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Assessment of Pastoral Vulnerability on Socio-Economy of Local Communities Using Geospatial Analysis

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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 pastoral vulnerability and its impacts on socio-economy of local communities are urgently needed. This study identified the impacts of pastoral 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 climate related drought and human activity related pasture use are main driving factors for the pastoral vulnerability. Four soums (administrative unit) in the Gobi-Altai province were found to have the highest level of pastoral vulnerability, and the pastoral vulnerability coupled by dzud has a strong effect on miscarriage rate of breeding livestock especially in female goats, and livestock losses. This process is one of the main factors that directly affect the income of herders, which demonstrates the need for adaptation measures to ensure sustainability of livestock sector and to reduce risks for herders. Differences in life expectancy for men and women are high in this province, suggesting further detailed studies and policies are needed to address the working conditions of herders impacted by climate change and their potential social service needs. The flexibility of the local pastoral vulnerability assessment has allowed the application of geo-visualisations in place-based problem-solving and decision-making processes in a specific socio-political context of municipal and regional governments.

Key words: pastoral vulnerability; grazing livestock; miscarriage, and local community

1. Introduction

Nomadic pastoralism is a complex human-environmental system in which livestock, pasture and herder interdepend each other [1, 2]. It has been developing as an adaptive mechanism, switching pastureland in accordance with pasture recovery capacity, for fluctuations of arid-terrestrial ecosystems [3-5]. 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

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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) [6, 7]. The annual average temperature in Mongolia over the last 70 years has increased by 2.14°C [8], which is 2-3 times higher than the annual average of the last 100 years in the world (0.74°C). During the last 74 years, the hottest 10 years has happened since 1997 [8]. 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 [9].

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 reduction 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 sudden growth of livestock, pasture degradation and shrinking of suitable pastures for livestock grazing. In the last 60 years, the degradation of pasture land has increased 2.8 times [10], pasture yield has fallen by 20-30% in almost all regions of Mongolia, and the pasture carrying capacity has dropped by 20% [11]. Some research results are warning that pastureland suitable for livestock grazing will decrease in the future [12].

To effectively align adaptation policies and prioritize implementation measures, policy makers require comprehensive information on regional and various sectors vulnerability assessments [13-15].

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 [13, 16-20]. In terms of ecological vulnerability to drought and dzud disaster, majority of studies applied in Mongolia referred to Dryland Development Paradigm (DDP) [21]. Natsagdorj & Sarantuya (2004) [22] assessed impact of drought and dzud on livestock loss due to extreme weather, Chuluun et al. (2012, 2017) [7, 23] 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 [19] of ecosystems due to climate and human impacts to adapt by perceiving, mitigating and taking advantage of new opportunities created by change [17, 24]. Researchers studying climate change adaptation [19, 25-26] 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) [2] 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 (Smallest administrative unit) livestock sector and herders are susceptible to pastoral vulnerability. It is important for sustainable pasture use, pasture management planning, and effective implementation of adaptive measures [17, 18].

This study aimed to conduct a quantitative analysis using main drivers and threshold value of pastoral vulnerability caused by climate change and human factors and assess its impacts on socio-economics of herding societies in the soum levels of Gobi-Altai province, from 1999 and 2017 which is important to

provide an adaptation options for the policymakers and local communities.

2. Method and Data

2.1 Study Area

Located in the southwestern part of Mongolia and bordered by the People`s Republic of China in the southern part, Gobi-Altai aimag (province) 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 80-135 mm, most of the rainfall is during summer season. As of 2018, 5.7% (3513370 livestock) of the total livestock graze in Gobi-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, decreasing by 18.4% compared to 1998 value, and 32.1% of the population is settled in Altai city, (Esunbulag soum) which is the center of Gobi-Altai province. It is among the provinces with highly vulnerable ecosystem and the largest population out-migration.

2.2 Used Data Source

This research used statistical, meteorological, and remote sensing data covering the period of 1998-2017, collected from various sources. The meteorological 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, and eMODIS satellite data [1], the pasture carrying capacity data is derived from the Mongolian National Atlas 1990, and other relevant statistical datasets are obtained from the National Statistical Offices of Mongolian.

2.3 Pastoral vulnerability Assessment

The methodology of assessment of grazing pasture vulnerability to climate change [23], is modified for pastoral vulnerability assessment in this paper. Also, DDP application [21], key factors, affecting pasture productivity, and threshold values of each key factor are applied to determine pastoral vulnerability. To assess pastoral vulnerability, main drivers are drought, vegetation cover changes and pasture use. However, if each variable exceeds the threshold value, it will reduce pasture productivity.

Pastoral vulnerability was calculated by Eq. (1):

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

Here, $V_{t,i}^{eco}$: Pastoral 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

2.3.1 Drought Index

Vulnerability mainly defines drought risk rather than the frequency and severity of weather anomalies [27, 28]. 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 [29]. To assess drought index, S = 3 value is chosen as the threshold value for pastoral vulnerability.

Ped's index and share of area affected by drought were calculated by Eqs. (2) and (3):

$$S_{summer} = \sum_{t=1}^{n}\left(\frac{T_j - \overline{T}_j}{\sigma_T}\right) - \sum_{t=1}^{n}\left(\frac{R_j - \overline{R}_j}{\sigma_R}\right) \quad (2)$$

$$\text{If } S > 3 \quad \Delta Si = \frac{S_{t,i}}{S_i} \quad (3)$$

[1] https://earthexplorer.usgs.gov/.

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*;

$\sigma_T\sigma_R$: 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*.

