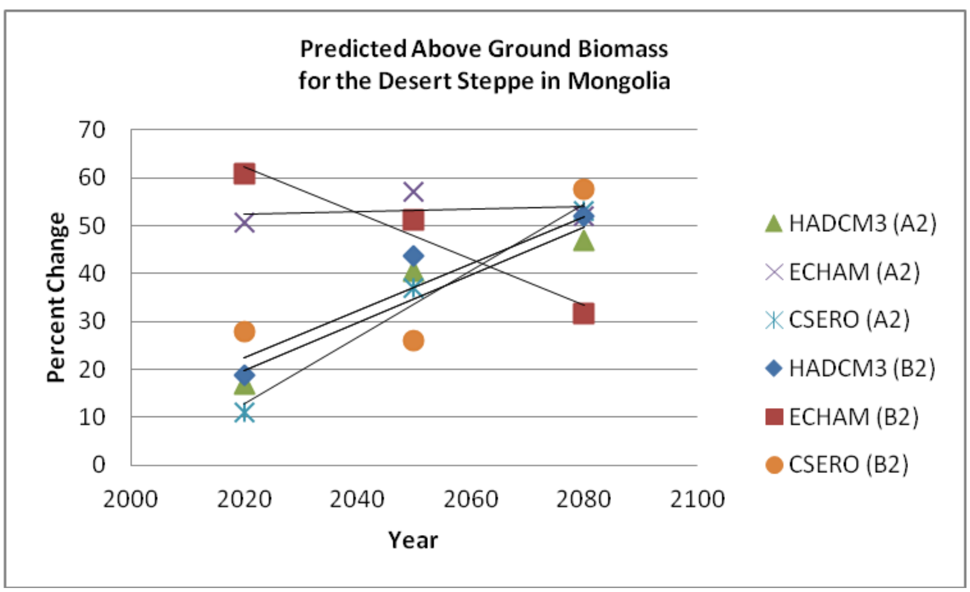


Figure 2. In 2008 Batima shows that in both A2 and B2 the HADCM3 and CSERO models showed increased biomass.

As projected by both the (NPOESS) Preparatory Project, the Net Primary Productivity (NPP) and Aridity Index for the ecozones of Mongolia are expected to shift to the north due to increased dryness and higher air temperature. The results of the climate change models, the HadCM3, ECHAM3, and CSIRO all agree within the context of scenarios A2 and B2. This means the Gobi will shift north due to combined impacts of increased temperature and reduced precipitation while at the same time experiencing an increase in biomass (Batima, 2008).

C. Water

Mongolia's total water resource is estimated at 599 cubic km of water (Ministry of Nature and Environment, 2008) and precipitation plays an enormous role in its recharge and cycling. Unfortunately, precipitation is not reliably simulated in present climate models and there are conflicting results, often because of the localized nature of precipitation. However, it is well established that precipitation variability increases due to climate change (Kundzewicz, 2007, Ministry of Nature and Environment, 2008, Natsagdorj, 2005, and Batima, 2008).

The Gobi desert and desert-steppe areas are expected to receive less rainfall. This will lead to reduced river runoff, lower water levels in the lakes basin, and the cause drying-up of small lakes in the Gobi region (Ministry of Nature and Environment 2008, Figure 3).

