ASSESSMENT OF PASTURELAND VULNERABILITY ON SOCIO-ECONOMY OF LOCAL COMMUNITIES USING RS AND GIS

B.Kherlenbayar (1, 2), B.Suvdantsetseg (2, 3), M.Altanbagana (1, 2), Kh.Nominbolor (4)

[1] Socio-Economic Geography Division, Institute of Geography and Geoecology, MAS,
[2] Sustainable development Institute for western region of Mongolia
[3] International Cooperation Department, Mongolian Academy of Sciences
[4] Institute for Strategic Studies
Email: bkherlenbayar@gmail.com; suvd16@gmail.com

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ABSTRACT

A grazing pasture in arid and semi-arid ecosystems is particularly vulnerable to climate variability. To prevent a harm of pasture degradation induced by climate change and human impact, the assessment of grazing pasture vulnerability and its impacts on socio-economy of local communities as well as proper adapting mechanisms are urgently needed. This study identified the impacts of grazing pasture vulnerability to the socio-economy of local communities in Gobi-Altai province, western Mongolia. The research analyses used the remote sensing techniques and geostatistical analysis with observation data of temperature and precipitation from weather stations, satellite data of eMODIS and SPOT, and statistical data on socio-economic indicators from 1999 to 2017.

The findings of the study show that pasture vulnerability is a precondition of dzud, a harsh winter disaster, and a main factor in loss of grazing livestock. When pasture vulnerability increases, livestock loss and breeding livestock miscarriage will increase in the coming winter and spring in the next year, on the contrary, the pasture vulnerability decrease positively affects the growth of livestock number. This process is one of the main factors that directly affect the income of herders. Having high pasture vulnerability, Jargalan and Khaliun soums have greater livestock loss and miscarriage, making the livestock sector in these soums highly sensitive to pasture vulnerability. However, livestock sector of Tugrug soum, having a high adaptive capacity in spite of high pasture vulnerability, is less sensitive to the pasture vulnerability. As a conslusion, careful attention should be paid to soums in the mountain steppe zone and to more sensitive soums in terms of pasture vulnerability in order to improve pasture management, reduce the risk of livestock sector and provide the sustainability of pastoral animal husbandry.

1. INTRODUCTION

Nomadic pastoralism is a complex human- environmental system in which livestock, pasture and herder interdepend each other (Bazargur, 2005; (Chuluun, 2014). It has been developing as an adaptive mechanism, switching pastureland in accordance with pasture recovery capacity, for fluctuations of arid-terrestrial ecosystems (Chuluun, 2006, Maria 1999, 2006). Pastoral livestock production contributes 10.52% of GDP using 72.1% of Mongolia's total land area and employing 21.6% of total workforce. Mongolian parliament has declared the livestock sector as one of the leading economic sectors in the Sustainable Development Vision for 2030 document. In the policy directions of the state policy on food and agriculture, a nomadic pastoralism, preserving the culture of traditional heritage and adapted to climate change, is identified as a main form of animal husbandry in the country. Therefore, it is a challenge to develop traditional pastoralism adapted to climate change in vulnerable arid regions.

Maintained under variety of pastoral ecosystem features including mountain range, steppe, desert and desert-steppe zones with extreme weather, Mongolian pastoral livestock sector is highly vulnerable to climate change, drought and *dzud* (harsh weather condition with heavy snow fall and extreme cold) (Chuluun, Ojima, & Altanbagana, 2011, Chuluun et all, 2012). The annual average temperature in Mongolia over the last 70 years has increased by 2.14^{0}C (MET., 2014), which is 2-3 times the annual average of the last 100 years in the world (0.74^{0}C). During the last 74 years, the hottest 10 years has happened since 1997 (MET, 2014). Drought and dzud of 1998-2002 and the dzud of 2009-2010 caused significant damage to livestock breeding, intensified poverty and internal migration of herders and caused a direct and indirect impact on the economy of the country (Altanbagana, Kherlenbayar 2016).

Since the transition of Mongolia from a centrally planned socialist economy to a free market economy in 1990, limitation of livestock number, supply system of animal raw materials, risk protection system and pasture management on animal husbandry sector have been lost. This socio-economic system transition has generated new issues related to human impact such as livestock, pasture degradation and shrinking of suitable pastures for livestock grazing. However, main resource for pastoral livestock has been decreasing until now. In the last 60 years, the degradation of pasture land has increased 2.8 times (Tserendash & Bilegt 2017), pasture yield has fallen by 20-30% in almost all regions of Mongolia, and the pasture carrying capacity has dropped by 20% (Bolortsetseg, Erdenetsetseg and Bat-Oyun, 2002). In the future, some research results are warning that pasture land suitable for livestock grazing will decrease (JICA & Almac.corp, 2016).

To effectively align adaptation policies and prioritize implementation measures, policy makers require comprehensive information on regional and various sectors vulnerability assessments (O'Brein et al. 2004; Ciscar et al. 2011; Preston et al. 2011).

Over the last two decades, many researchers have proposed various vulnerability frameworks to climate change, and quantitative analyses have been performed in different spatial scales and sectors (Moss et al. 2001; Tuner et al., 2003; O'Brien et al. 2004; Brooks et al. 2005; Adger 2006; Altanbagana et al., 2015). In terms of ecological vulnerability to drought and dzud disaster, majority of studies applied in Mongolia referred to Dryland Development Paradigm (DDP) (Reynolds et al. 2007). Natsagdorj & Sarantuya (2004) assessed impact of drought and dzud on livestock loss due to extreme weather, Altanbagana et al (2011) and Chuluun et al (2012, 2017) conducted assessment of vulnerability of Mongolia's pastoral social-ecological system at province level and applied 2 main drivers, consisting of drought-dzud index and pasture use.

The ecological vulnerability is defined as a combination of the degree of exposure or sensitivity (Adger, 2006) of ecosystems due to climate and human impacts to adapt by perceiving, mitigating and taking advantage of new opportunities created by change (Ainong.Li, 2006), (Turner. B.L, et al., 2003). Researchers studying climate change adaptation (Adger 2003, 2006, Armitage 2005, Bruck 2003, Ford et al 2006) claim the need to consider linkages between ecosystem situation, supporting local community's sustainable livelihoods through its primary products and services, and local communities' adaptive capacities on ecosystem. For instance, the adaptive capacity of groups in society is classified as inactive and observer group, regulator group and adaptive capacity group. Chuluun (2014) revealed that most of the herder households in Mongolia are included in the "inactive and observer" group, and that the capacity of social adaptability and pastoral ecosystems is poor.