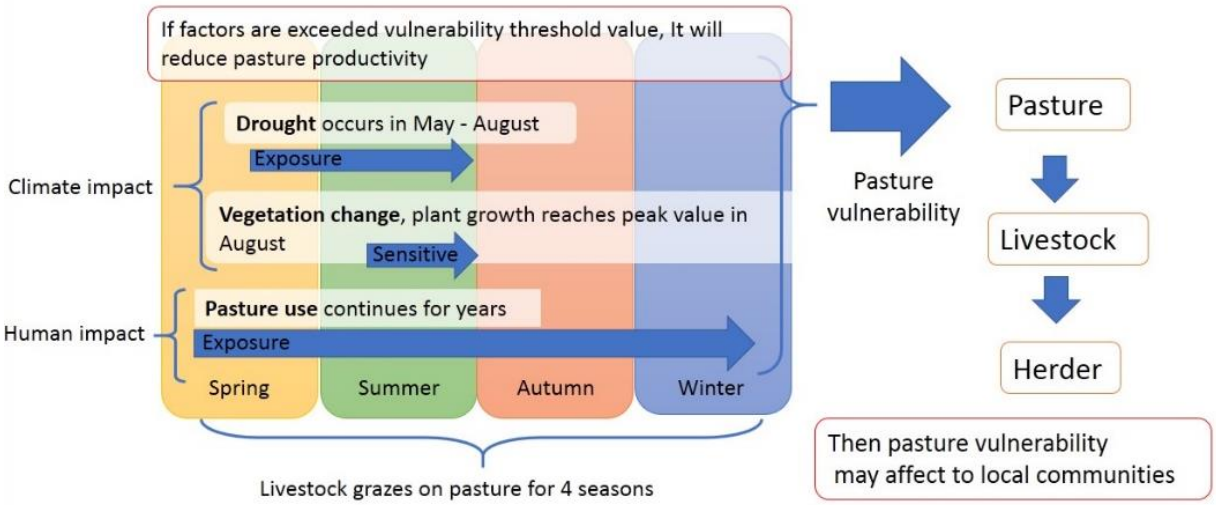

Fig. 1 Pastoral vulnerability framework.

2.3.2 Pasture Use

In 1990, the number of animals that were suitable for grazing in 1-hectare area in a soum was determined [30]. These values were selected as the threshold value of vulnerability of pasture use and Tserendash. C's (2006) [31] pasture use index was modified in pastoral vulnerability assessment.

If the number of livestock per hectare of pastureland exceeds the suitable number of livestock [30] or pasture carrying capacity, it will adversely affect pasture biomass in such ways as decreasing pasture yield and increasing pasture ecosystems vulnerability. Pasture use index was calculated by Eq. (4):

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

a_i– Coefficient to transfer a type of livestock i to sheep head; L_i –number of livestock of type i in a soum

S– Total pasture land area of a soum;

Coefficient to transfer livestock of type i 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 $\Delta N > 1$ it means that vulnerability is increasing. Pasture use index was calculated by following Eq. (5).

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

Here, ΔN: Pasture use index in a soum; N: Number of livestock per hectare area in a soum pastureland in sheep heads; N_0: Pasture carrying capacity, suitable number of livestock per hectare area in a soum pastureland in sheep heads

2.3.3 Vegetation Cover Change

Yields of pasture vegetation in Mongolian territory reach peak levels in August of every year spatially depending on drought, climate change variability and pasture use [1, 32]. 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 pastoral vulnerability as pastureland degradation and reduction of suitable area for livestock grazing [33, 34].

The vulnerability assessment considers how much of the total area of a soum has been affected by changes in vegetation cover or degradation. Alternatively, the degraded area was calculated whether or not it exceeds the threshold value of vegetation vulnerability for each pixel. The threshold value of the vegetation vulnerability was selected by difference of the mean value and standard deviation between 1999 and 2017 and was 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 Eqs. (6) and (7)

$$\Delta V_{ti} = \left(V_{ti} - \left(\frac{\sum_t^n V_{ti}}{n} - \sigma\right)\right) \quad (6)$$

$$\Delta V_{ti} < 0 \qquad \Delta Vci = \frac{Vst,i}{Vsi} \quad (7)$$

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.*

2.4 Correlation Analysis of Pastoral Vulnerability on Socio-Economics of Local Communities

In this part of the study, we assessed the impacts of pastoral vulnerability on the socio-economic variables of selected pastoral communities. When examining a pastoral socio-ecological system, it is important to examine how vulnerable pastoral ecosystem is to human- and climate-induced change, including which areas are most affected and which indicators are more sensitive to the effects of the change on the herders' socio-economic condition. Pearson correlation analysis [35] was applied to measure the strength of the relationships among variables. We performed a correlation analysis using 19 social, economic, and environmental indicators. The most significant results, miscarriage rates among breeding stock in the livestock sector, savings and loan of herders and insurance in the economic sector, and demographic changes and human life expectancy in the pastoral society are discussed in this paper.

3. Assessment of Pastoral Vulnerability

3.1 Vegetation Cover Change

The eMODIS satellite has been used for vegetation NDVI data for the second 10 days of August with a peak of vegetation, from 1998 to 2017. After this period the vegetation is reduced and the crop in the pasture is used for coming winter and spring grazing. In Gobi-Altai province, the average NDVI changes is relatively high in mountain steppe, middle in desert steppe, and lowest in desert region. The changes especially occurred in the bordering places between soums. The frequency of changed vegetation cover in the areas relatively high in Tsogt, Darvi, Bugat, Bayan-Uul, Esunbulag, and Biger soums (Fig. 2a).

3.2 Drought Index

Based on precipitation and temperature data in meteorological observation stations, drought index was calculated, and mapped drought spatial distribution 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 times) in Altai, Tsogt, Bayan-Uul and Khukhmorit soums, average (4 to 6 times) in Tseel, Bugat, Tonkhil, Tugrug, Biger, Darvi and Esunbulag soums, and highest (6 to 9 times) 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 (Fig. 2b).

3.3 Pasture Use

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 in 1990 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. The average pasture use in the province has been evaluated for the last 20 years: it has been higher in nine soums, medium in six soums and low in four soums. Depending on the number of livestock and grazing land size, the pasture use of each soum is expected to grow in the future. Because there is no limiting factor other than dzud and pastoral vulnerability.Due to increased number of livestock in the small size of land, pasture use value is particularly high in Esunbulag soum, the province center, in the mountain steppe zone. The carrying capacity of pasture land was determined at the soumlevel by the Mongolian government [30], which was used for the reference. Currently, pasture carrying capacity has exceeded in majority of 17 soums, and Bugat soum only is under capacity level (Fig. 2c).