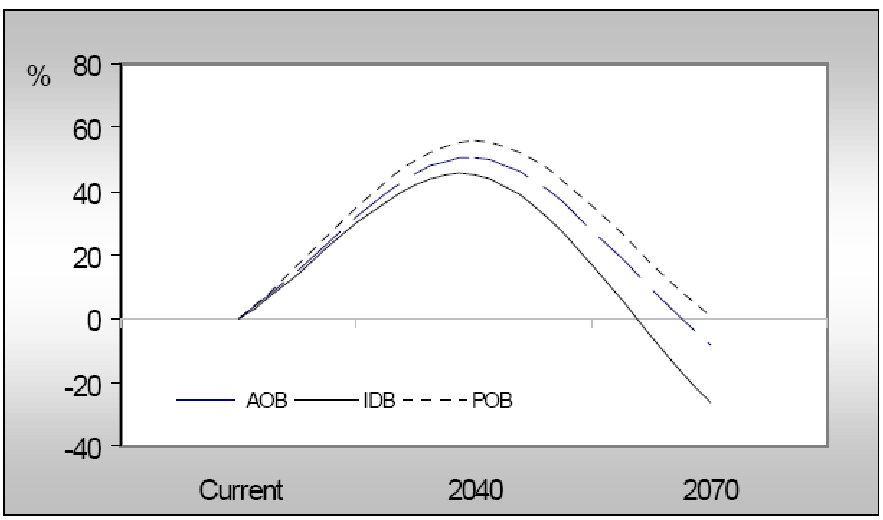


Figure 3. Changes in river flow by the computer model CCCM

In the last sixty years, annual precipitation has increased by 30-70 mm in the most south-eastern part of the country (Batima, 2008). The findings of the five computer models (CCCM, CSERIO, ECHAM, GDFL, HADLEY) show that this trend will continue in the first quarter of the century and then decrease, returning close to current levels by the mid-21st Century as shown in figure 3 (Ministry of Nature and Environment 2008).

If there is an increase of summer rainfall, there might be a much higher increase of evapotranspiration. Already, potential evapotranspiration has increased by 7-12% over the previous 60 years (Batima, 2008). The impact of precipitation change is predicted to be greater than that of temperature in relation to river flows. For example, Batima found in 2008 that if the annual precipitation drops by 10% while the temperature remains constant, the average river flow would reduce from 7.5% to 20.3%. For each degree C of temperature increase, there is an additional 2% decrease in flow.

Recent drought and growing water demands is already creating a need for both new infrastructure and rehabilitation of old infrastructure such as wells. Water use, and in particular irrigation water use, generally increases with temperature and decreases with precipitation (Kundzewicz, 2007). Coping capacity is particularly low in rural populations found in Dundgov, Omnogov, and Dornogov provinces that are without access to reliable water supply from large reservoirs or deep wells. Even in semi-arid areas where water resources are not overused, increased climate variability may have a strong negative impact. For example, droughts in 1999 to 2002 affected 70% of grassland and killed 12 million livestock (Batima et al., 2005 and Natsagdorj et al., 2005). Adopting management measures that are flexible may be the best approach to dealing with a largely unpredictable climate (Stakhiv, 1998).

D. Temperature

The driver of global climate change is rising temperatures. Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature dating back to 1850 (Intergovernmental, 2007). In Mongolia, annual mean temperatures between 1940-2003 have risen by 1.8°C. Warming has been most pronounced in winter, with a mean temperature increase of 3.6°C, while spring, autumn, and summer mean temperatures have risen by 1.8°C, 1.3°C, and 0.5°C respectively (Batima, 2008). However, warming temperatures has been lowest in the Gobi desert (Natsagdorj, 2005). The cold wave duration has shortened by 13 days nationwide in the last 60 years, but again, it hasn’t been as pronounced in the Gobi Desert (Batima, 2008). Heat wave duration has increased by 8 to 18 days in last 40 years. One direct consequence of the warming is that frequency and aerial extent of the forest and steppe fires in Mongolia has significantly increased (Erdnethuya, 2003).

In the future, all models predicted winter warming would be more pronounced than summer warming, especially after 2040 (Ministry of Nature and Environment, 2008). The rate of winter warming varies from 0.9°C to 8.7°C, while the summer temperature increase varies from 1.3°C to 8.6°C (Batima, 2008). As winter temperatures have increased in the past, the occurrence of abnormal or unseasonable weather phenomenon such as windstorms in winter and rapid warming that causes ice sheets have increased. This trend of increasing dzud and associated domestic animal mortality can be expected to continue if climate scenarios are correct in their predictions (Batima, 2008).

VI. Impact on Livestock

How a changing climate affects the livestock industry in Dundgov, Omnogov, and Dornogov will ultimately be of greatest concern to herders who live in the region. This effect is a culmination of the economic, pasture, water, and temperature effects mentioned previously.

Some research points towards a small weight gain for animals in the Gobi Desert, if pasture biomass and temperature increases as seen in figure 4. For example, temperature rise has a dominant role in ewe weight gain (Batima, 2008). Ewe weight changed relative to pasture biomass and temperature did not affect this change greatly.