It is important to prevent the dzud disaster risks, however adverse effect of human and climate change impacts on pastoral ecosystem services is not ignored. Therefore, interaction of pastoral social-ecological is significant to examine how pastoral ecosystem services are vulnerable to human and climate change, and which soum's the livestock sector and herders are susceptible to pasture vulnerability. It is important for sustainable pasture use, pasture management planning, and effective implementation of adaptive measures (Turner et al., 2003, Brooks et al. 2005).

This study aimed to conduct a quantitative analysis using main drivers and threshold value, for pasture vulnerability caused by climate change and human factors in the soums of Govi-Altai province, between 1999 and 2017. A pasture vulnerability is developed in this paper to evaluate how impacts on pastoral livestock, which soum is more vulnerable and thus impact on migration. Identifying a highly sensitive and less sensitive soums in pasture vulnerability is important to provide a knowledge to adapt to pasture vulnerability and dzud disaster.

2. METHOD AND DATA

2.1 Study area and data source

Located in the southwestern part of Mongolia and bordered by the People's Republic of China in the southern part, Gobi-Altai province (aimag) is the second largest province in terms of territory in Mongolia, with a total area of 141400 sq.km and the elevation ranges from 1000-3802 m above sea level. The Mongol Altai mountain range is located in the north-west direction. Whole territory of the province belongs to arid and semi-arid zone, the mountain steppe and alpine zones are distributed in high altitude of Mongol Altai mountain range, with four seasons. The annual average precipitation is 80-135mm, most of the rainfall is during summer season. As of 2018, 5.7% (3513370 livestock) of the total livestock graze in Govi-altai province and total population is 58471. 43.5% of total households in the province are herder households and 43.8% of the province's GDP is generated by the livestock sector alone. As of 2018, the population has reached 58.4 thousand, decreased by 18.4% compared to 1998 value, and 32.1% of the population is settled in Altai city, Esunbulag soum, the center of Govi-Altai province. It is among the provinces with highly vulnerable ecosystem and largest population out-migration.

The data during the period 1998-2017 covering the component index of pasture vulnerability are derived from various sources: observed precipitation and temperature data are derived from National Agency of Meteorology and Environmental Monitoring (NAMEM), the Normalized Difference Vegetation index (NDVI) imageries are derived from SPOT, eMODIS satellite data, the pasture carrying capacity data is derived from the Mongolian National Atlas of 1990, and other relevant statistical data are obtained from the Mongolian Statistical Information Service website.

2.2 Pasture vulnerability assessment

The methodology of grazing livestock vulnerability assessment due to climate change (Chuluun et al. date), is modified for pasture vulnerability assessment in this paper. Also, DDP application (Reynolds JF etc, 2007), key factors, affecting pasture productivity, and threshold values of each key factor are applied to determine pasture vulnerability. To assess pasture vulnerability, main drivers are drought index, vegetation cover changes and pasture use. However, if each variable exceeds the vulnerability threshold value, it will reduce pasture productivity.

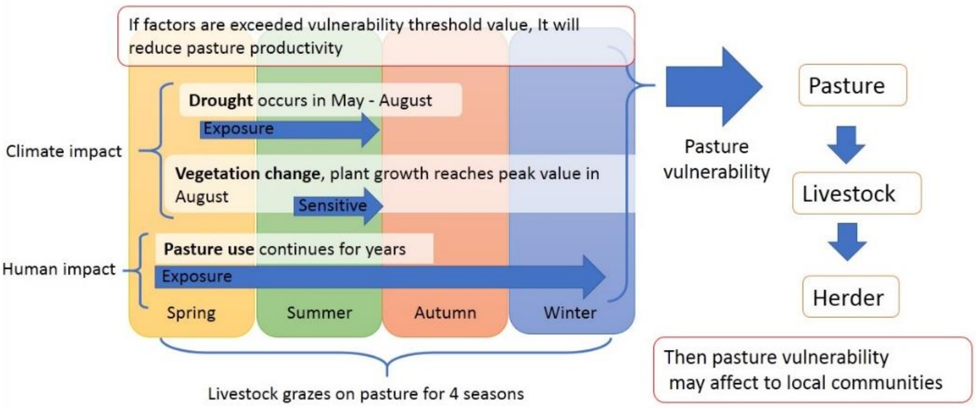


Figure 1. Pasture vulnerability framework

Pasture vulnerability was calculated by Equation (1):

$$V_{t,i}^{eco} = \frac{\frac{(\Delta S_{t,i}^{norm} + \Delta N_{t,i}^{norm})}{2} + Vg_{t,i}^{norm}}{2} \qquad (1)$$

Here, $V_{t,i}^{eco}$– Pasture vulnerability ; $\Delta S_{t,i}^{norm}$ – Normalized drought index; $\Delta N_{t,i}^{norm}$ - Normalized pasture use index; $Vg_{t,i}^{norm}$ – Normalized vegetation cover change index

Drought index

Vulnerability mainly defines drought risk rather than the frequency and severity of weather anomalies (Downing TE, Bakker K, 2000; Yanqiang.Weia, 2017). Drought estimates are calculated using the Ped's index, which represents long-lasting atmospheric degradation. The Pedi index value means that if S > 3 is a high intensified drought, 2<S<3 is a moderate intensified drought and S<0 is humid (Natsagdorj.L, 2009). To assess drought index, S = 3 value is chosen as the threshold value for pasture vulnerability.
Ped's index and share of area affected by drought were calculated by Equation 3 and 4:

$$S_{summer} = \sum_{t=1}^{n}\left(\frac{T_j - \bar{T}_j}{\sigma_T}\right) - \sum_{t=1}^{n}\left(\frac{R_j - \bar{R}_j}{\sigma_R}\right) \qquad (2) \qquad S>3 \qquad \Delta Si = \frac{S_{t,i}}{S_i} \qquad (3)$$

Here, Tj, Rj – observed monthly average temperature and monthly total precipitation of summer period (May-August) at the weather station *j*;
$\overline{Tj}, \overline{Rj}$ – Multi-year average of monthly temperature and total precipitation at the weather station *j*;
σ_T σ_R – Standard deviation from multi-year average of monthly temperature and total precipitation at the weather station *j*
$\Delta S_{i,t}$ – share of area affected by drought or pixel value is over 3 in total area of soum i in year t, $S_{t,i}$ – Total area affected by drought of soum i in year t, S_i – total area of soum i.