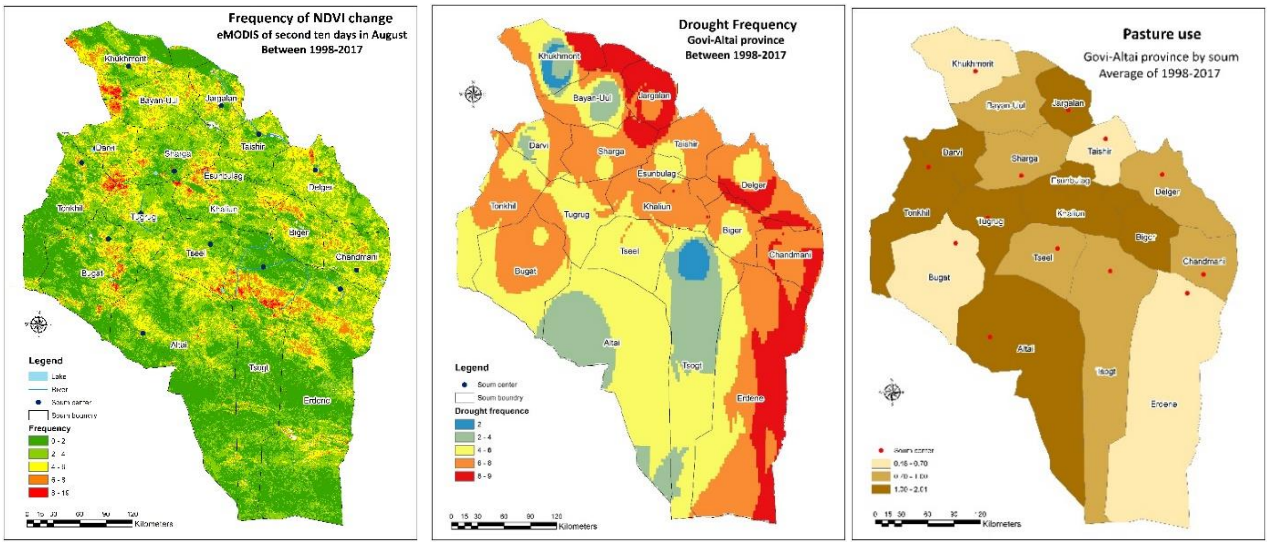

Fig. 2 a) Frequency of NDVI change between 1999 and 2017, b) Drought frequency, c) Average pasture use.

3.4 Integrated Pastoral Vulnerability

The pastoral vulnerability during the last two decades is presented in Fig. 3. In the map, base colors show the level of pastoral vulnerability and the graph shows the average value of components in each soum. As seen from the result, Darvi, Jargalan, Chandmani, Biger and Khaliun soums have been evaluated to have the highest pastoral vulnerability under climate and human activity related impacts. The pastoral vulnerability interdepends on each of three indicator values, where the most affective variable is drought followed by pasture use. Human related activities, in particular, increased number of livestock due partly to the lack of the accessibility to markets and low product price and productivity, water scarcity in grazing areas, and ineffective pasture managements are considerable issues.

Table 1 presents the affecting level of vulnerability in the case area through indicators on human, livestock and pasture.

4. Impact of Pastoral 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, cashmere and the livestock after slaughter such as skin, hides and meat. Until 1999, the number of livestock, slaughtered livestock and growth of total livestock in Gobi-Altai province remained steady. However, due to the pastoral vulnerability combined with dzud disasters in 2000-2002 and in 2009-2010 the stability had been lost. 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 (Fig. 4).

The herders decreased the number of livestock for consumption per year down to 0.1-0.3 million sheep heads to increase their herds. After the disaster, the herders' income declined due to reduction in the productivity of live animals and the number of slaughtered livestock dropped, ultimately resulting in the increased number of poor households. Also, the reduction in income instigated herders' interest in raising more goats in order to increase productivity from live animals. However, it is possible to reduce the herders' risk and increase their income by increasing the number of slaughtered livestock for consumption.

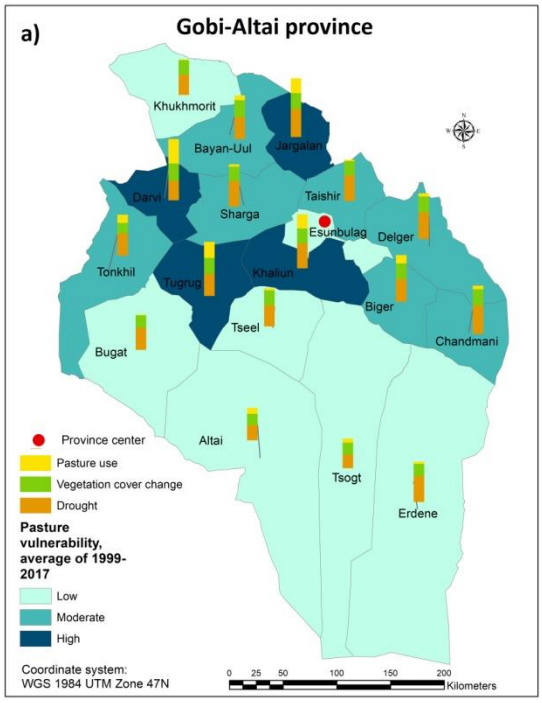

Fig. 3 Levels of pastoral vulnerability and component indicators in Gobi-Altai province.