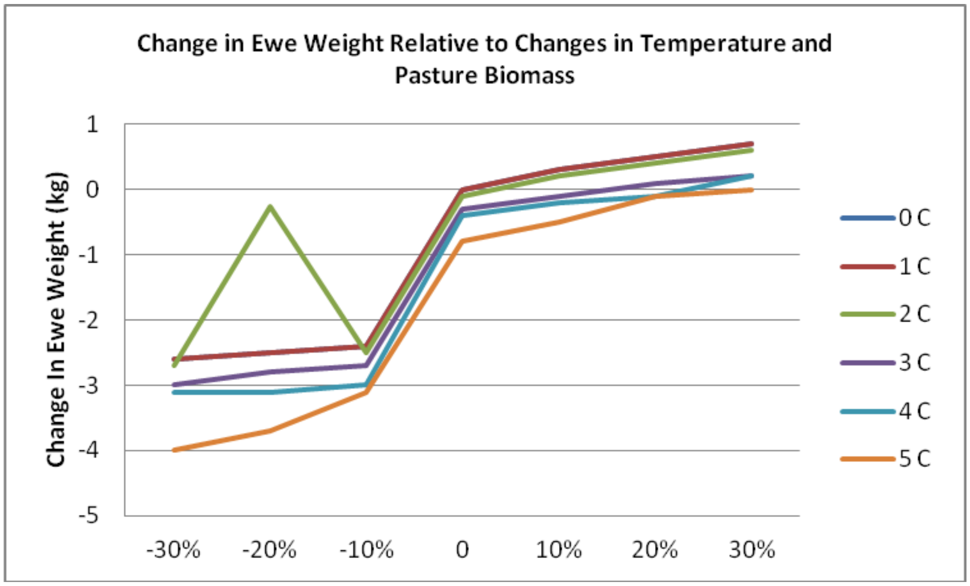


Figure 4. Change in ewe weight relative to changes in temperature and yield.

However, there can be adverse affects as well. Indirectly, decreased animal grazing time can be a large factor in decreased weight gain. The threshold temperature above which animals cannot graze has been shown to be 26°C in the Gobi desert. If animals can't graze pasture because of excessive heat, their daily intake decreases, weight gain suffers, and it may impact their ability to survive a harsh winter (Batima, 2008). However, warmer temperature in the winter should provide more opportunity to graze and may more than offset any detriment of summertime heat.

The Mongolia word *dzud* describes weather events such as heavy snowfall, long-lasting or frequent snowfall, extremely low temperatures, or drifting windstorms that reduce grazing time and have caused serious animal mortality in recent years. *Dzud* also represents a high risk to humans in the affected areas (Batima, 2008). Omnigov and Dornogov provinces have both experienced extreme dzud events in the past. It is unknown, but possible that greater climate variability associated with predicted climate change will increase the frequency or severity of these winter events (Figure 5).

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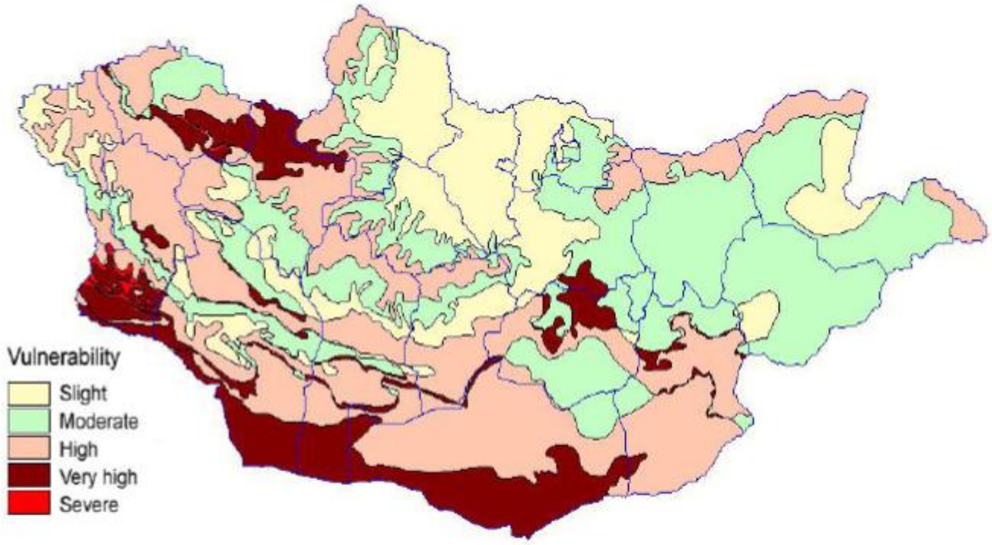

Figure 4.24: Black and white dzud *frequency overlay map*

Figure 5. Dzud-prone regions of Mongolia.

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Back Cover Photo

The photo was taken in mid-August, 1997 in the Semi-Desert ecozone of the South Gobi Region. In the photo, monitoring team members are evaluating a rangeland condition (from left S. Tserendash, D. Damiran, M. Porter, C. Sheehy, and D. Sheehy)