Pasture use

In 1990, the number of animals that were suitable for grazing in 1 hectare in the soum was determined (National Atlas of Mongolia, 1990). These values were selected as the threshold value of vulnerability of pasture use and Tserendash.C's (2006) pasture use index was modified in pasture vulnerability assessment.
If the number of livestock per hectare of pastureland exceeds the suitable number of livestock (National Atlas of Mongolia, 1990) or pasture carrying capacity, it will adversely affect pasture biomass such as decreasing pasture yield and increasing pasture ecosystems vulnerability. Pasture use index was calculated by Equation (4):

$$N = \sum_{i=1}^{n}(a_i * L_i)/S \qquad (4)$$

a_i – Coefficient of transferring type of livestock i to sheep head; L_i – the number of type of livestock i of soum
S– Total pasture land area of soum;
Coefficient of transferring livestock to sheep head:

Livestock	*Camel (a_1)*	*Horse (a_2)*	*Cattle (a_3)*	***Sheep (a_4)***	*Goat (a_5)*
Sheep head	5	7	6	**1**	0.9

the threshold value of pasture use is 1, if ΔN > 1 it means that vulnerability is increasing. Pasture use index was calculated by following Equation (5).

$$\Delta N = \frac{N}{N_0} \qquad (5)$$

Here, ΔN – Pasture use index in soum; N- The number of livestock per hectare in soum pastureland by sheep heads; N_0– The pasture carrying capacity, suitable number of livestock per hectare in soum pastureland by sheep heads

Vegetation cover change

Vegetation yields of pasture in Mongolian territory reach peak levels in August of every year and spatially depending on drought, climate change variability and pasture use (Sanjid, 2002) (Bazargur, 2005). The annual vegetation biomass has an important role for grazing of livestock in winter and spring. If there is more change in vegetation cover, it will affect to pasture vulnerability by pasture land degradation and reduction of suitable area for livestock grazing (Zhou, Gang, & Jianlong, 2014), (Miyasaka, Okura, Zhao, & Takeuchi, 2016).

The vulnerability assessment considers how much of the total area of the soum has been affected by changes in vegetation cover or degradation. Alternatively, the degraded area was calculated whether it exceeds the threshold value of vegetation vulnerability for each pixel or not. The threshold value of the vegetation vulnerability was selected by difference of the mean value and standard deviation during period of 1999-2017 and determined for each of the pixels by the following equation.

Decreased vegetation cover and Share of decreased vegetation cover area in total area were calculated by Equation (6) and (7)

$$\Delta V_{ti} = \left(V_{ti} - \left(\frac{\sum_t^n V_{ti}}{n} - \sigma\right)\right) \quad (6) \qquad \Delta V_{ti} < 0 \qquad \Delta Vci = \frac{Vst,i}{Vsi} \quad (7)$$

ΔV_{ti} – changes in vegetation cover of pixel i in year t; V_{ti} –NDVI value of pixel i in year t; σ – Standard deviation of NDVI; n – total years

ΔVci – Share of decreased vegetation cover area in total area in year i;

$Vs_{t,i}$ – the total area exceeds vulnerable threshold value in year i or the area which NDVI value in year i decreased from multi-year value; Vs_i – Total area of soum i

3. ASSESSMENT OF PASTURE VULNERABILITY

Component indexes of pasture vulnerability assesment and integrated pasture vulnerability assessment are shown in Fig.... including land highly exposed to vegetation cover change, drought frequency, average pasture use, livestock miscarriage, livestock loss and total livestock during 1997 and 2017.

Drought index: Based on precipitation and temperature data in weather stations, drought index was calculated, followed by drought map using Inverse Distance Weighting (IDW) model.

Gobi-Altai province experienced considerable droughts which covered major soums in 2001, 2007-2009 and 2017 respectively. During the first ten years, frequency of the drought was higher, and it was lower in the last ten years providing greener summer. In Gobi-Altai province, frequence of drought within the last 20 years between 1998 and 2017 was lowest (2 to 4) in Altai, Tsogt, Bayan-Uul and Khukhmorit soums, average (4 to 6) in Tseel, Bugat, Tonkhil, Tugrug, Biger, Darvi and Yesunbulag soums, and highest (6 to 9) in Chandmani, Jargalan, Delger, Erdene, Taishir, Khaliun and Sharga soums. In terms of geographical location, soums that are located in the far east have experienced more drought than the others did. Both frequency of the drought and the spatial coverage are high in Jargalan, Delger and Chandmani soums.

Pasture use: With transition to the market economy, livestock once owned by the state was transferred to herders, and the system of collectives that brought together herders to prepare livestock raw materials collapsed. Also, the loss of control over the number of livestock has resulted in dramatic increase in the number of livestock throughout the country. In Gobi-Altai province, for instance, the number of livestock has more than doubled from 1.6 million heads right after the collapse of the socialist system to 3.8 million heads in 2017. Although the dzud of 2009-2010 claimed half of 2.5 million heads of livestock, it has tripled again within only 6 years following the incident. The pasture use in the province has intensified since 2010. Depending on the number of livestock, the pasture use of each soum is expected to grow further. Because there is no limiting factor other than dzud for the of livestock number. Darvi soum has the highest pasture use; but Bugat, Altai, Tsogt and Erdene soums are located at the Great Gobi Strictly Protected Area and border areas with China, so the entire soum area is not suitable for use in grazing.

Vegetation cover change: The eMODIS satellite has been used for vegetation NDVI data for the second 10 days of August, the peak of vegetation, from 1998 to 2017. Since then the vegetation is reduced and the crop in the pasture is used for winter and spring pastures. In Gobi-Altai province, vegetation is relatively higher in mountain steppe zone. Vegetation cover is highest in mountain steppe zone (Yesunbulag, Jargalan, Taishir, and Khaliun soums) at 0.19-0.23, middle in desert steppe zone at 0.12-0.18 (Darvi, Bayan-Uul, Tonkhil, Delger, Chandmani, Biger, Tseel, Sharga, Tugrug, Bugat and Khukhmorit soums), and lowest in desert zone at 0.09-0.11 (Altai, Erdene, and Tsogt soums).