Table 1. Impacts of pastoral vulnerability

Vulnerability level	Gobi-Altai		
	People %	Livestock %	Pasture area %
High	14	20.8	12.6
Moderate	28.4	39.8	26.8
Low	57.5	39.4	60.6

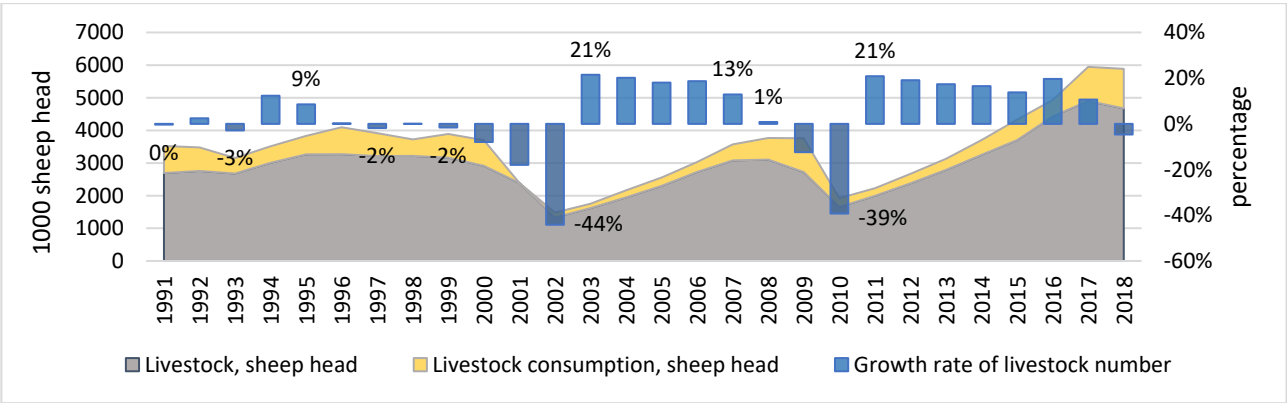

Fig. 4 Comparison of dynamic changes in total number of livestock, number of livestock consumption and growth rate of livestock number in Govi-Altai province.

Pastoral vulnerability is a key factor in increased livestock miscarriage and loss, which may negatively impact the herders' income. *Dzud* is one of the main causes of livestock loss [29], but its frequency is low compared to pastoral vulnerability. Livestock miscarriage and loss increased in the winter and spring months following the years with high pastoral vulnerability. High pastoral vulnerability for 2-3 consecutive years leads to insufficient fat intake in the livestock animals during the summer months,

negatively impacting their ability to survive during the upcoming cold winter months and, ultimately, increasing their mortality rates. In the years with low pastoral vulnerability, the number of livestock animals increased rapidly (Fig. 5). In other words, increased pastoral vulnerability results in increased livestock mortality and slower growth, whereas, decreased pastoral vulnerability impacts positively on livestock growth. This is a key factor affecting livestock miscarriage, livestock loss, and livestock growth.

Statistical correlations were calculated for pastoral vulnerability and the miscarriage rate among breeding stock for four types of female animals (Table 2). High miscarriage rates devalue the herders' labour and reduce their income. In Gobi-Altai, 86%-98% of the total livestock are small animals (i.e., sheep and goats); goats comprise 45%-76% of the total herd. The miscarriage rates of small livestock animals were more susceptible to pastoral vulnerability, and the pastoral vulnerability was strongly correlated with female goats' miscarriage rates in this province. However, no strong correlations were found for other herd types. To increase the number of livestock, it is necessary to have a miscarriage rate to a minimum level.

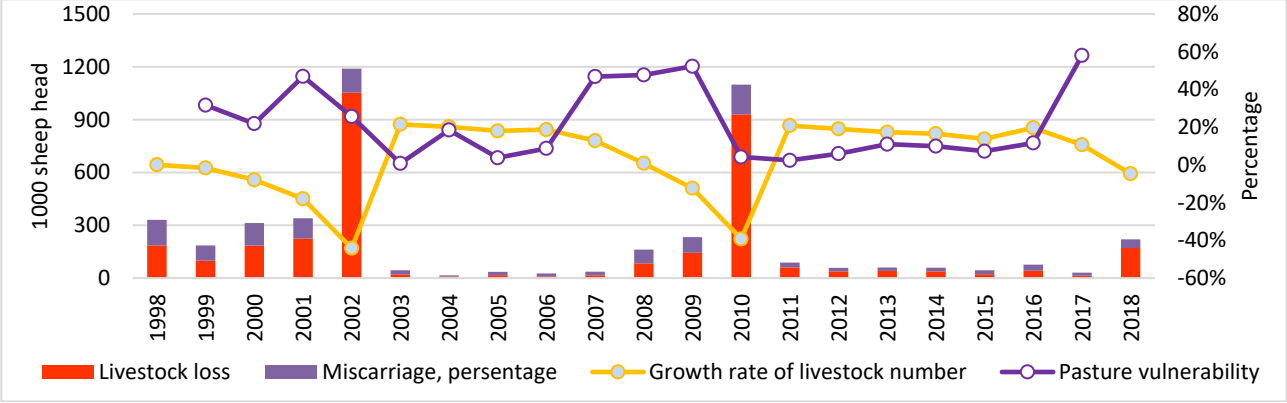

Fig. 5 Comparison of pastoral vulnerability, growth rate of livestock number, livestock loss and livestock miscarriage.

Table 2 Correlation analysis of pastoral vulnerability and livestock miscarriage rates among different types of livestock.

Name of Soums	Mares	Cows	Female sheep	Female goats
Delger	0.29	0.47	0.41	0.28
Taishir	0.08	0.29	0.10	0.34
Tugrug	0.17	0.43	0.27	0.37
Chandmana	0.50	0.26	0.49	0.50
Khukhmorit	0.36	0.32	0.39	0.51
Esunbulag	0.50	0.13	0.63	0.53
Altai	0.29	0.56	0.55	0.56
Dariv	0.40	0.46	0.30	0.57
Khaliun	0.17	0.46	0.51	0.60
Biger	0.29	0.34	0.36	0.61
Jargalan	0.24	0.57	0.57	0.61
Tsogt	0.52	0.36	0.49	0.64
Bayan-Uul	0.07	0.25	0.37	0.68
Sharga	-0.04	0.31	0.58	0.68
Erdene	0.45	0.47	0.58	0.69
Tonkhil	0.35	0.17	0.57	0.72
Tseel	0.30	0.33	0.29	0.74
Bugat	0.29	0.62	0.74	0.86