Over the past decade, vegeration cover change has been low in desert zone due to plenty of rain in summer. Chandmani, Khaliun and Sharga soums have the largest areas containing NDVI vegetation cover change.

When looking in spatial detail at the frequency of vegetation NDVI changes, in the average of 1998-2017, desert region has the lowest frequency with up to 6 times, back, front and valley of mountains have moderate frequency of 6 to 8 times, adjacent areas of Tonkhil, Darvi and Tugrug soums, adjacent areas of Yesunbulag, Khaliun and Sharga soums, and Huhmorit, Bayan-Uul, Jargalan and Chandmani soums have the highest frequency of 8-19 times, or vegetation change occurs once every 2 years in these areas. In these soums, pasture use is 1-2 times higher than in the other soums.

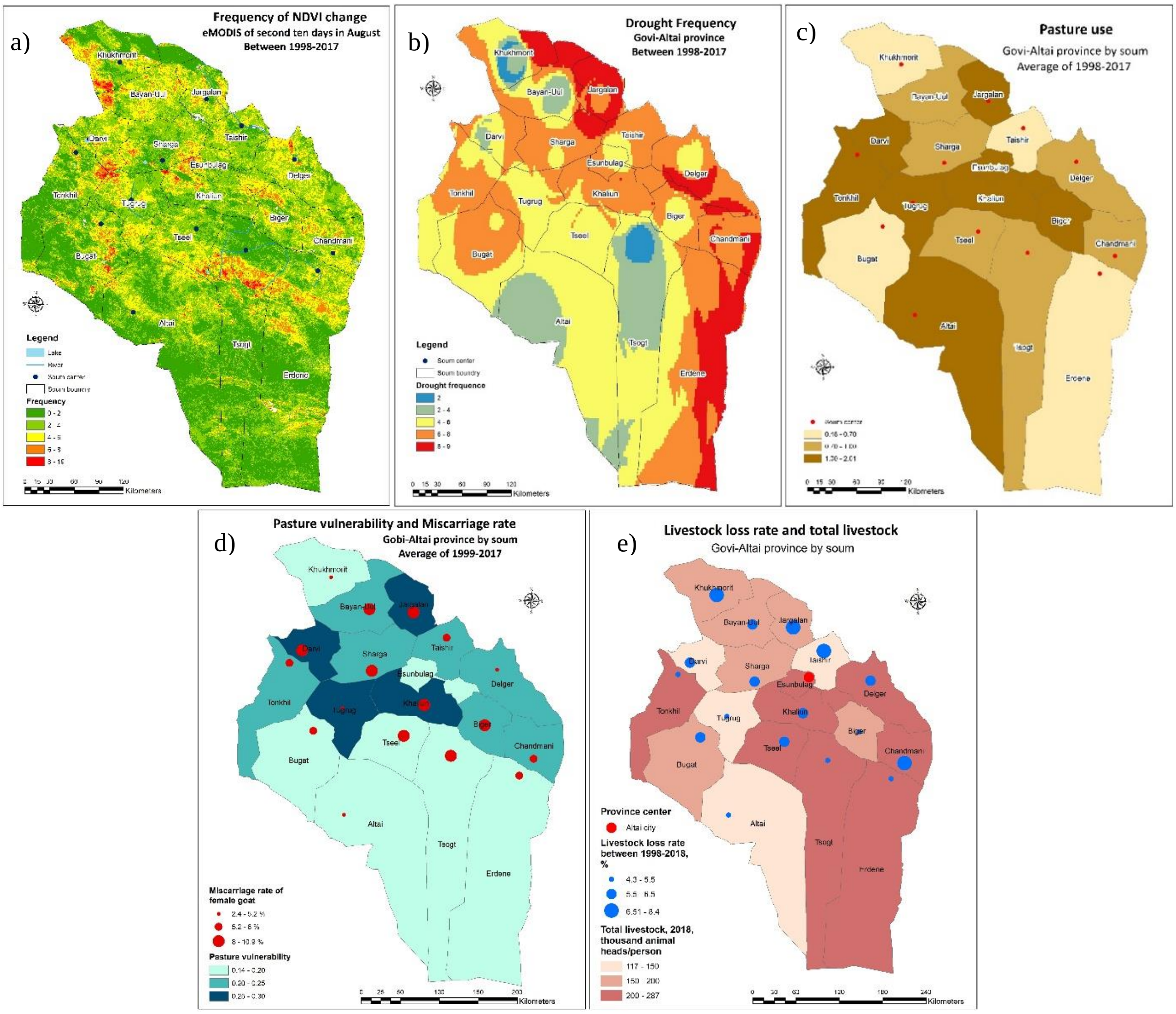


Figure 2. a. Frequency NDVI change between 1999-2017, b. Drought frequency, c. Average pasture use, d. Average pasture vulnerability and average miscarriage, e. Average livestock loss and total livestock in 2018

According to evaluation of pastoral ecosystem vulnerability, soums in mountain steppe zone including Darvi, Jargalan, Tugrug and Khaliun are the most vulnerable (0.26 to 0.29), Chandmani, Tonkhil, Biger, Delger, Taishir, Bayan-Uul and Sharga soums are moderately vulnerable (0.21 to 0.24) and soums in desert dominated zone including Altai, Tsogt, Erdene, Tseel, Bugat and Khukhmorit soums are the least vulnerable (0.16 to 0.20).

In Jargalan, Khaliun, Sharga, Darvi, Biger, Tseel and Tsogt soums, miscarriage of female goat is very high. Tugrug and Delgerekh soums, which have high pasture vulnerability, have lowest miscarriage in female goat, but lesser prepared hay and fodder. Interestingly, livestock miscarrage is high in soums that are preparing fodder. Therefore, the impact on livestock sector varies greatly depending on the pastoral status of the soum.

4. IMPACT OF PASTURE VULNERABILITY ON SOCIO-ECONOMY OF LOCAL COMMUNITIES

4.1 Livestock sector

The main source of income for herders comes from the productivity of live animals such as milk, wool, and cashmere, and the livestock after slaughter such as skin, hides and meat. Until 1999, the number of animals, slaughtered animals and change in total livestock number in Govi-Altai province remained stable. However, due to the vulnerability of the pastures and dzud disasters (2000-2002 and 2009-2010) the stability had been lost.

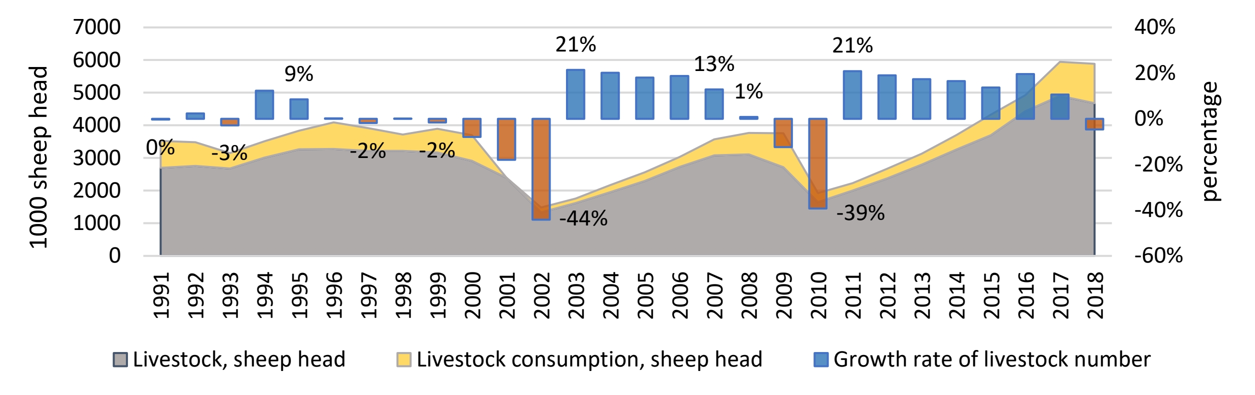


Figure 3. Comparison of dynamic changes of total number of livestock, number of livestock consumption and change in livestock number in Govi-Altai province

Since 2000, the number of livestock has fallen down by 8-44% than the previous year due to the vulnerability of pasture multiplied by the dzud. The growth in livestock number flactuated from 13% to 21% in the post-high mortality years. The herders decreased the number of livestock for consumption per year down to 0.1-0.3 million sheep head to increase their herds. After the risk, the income of herders has decreased as the productivity of live animals reduced and the number of slaughtered animals dropped, ultimately resulting in the increased number of poor households. Also, slaughtering lesser animals for consumption adversely affects the herders' income, and it instigates herders' interest in raising goats in order to increase productivity from live animals. Therefore, it is possible to reduce the herders' risk and to increase their income by increasing the number of livestock for consumption.

Livestock miscarriage and loss, as the risk indicators for livestock sector, reduce herder income and limit livestock growth. The pastureland vulnerability acts as a limiting factor that increases livestock miscarriage and loss, and reduces livestock growth.

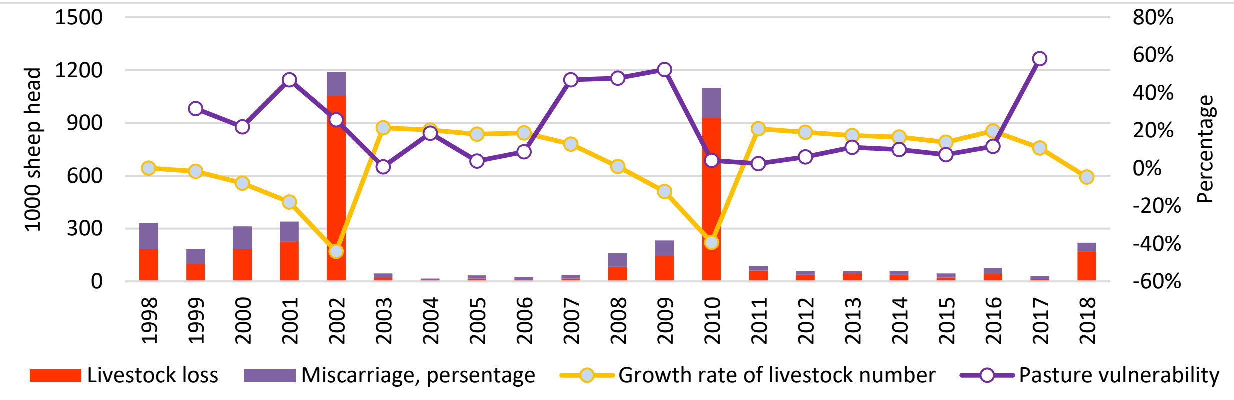


Figure 4. Comparison of pasture vulnerability, change of livestock number, livestock loss and livestock miscarriage

Dzud conditions tend to increase livestock miscarriage and loss, but are less likely to occur when compared with pastureland vulnerability. Livestock miscarriage and loss are increasing in the winter and spring following the year with high pastureland vulnerability. Increased pastureland vulnerability for 2 to 3 consecutive years leads to inadequate fattening of animals in summer, decreased ability to overcome the coming winter, and ultimately, increased livestock mortality. In the years with low pasture vulnerability, the number of livestock increased rapidly. Therefore, the pastureland vulnerability in 17 soums of Govi-Altai province was statistically analyzed as a factor influencing the next year's livestock mortality, loss, and the number of animals. See Table 4.