4.2 Economic Factor

One of the criteria for expressing economic capability of herders is the short and long-term savings of banks and financial institutions. The amount of money savings and its growth will show the economic activity and capacity of the soum and the cash accumulation will be important to overcome the household risks and to improve the economic resources. In contrast, herders need to get a loan from banks and financial institutions if they do not have sufficient financial resources to increase their income, buy their supplies, and improve their living conditions. As a result, herders use livestock, the main source of their income, as collateral. If somehow there is a risk for herder's source of income, repayment of loans will slow down or be delayed resulting in debt burden on herders. Herders might face risks, such as losing the

rest of the livestock as collateral, and therefore, getting too much bank loan is a risky business for herders. Total loans and savings in Gobi-Altai province amounted to 6.9 billion tugrug in 2010, and 59 billion tugrug in 2018. In 2010 the loan debt was higher than the deposit amount, and the amount of loans and deposits have become similiar in 2018 (Fig. 6).

As seen from Fig. 7a, the savings per person is more than 2.6 million tugrug in Altai and Taishir soums, and less than 1.2 million tugrug in Tonkhil, Darvi, Sharga, Khukhmorit, Khaliun, Chandmani, Tsogt and Erdene soums. The base color shows a deposit per capita and the graph shows pastoral vulneraility by soums (Fig. 7a), where soums with high vulnerability have smaller amount of savings. In Fig. 7b, base color is a bank loan per capita and the graph shows pastoral vulnerability. Soums with high vulnerability tend to have smaller amount of loans that may be explained by low income sources for repayment. The loan per person is more than 2.1 million tugrug in Altai and Esunbulag soums and less than 1.35 million tugrug in Darvi, Bayan-Uul, Bugat, Tugrug, Tseel, Khaliun and Biger soums (Fig. 7b).

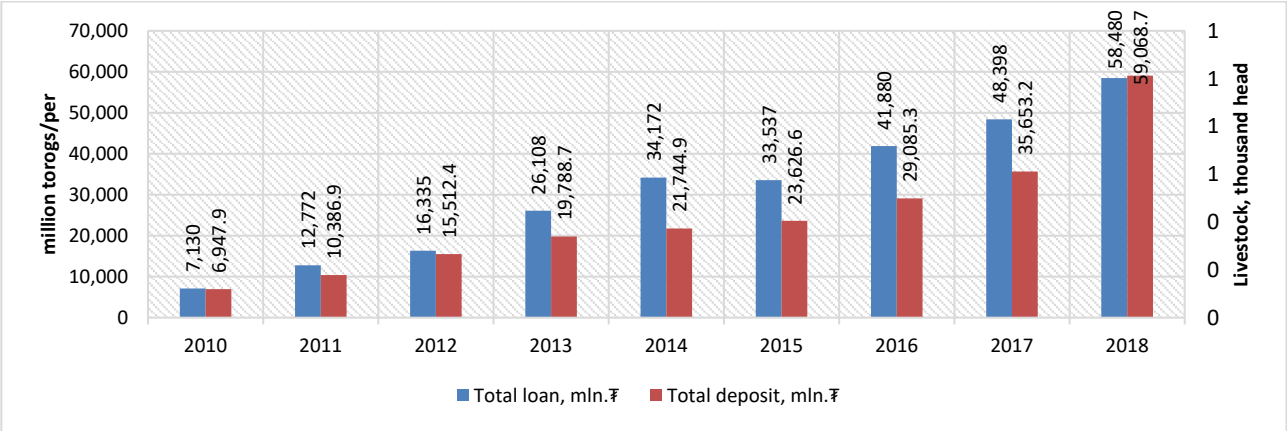

Fig. 6 Bank savings and loan.

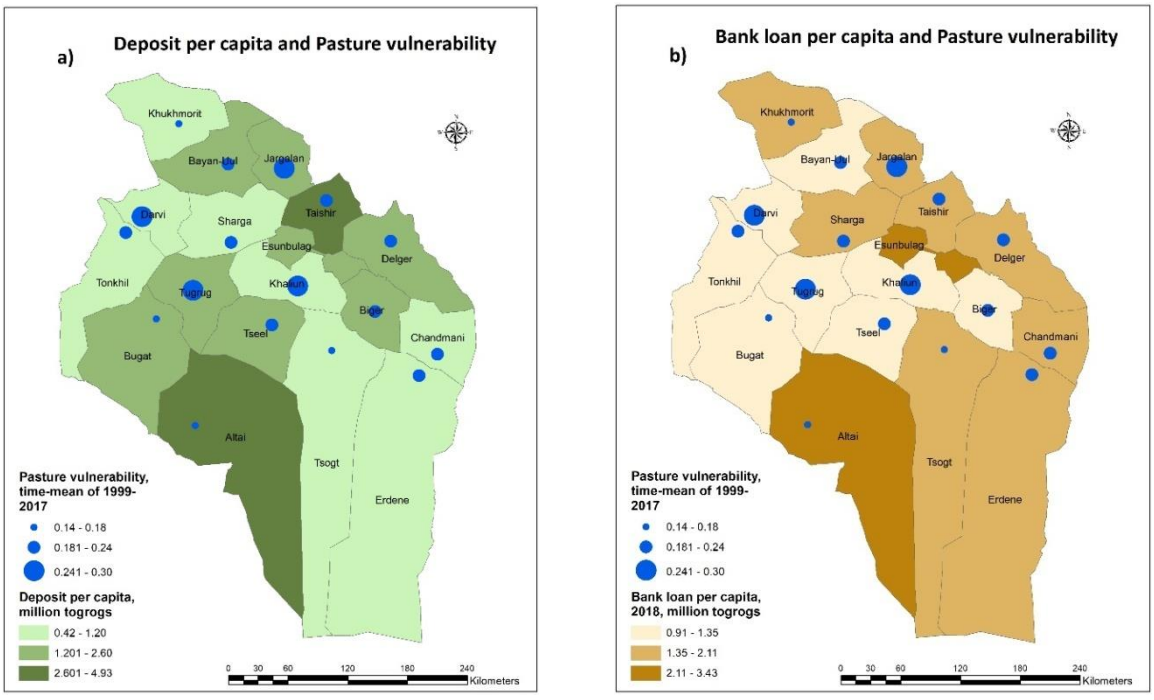

Fig. 7 a) Savings vs. pastoral vulnerability per person; b) Loan vs. pastoral vulnerability per person.

Insurance is one of the adaptation options to reduce pastoral vulnerability. In 2010, 0.9 thousand households (20% of total herder households) and 112 thousand livestock have been insured in Gobi-Altai province, and these numbers increased to 1.9 thousand households (26% of total herder households) and 485 thousand livestock in 2018. The Fig. 8 shows the number of insured livestock and herding households vs. number of livestock loss. Herders' understanding about risk reduction mechanisms has improved, and therefore, they take mitigation measures through increasing the number of insured livestock and households.

4.3 Social Demography

The population in a soum lives in 2 main types of areas: town center and rural herding places. Majority of the rural population are herders. Herders are affected by pastoral vulnerability coupled with dzud disaster leading to poverty, as well as population change and migration of the population. The total population of the province was 73 thousand in 1995, it declined to 53 thousand from 1998 to 2013 and increased to 58 thousand within 5 years from 2014 to 2018 (Fig. 9).

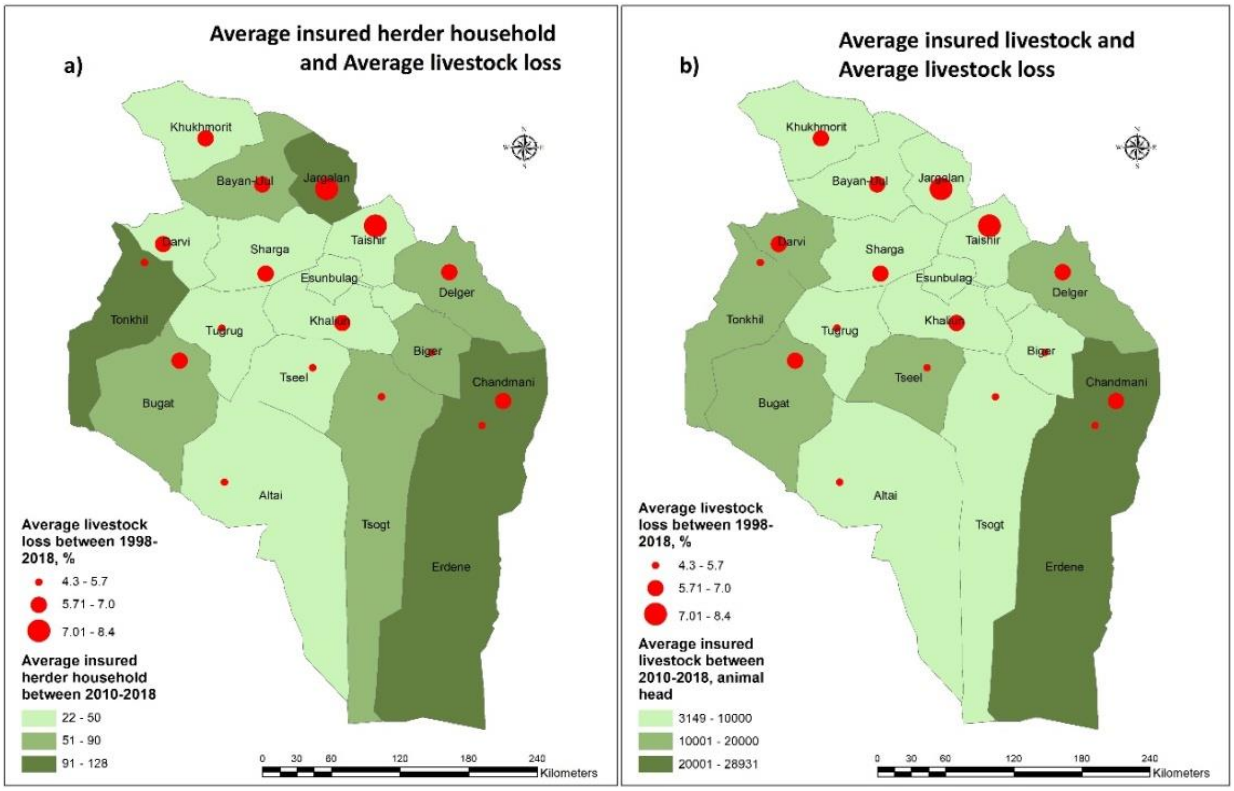

Fig. 8 a) Number of insured herding household, and b) Number of insured livestock vs. livestock loss.

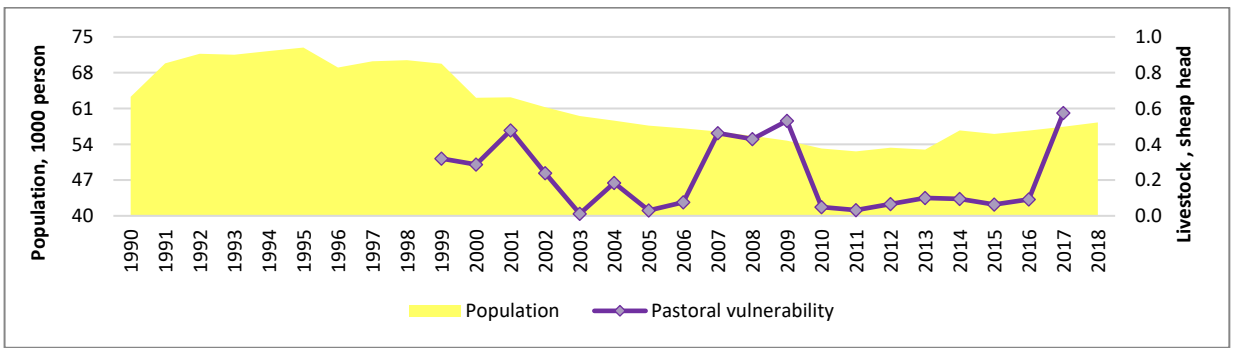

Fig. 9 Population change with pastoral vulnerability.