Table 1. Sample of Pearson correlation coefficients computed between pasture vulnerability and livestock loss, livestock miscarriage and changes of livestock number in next year

№	Soum name	Livestock loss	Miscarriage	Changes of LN
1	Khaliun	0.29	0.60	-0.44
2	Delger	0.52	0.30	-0.47
3	Sharga	0.59	0.65	-0.60
4	Khukhmorit	0.51	0.50	-0.60

5	Taishir	0.45	0.39	-0.61
6	Chandmani	0.58	0.52	-0.62
7	Bayan-Uul	0.58	0.58	-0.68
8	Biger	0.49	0.59	-0.72
9	Darvi	0.68	0.59	-0.73
10	Erdene	0.54	0.66	-0.79
11	Altai	0.65	0.66	-0.80
12	**Tugrug**	0.47	0.40	-0.80
13	Bugat	0.72	0.89	-0.81
14	Tonkhil	0.57	0.70	-0.82
15	Tseel	0.69	0.75	-0.83
16	**Jargalan**	0.67	0.64	-0.84
17	Tsogt	0.59	0.61	-0.87

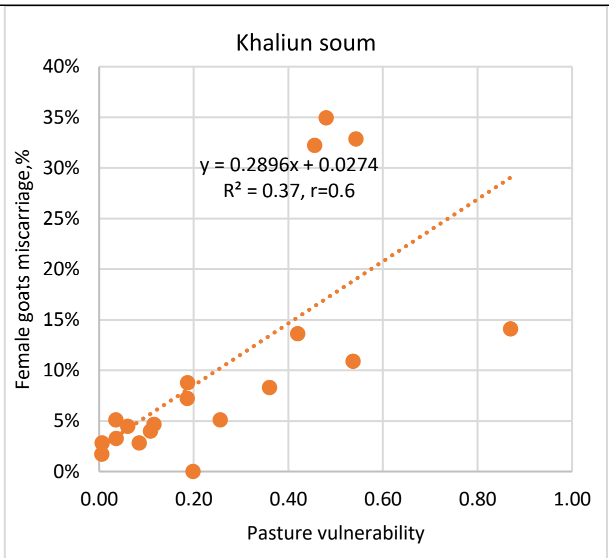
Reference: LN – Livestock Number

In 10 soums of Govi-Altai province, the number of livestock in the coming year decreases with the increase in pasture vulnerability, showing significant statistical correlation (r=0.72-0.87). In the remaining 7 soums there is a weak statistical correlation between the pasture vulnerability and the number of livestock in the coming year (r=0.44-0.68). In other words, increased pasture vulnerability results in increased livestock mortality and slower growth, in turn, decreased pasture vulnerability impacts positively on livestock growth. This is a key factor affecting livestock miscarriage, livestock loss, and livestock growth.

To increase the number of livestock, it is necessary to have a miscarriage rate to a minimum level. 86-98% of all livestock in 17 soums of Gobi-Altai province are small animals, and the miscarriage of small animals is more susceptible to pasture vulnerability. Particularly, 45-76% of total herd is a goat population and the pasture vulnerability more strongly affects the miscarriage in female goats .

Table 2. Sample of Pearson correlation coefficients computed between pasture vulnerability and each type of livestock without camel, example of Khaliun soum.

№	Soum name	Mare	Cows	Female goats	Female sheeps
1	Delger	0.29	0.47	0.41	0.28
2	Taishir	0.08	0.29	0.10	0.34
3	Tugrug	0.17	0.43	0.27	0.37
4	Chandmani	0.50	0.26	0.49	0.50
5	Khukhmorit	0.36	0.32	0.39	0.51
6	Esunbulag	0.50	0.13	0.63	0.53
7	Altai	0.29	0.56	0.55	0.56
8	Dariv	0.40	0.46	0.30	0.57
9	Khaliun	0.17	0.46	0.51	0.60
10	Biger	0.29	0.34	0.36	0.61
11	Jargalan	0.24	0.57	0.57	0.61
12	Tsogt	0.52	0.36	0.49	0.64
13	Bayan-Uul	0.07	0.25	0.37	0.68
14	Sharga	-0.04	0.31	0.58	0.68
15	Erdene	0.45	0.47	0.58	0.69
16	Tonkhil	0.35	0.17	0.57	0.72
17	Tseel	0.30	0.33	0.29	0.74
18	Bugat	0.29	0.62	0.74	0.86



There is a significant statistical impact on grazing in Tonkhil, Tseel, and Bugat soums (r = 0.72-0.86) and weak statistical impact in 12 soums (r = 0.50-0.69). In other words, the increase in pasture vulnerability increases the miscarriage in female goat, and vice versa. There is no statistically significant effect on livestock miscarriage in Tugrug, Delger and Taishir soums, which have high pasture vulnerability. Therefore, it is necessary to study what adaptation measures are these soums taking to reduce the risks of vulnerability.

4.2 Society

Impacts of pastureland vulnerability on livestock sector in 17 soums of Gobi-Altai province are shown in Table 3. Based on livestock loss and livestock miscarriage, it shows the sensitivity of each soum, share of slaughtered animals in total livestock, and annual average growth rate of population. The pasture vulnerability is occurring more frequently than the dzud does, and is a main factor for livestock loss and livestock miscarriage, which further affect reduced number of livestock for consumption for herders.

Table 3. Sensitivity of livestock sector in pasture vulnerability (average 1999-2017), livestock loss, livestock miscarriage and slaughtered livestock in total livestock (average of 1998-2018), and annual average growth of population between 1998-2018

№	Natural zone	Soum name	Veco	LLoss	LMis	Sensitivity	SL	AAGP
1	Mountain steppe	Jargalan	0.26	8.4%	6.1%	High	14%	-2.07%
2	Desert-steppe	Darvi	0.29	5.7%	6.8%	Medium	22%	-0.76%
3	Mountain steppe	Khaliun	0.26	6.2%	7.3%	High	17%	-1.54%
4	Desert-steppe	Tugrug	0.26	4.4%	2.8%	Low	21%	-0.84%
5	Mountain steppe	Taishir	0.21	7.4%	3.9%	High	16%	-1.16%
6	Desert-steppe	Chandmani	0.24	6.9%	5.5%	High	12%	-1.11%
7	Desert-steppe	Bayan-Uul	0.23	6.3%	4.6%	Medium	17%	-0.97%
8	Desert-steppe	Delger	0.23	6.2%	2.0%	Low	18%	-1.22%
9	Desert-steppe	Sharga	0.21	6.1%	6.2%	Medium	18%	-1.49%
10	Desert-steppe	Biger	0.23	5.1%	5.3%	Medium	15%	-1.36%
11	Desert-steppe	Khukhmorit	0.20	7.0%	2.0%	High	13%	-1.10%
12	Desert-steppe	Bugat	0.18	5.9%	5.6%	Medium	16%	-1.28%
13	Desert-steppe	Tseel	0.20	5.6%	6.5%	Medium	17%	-0.99%
14	Desert	Altai	0.16	5.2%	4.9%	Medium	18%	-0.80%
15	Desert-steppe	Tonkhil	0.19	5.2%	3.8%	Low	23%	-1.61%
16	Desert	Tsogt	0.16	5.1%	8.4%	Medium	19%	-1.28%
17	Desert	Erdene	0.20	4.7%	5.5%	Low	18%	-0.53%

Reference: Veco – Pasture vulnerability, LLoss - Livestock loss, LMis - Livestock miscarriage, SL – Slaughtered livestock in total livestock, AAGP – Annual average growth of population.