Tsogt, Delger, Bayan-Uul and Esunbulag soums have more than 3,000 inhabitants, and Darvi, Jargalan, Sharga and Taishir soums have a population of less than 2000 (Fig. 10a). Darvi and Jargalan soums with high pastoral vulnerability have a population of up to 2000 and up to 350 herder households. Khaliun and Tsogt soums have more than 500 herder households, and Darvi, Tugrug, Taishir, Altai, Bugat and Tseel soums have up to 350 herder households. Herder households constitute over 60 percent of total households in 8 soums, 50-60 percent in 6 soums, and less than 50 percent of total populations in 4 soums (Fig. 10b).

The net migration of the population has been negative from 1993 to 2016, with the population migration out of the province and soums (Fig. 11). In particular, the out-migration increased in 2002 and during 2008-2010, the years with high pastoral vulnerability.

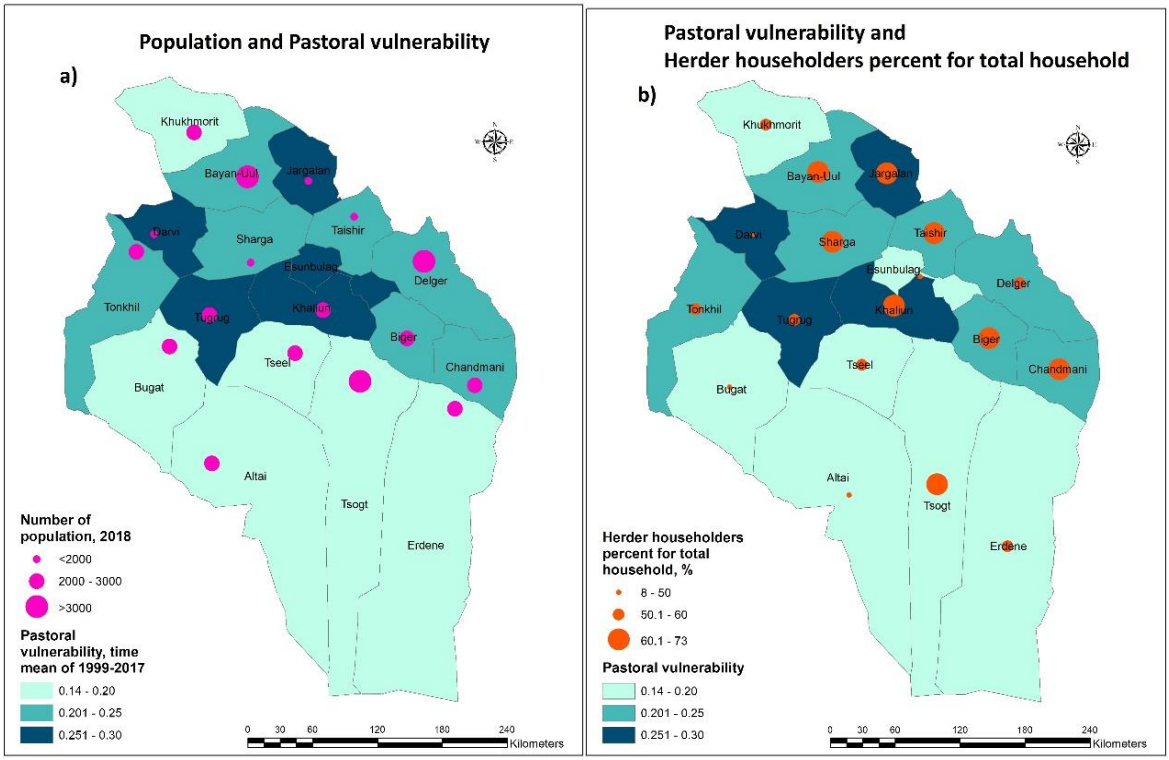

Fig. 10 a) Population vs. pastoral vulnerability, b) Proportion of herder households in total households vs. pastoral vulnerability.

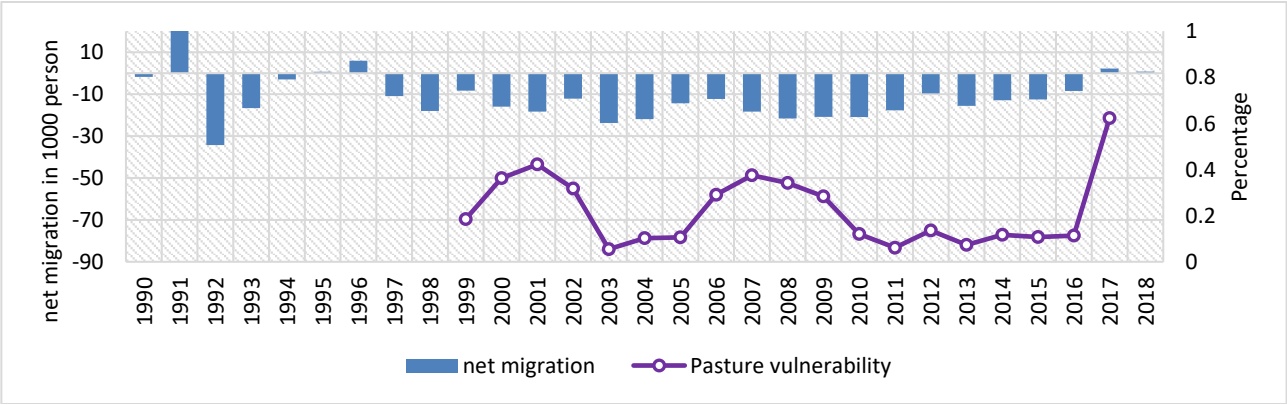

Fig. 11 Net migration vs. pastoral vulnerability.

During the last 20 years, the life expectancy in Gobi-Altai province has reached the national level (Fig. 12). The difference of life expectancy between men and women was 5 years in 2000 and 9 years in 2018. It shows that the average life expectancy of men over the last 20 years has increased by 5 years, while that of women has increased by 10 years. Herders, especially men are more affected by pastoral activities due to hard working condition with harsh climate and other limited services of social systems in Gobi-Altai province. In 2008, the average life expectancy of men decreased from 61 to 59 compared to the previous year, while it dropped from 68 to 67 for the counterpart. When pastoral vulnerability is high for 2-3 consequent years, such as 2000-2003, 2007-2009 and 2012-2017, the life expectancy of men is constant or decreases. The numbers suggest that men are more sensitive to pastoral vulnerability. This result is a considerable issue, especially in Gobi-Altai province, as well as at the national level for pension system policy related to men.

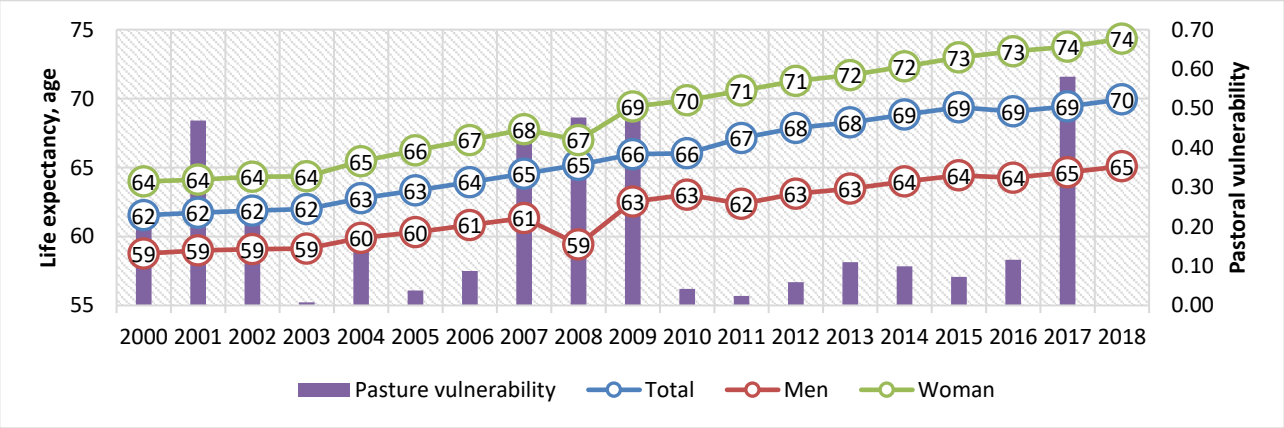

Fig. 12 Life expectancy .

5. Discussion

The pastoral vulnerability in the case area is influenced by each of the three indicator values; the variable with the most significant impact is drought, followed by pasture use. Four soums in Gobi-Altai province were found to have the highest level of pastoral vulnerability based on climate and human activity related impacts. The results of the research show that the pastoral vulnerability, coupled by dzud has a strong effect on miscarriage rate of breeding livestock, especially female goats, and livestock loss in soums of Gobi-Altai province. This demonstrates the need for adaptation measures to ensure sustainability of livestock sector and to reduce risks for herders. The impacts of pastoral vulnerability on economic factors, bank savings and loans for herders are relatively effective. Differences in life expectancy for men and women are high in this province, suggesting further detailed studies and policies are needed to address the working conditions of herders impacted by climate change and their potential social service needs.

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 nomadic pastoralism, sustainable pasture use management or strong policy and adaptation experiences and the knowledge options of herders. Because Tugrug soum has the highest pastoral vulnerability, yet the risk for animal husbandry is minimal. Unlike Tugrug, Jargalan soum has the largest livestock loss and miscarriage rate, and the population migration. It is also important to improve pasture management by taking into account the prevailing natural zones in the soum.

Reducing the impact of pastoral vulnerability due to human factors and applying risk management with minimal losses and manageable pasture rotationsare a key requirement for the sustainability of nomadic pastoralism. There is a need to bring traditional grazing system to the new stage of development. The potential measures include grazing of livestock in accordance with pasture capacity, increasing income of herders through developed market and new system for raw materials production, grazing of animals to get enough fat in autumn, reducing the risks by quick information transformation, adaptive knowledge sharing and implementation, increasing hay and forage preparation, establishment of a supply network for improving transportation and logistic services forherders` movement process, part time grazing, and marketing for livestock raw materials.

In addition, the use of some pastures, speciallylong-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 point overgrazing. Therefore, surface water data should be taken into account for further studies. In order to reduce the vulnerability of pastureland due to human factors, a number of water points in pasture areas need to be added.

6. Conclusion

The study applied geospatial tools to assess pastoral vulnerability, and conducted correlation analyses of variables related to the socio-economics of pastoral societies by evaluating key factors developed by the research team and analysed the relevance of factors in the socio-economic conditions of herding society over the past 20 years in the selected area of western Mongolia. The most significant variable was climate change-related drought, followed by intensive pasture use in the case areas. The study findings reveal that pastoral vulnerability results in increased miscarriage rates in female goats, which is reflected in high correlation values of 0.5-0.8. This process is one of the main factors to directly affect the income of herders. Jargalan, Darvi, Khaliun, and Tugrug soums, located in mountain steppe, have high pastoral vulnerability. Livestock sector of Jargalan and Khaliun soums are more sensitive to pastoral vulnerability, while livestock sector of Tugrug soum, having high adaptive capacity, is less sensitive to the pastoral vulnerability. A careful attention should be paid to soums in the mountain steppe zone and to more sensitive soums in terms of pastoral vulnerability in order to improve pasture management, reduce the risk of livestock sector and provide the sustainability of nomadic pastoralism. This demonstrates the need for adaptation measures to ensure sustainability of livestock sector and to reduce risks for herders. Differences in life expectancy for men and women are high in Gobi-Altai, suggesting further detailed studies and policies needed to address the working conditions of herders impacted by climate change and their potential social service needs. The flexibility of the local pastoral vulnerability assessment has allowed the application of geo-visualisations in place-based problem-solving and decision-making processes in a specific socio-political context of municipal and regional governments.

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