In terms of livestock loss, Jargalan, Khaliun, Taishir and Chandmani soums with high pasture vulnerability, and Khukhmorit soum with low pasture vulnerability act as Passive observer having livestock loss of 6.2-8.4%, livestock miscarriage of 2-7.3%, and share of slaughter animals of 12-17% (more vulnerable). In contrast, Tugrug soum with high pasture vulnerability, and Tonkhil soum with low pasture vulnerability act as regulator 2.8-3.8%, livestock loss of 4.4-5.2% and share of slaugher animal in total livestock of 21-23% (low sensitive). The average annual population growth rate between 1998 and 2018 reveals population decrease in all soums except for the Yesunbulag soum, the province center. Particularly, the population of Jargalan and Khaliun soums, where the pasture vulnerability is high, has decreased by 1.54-2.07% per year.

5. DISCUSSION

The results of the research show that the pasture vulnerability, coupled by livestock miscarriage, livestock loss and dzud, has a strong effect on change in livestock number in soums of Govi-Altai province. The pasture vulnerability is mainly caused by change in vegetation cover and drought, and impacts on miscarriage of female goats. This demonstrates the need for adaptation measures to ensure sustainability of livestock sector and to reduce risks for herders.

There is a need to investigate the cases of the passive observer Jargalan soum, and highly adaptive Tugrug soum to implement adaptation measures directed at ensuring the sustainability of pastoral animal husbandry, sustainable pasture use and mitigating the risks of herders. Because Tugrug soum has the highest pasture vulnerability, yet the risk for animal husbandry is minimal. Unlike Tugrug, Jargalan soum has the largest livestock loss and miscarriage rate, and the movement of population. It is also important to improve pasture management by taking into account the prevailing natural zones in the soum.

Reducing the impact of pastureland vulnerability due to human factors and managing the risks with minimal losses is a key requirement for the sustainability of pastoral animal husbandry. There is a need to bring traditional pastoral animal husbandry to the new stage of development. The potential measures include grazing of animals in accordance with pastoral rehabilitation capacity, increasing income of herders by slaughtering animals that did not get enough fat in autumn based on the yearly pasture vulnerability, reducing the risks by increasing hay preparation in accordance with pasture vulnerability, improving transportation and logistics network to supply livestock raw materials to the market.

The pasture vulnerability assessment has limited spatial accuracy due to lack of pasture data and meteorological stations. Highly accurate spatial information should be used in this study. In order for herders to adapt to drought, dzud and the risks of pasture vulnerability, consideration should be given to the establishment of a supply network of livestock raw materials and the use of integrated pastureland policy and planning rather than looking at government policies and programs.

In addition, the use of some pastures, specially long-distance pasture areas are limited due to lack of surface and ground water sources both for human and animal use. Pastures near water sources are mainly used by herders, resulting in the overgrazing of pastureland, which adds to the vulnerability of pastureland. Therefore, surface water data should be taken into account for further studies. In order to reduce the vulnerability of pastureland due to human factors, the number of water points in pasture areas need to be added.

6. CONCLUSION

A quantitative analysis of pasture vulnerability of 17 soums in Govi-Altai province during the period 1999-2017 was conducted in this paper, and determined how pasture vulnerability impacts on nomadic animal husbandry, herder's income and out-migration. The results identified which soum's pastoral livestock sector is more or less sensitive to the risks of pasture vulnerability.

Pasture vulnerability is a precondition of dzud disaster. Compared to the dzud disaster, pasture vulnerability is frequently occurred and caused less damage to livestock. When pasture vulnerability increases, livestock loss and livestock miscarriage increases too in the coming winter and spring, and it slows down the growth of livestock. This process is one of the main factors to directly affect the income of herders. Jargalan, Darvi, Khaliun, Tugrug soums, especially located in mountain steppe, are more vulnerable. Having high pasture vulnerability, livestock sector of Jargalan and Khaliun soums are more sensitive to pasture vulnerability. However, livestock sector of Tugrug soum, having highly adaptive capacity and high pasture vulnerability, is less sensitive to the pasture vulnerability. A careful attention should be paid to soums in the mountain steppe zone and to more sensitive soums in terms of pasture vulnerability in order to improve pasture management, reduce the risk of livestock sector and provide the sustainability of pastoral animal husbandry. In future, measures taken by Tugrug and Jargalan soums against dzud disaster and the risks of pasture vulnerability need to be investigated. The sensitivity to pasture vulnerability is very different in these two soums depending on herders' activities in pasture vulnerability.

References from Journals:

Adger, W. N., 2006. Vulnerability. Global Environmental change, pp. 268-281.

Ainong.Li, A. S., 2006. Eco-environmental vulnerability evaluation in mountainous region using remote sensing and GIS- A case study in the upper reaches of Minjiang River, China. Ecological modelling, 192, pp. 175-187.

Armitage, D. 2005. Adaptive capacity and community-based natural resource management. Environmental Management 35, pp. 703–715.

Bolortsetseg, B., Erdenetsetseg, B., Bat-Oyun, Ts., 2002. The last 40 years of pasture vegetation change. Research Institute of Meteorology and Hydrology, 24, pp. 108-114.

Brooks N, Adger WN, Kelly PM., 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Glob Environ Chang 15:151–163.

Ford, J. D., B. Smit, and J. Wandel., 2006. Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada. Global Environmental Change 16:145–160.

Maria, E. F.-G., 1999. Sustaining the steppes: A geographical history of pastoral land-use in Mongolia. Geographical Review 89, pp. 315-342.

Miyasaka, T., Okura, T., Zhao, X., & Takeuchi, K., 2016. Classification of land use on sand-dune topography by object-based analysis, digital photogrammetry and GIS analysis in the Horqin Sandy land, China. Environments.

O'Brien K, Leichenko R, Kelkar U, Venema H, Aandahl G, Tompkins H, Javed A, Bhadwal S, Barg S, Nygaard L, West J., 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob Environ Change 14, pp. 303–313.

Reynolds JF, Stafford Smith DM, Lambin EF, Turner BL, II, Mortimore M,Batterbury SPJ, Downing TE, Dowlatabadi H, Fernández RJ, Herrick JE,Huber-Sannwald E, Jiang H, Leemans R, Lynam T, Maestre FT,Ayarza M, Walker B., 2007. Global Desertification: Building a Science for Dryland Development. Science 316, pp. 847–851.

Preston BL, Yuen EJ, Westaway RM., 2011. Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. Sustain Sci 6, pp. 177–202.

Zhou, W., Gang, C., & Jianlong, L., 2014. Dynamic of grassland vegetation degradation and its quantitative assessment in the Northwest China. *Acta Oecologica*, pp. 86-96

Yanqiang.Weia, S. Y. (2017). Integrated assessment on the vulnerability of animal husbandry to snow disasters under climate change in the Qinghai-Tibetan Plateau. *Global and Planetary change, 157*, pp. 139-152.

References from Books:

Adger, N., 2003. Social aspects of adaptive capacity. in J. Smith, J. Klein, and S. Huq, editors. Climate change, adaptive capacity and development. Imperial College Press, London, UK, pp. 29–49.

Altanbagana, M., Suvdantsetseg, B., Nominbolor, K., Kherlenbayar, B., & Chuluun, T., 2015. Social ecological

vulnerability analysis for the green development policy implementation in local level of Mongolia. Proceedings of Trans-displinary research conference: Building resilience of Mongolian rangelands. Ulaanbaatar: Nutag partner, pp. 179-184.
Bazargur, D. 2005. Geography of pastoralism. Ulaanbaatar: Admon printing press, pp. 203-238.
Chuluun, T., Altanbagana, M., Ojima, D., Tsolmon, R., & Suvdantsetseg, B. 2017. Vulnerability of Pastoral Social-Ecological Systems in Mongolia. In Y. Wanglin, & G. Will, Rethinking Resilience, Adaptation and Transformation in a Time of Change, Tokyo: Springer International Publishing, pp. 73-88.
Chuluun, T. 2014. Towards Green Civilization. Ulaanbaatar.
Chuluun, T., Altanbagana, M., Tserenchunt, B., & Davaanyam, S., 2012. From Vulnerability to Sustainable development: Social ecological system of Tuin-Baidrag river basin. Ulaanbaatar, pp. 47-80.
Chuluun, T., Ojima, D., & Altanbagana, M., 2011. Vulnerability and adaptation of pastoral human-environmental systems to climate impact at multiple scales in Mongolia. International Rangeland Congress: Diverse Rangelands for sustainable society, Rosario, Argentina, pp. 196-200.
Downing TE, Bakker K., 2000. Drought discourse and vulnerability. In: Wilhite DA (ed) Drought: a global assessment, natural hazards and disasters series. Routledge Publishers, Abingdon, pp 213–230.
Ellis, J., Price, K., Boone, R., Fangfang, Y., Chuluun, T., & Mei, Y. 2002. Integrated assessment of climate change effects on vegetation in Mongolia and Inner Mongolia. Ulaanbaatar: Interprets Publishing and Printing.
Natsagdorj.L. 2009. Drought and Dzud. Ulaanbaatar, pp. 25-52.
MAS(Mongolian Academy of Science)., 1990. Mongolian National Atlas. Ulaanbaatar, pp. 144.
Tserendash.S, Bilegt.Ts., 2017. Volume IV of Mongolian Environment: Pasture, soil, use and protection in Mongolia. Ulaanbaatar.
MET(Ministry of Environment and Tourism)., 2014. Mongolia: Assessment Report for Climate Change. Ulaanbaatar: Ministry of Environment and Tourism press, pp. 39-46.

References from Other Literature:

Altanbagana, M., Kherlenbayar, B., 2016. Ecological vulnerability influence on poverty and migration in Mongolia. Consideration of National Conditions and Territorial Characteristics in Socio – Economic Development, Ulaanbaatar. pp. 224-236.
Bruck, T., 2003. Coping strategies in post-war rural Mozambique. German Institute for Economic Research, Berlin, Germany.
Ciscar JC, Iglesias A, Feyen L, Szabo L, Van Regemorter D, Amelung B, Nicholls R, Watkiss P, Chris-tensen OB, Dankers R, Garrote L, Goodess CM, Hunt A, Moreno A, Richards J, Soria A., 2011. Physical and economic consequences of climate change in Europe. Proc Natl Acad Sci USA 108, pp. 2678–2683.
JICA, & Almac.corp., 2016. Final report of Integrated Research for Regional Development. Ulaanbaatar: JICA.
Maria, E. F.-G., 2006. Land use and land tenure in Mongolia: a brief history and current issues. USDA Forest Service Prooceedings RMRS-P-39, pp. 30-36.
Moss, R., Brenkert, A., & E, M., 2001. Vulnerability to climate change: a quantitative approach. Washington: US Department of Energy.
Natsagdorj, D., & Sarantuya, G., 2004. On the assessment and Forecating of Winter Disaster (Atmospheric Caused Dzud) Over Disaster. Sixth international Workshop Proceeding on Climate Change in Arid and Semi-Arid Region of Asia, Ulaanbaatar, Mongolia, pp. 72-88.
Turner. B.L, Roger. E.Kasperson, Pamela. A.Matsone, James. J.McCarthyf, Robert. W.Corellg, Lindsey. Christensene, Noelle. Eckleyg, Jeanne. X.Kasperson, Amy. Luerse, Marybeth. L.Martellog, Colin. Polskya, Alexander. Pulsiphera, and Andrew., 2003. A framework for vulnerability analysis in sustainability science. Proceedings of National Academy of Sciences, 100(14), pp. 8074-8079.
Sanjid, J., 2002. Impact of Climate Change on Vegetation Cover and Plant, Adaptation research. Ulaanbaatar: Project report Adaptation research, Exposure of climate change on pastoral livestock.