OPEN ACCESS
PAPER

Mongolian Journal of Geography and Geoecology - MJGG

Received: 09 May 2025; Accepted: 10 June 2025; Published online: 1 September 2025
https://doi.org/10.5564/mjgg.v62i46.4124

Assessing climate hazard risks for Mongolian herders: A county-level study in Khovd, Bayankhongor, Dundgovi provinces

Saruul Galtbayar[1,3], Altanbagana Myagmarsuren[1,*], Urantamir Gankhuyag[1], Otgonkhuu Tsedev-Ish[1], Dong Suocheng[2], Masato Shinoda[3], Munkhjargal Erdenebadrakh[4]

[1]*Institute of Geography and Geoecology, Mongolian Academy of Sciences, Ulaanbaatar 15170, Mongolia*
[2]*Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China*
[3]*Nagoya University, Nagoya, Japan*
[4]*Information and Research Institute of Meteorology, Hydrology and Environment of Mongolia, Ulaanbaatar, Mongolia*

***CORRESPONDING AUTHOR**
Altanbagana Myagmarsuren
altanbaganam@mas.ac.mn
ORCID
0000-0001-6196-1081

CITATION
Saruul G, Altanbagana M, Urantamir G, Otgonkhuu Ts, Dong S, Masato Sh, Munkhjargal E (2025) Assessing Climate Hazard Risks for Mongolian Herders: A County-Level Study in Khovd, Bayankhongor, Dundgovi Provinces. *Mongolian Journal of Geograhy and Geoecology,* 62(46), 1–7. https://doi.org/10.5564/mjgg.v62i46.4124

ABSTRACT

Mongolian herders are particularly vulnerable to climate change, as their livelihoods depend heavily on livestock production. Understanding the effects of climate hazards such as drought and dzud is crucial for planning and implementing the appropriate responses and effective adaptive measures. In this research, risk is defined as the potential for adverse consequences for herders due to hazardous climatic conditions, and is explained through 4 components including climate hazard, exposure, vulnerability, and response. The purpose of this study is to assess climate hazard risks of herders at the county (soum) level and explore the varying contributions of risk components. Based on a literature review and data availability, 15 factors of risk were selected including temperature and precipitation change, drought and dzud frequency, pasture use index, livestock loss, ratio of seasonal pastureland, water availability, poverty, dependency ratio, education, bank savings, prepared hay and forage, barns, and index-based livestock insurance. Principal Component Analysis (PCA) was used to aggregate the factors within 4 components of risk, and the composite risk index (RI) was calculated using the principal component scores at the soum level in Bayankhongor, Khovd, and Dundgovi provinces of Mongolia. The average RI was 19.2 in Bayankhongor, 14.2 in Khovd, and 17.0 in Dundgovi province. The results highlight the spatial heterogeneity of risk, emphasizing that the northern soums of Khovd and Bayankhongor, and the northeastern soums of Dundgovi are particularly susceptible to climate-related hazards. On the other hand, better hay and forage preparation in Khovd province contributed to its lower overall risk index. Enhancing long-term preparedness measures, such as hay and forage preparation and barn availability, alongside social and financial support mechanisms for vulnerable herder households is crucial for strengthening resilience.

KEYWORDS

Climate hazard, Risk, Assessment, Herders

1. INTRODUCTION

Annual near surface temperature over Mongolia has increased by 2.46°C between 1940-2022, the cold season precipitation has increased by 19%, high intensity rainfall has increased, and the dryness has intensified due to climate change [1]. Mongolian herders are particularly vulnerable to these changes, as their livelihoods depend heavily on livestock production. Livestock losses due to droughts and harsh winter conditions (dzud) are causing a cascade of social issues including increased poverty, unemployment, and internal migration in Mongolia [2].

Understanding the effects of climate hazards such as drought and dzud is crucial for planning and implementing the appropriate responses and effective adaptive measures. In 2025, the Mongolian government submitted its National Adaptation Plan to Climate Change, outlining various adaptation goals and actions, including those targeting the livestock sector [3]. Comprehensive assessments of climate-related risks and vulnerabilities at local and regional scales are essential to support informed decision-making by local governments.

Climate change, through hazards, exposure, and vulnerability generates impacts and risks that can surpass limits to adaptation and result in losses and damages [4]. Quantitative studies and assessments of risks or vulnerabilities have been conducted in many countries including Mongolia [2, 5, 6], employing different spatial scales, indicators/variables, and methodologies. These studies generally express risk or vulnerability by indexing and aggregating quantitative variables that define risk and its components [7, 8, 9].

However, many of the previous studies have focused on environmental, ecological, and disaster-related aspects, with limited consideration of social and economic indicators. In particular, there is a lack of research conducted at the soum level. The purpose of this study is to assess climate hazard risks of Mongolian herders at soum level, and explore the varying contributions of risk components.

2. RESEARCH METHODS

In this research, risk is defined as the potential for adverse consequences for herders due to hazardous climatic conditions which are increasing due to climate change. Four components of risk include climate hazard, exposure, vulnerability, and response [4], [10], and the components of risk are defined as follows:

$$R = f(haz, exp, vul, res)$$

R –Risk, the probability or potential for adverse consequences
haz – Climate hazard, hazardous climatic conditions that are increasing due to climate change
exp – Exposure, presence of people, livestock, or assets in places and settings that could be adversely affected
vul – Vulnerability, predisposition to be adversely affected
res – Response, strategies, and measures taken to manage, reduce, or adapt to the impacts

To identify the factors of risk in the context of this research, a literature review on international and domestic studies was conducted [11]. Various factors are used globally, depending on the country's climatic, social, and economic characteristics and the scope of the study. Based on the review and data availability, 15 factors were selected for this study. These include: temperature and precipitation change, drought and dzud frequency, pasture use index, livestock loss, ratio of seasonal pastureland, water availability, poverty, dependency ratio, education, bank savings, prepared hay and forage, barns, and index-based livestock insurance (Figure 1).

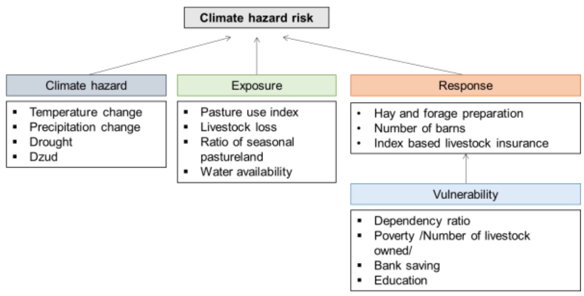

Figure 1. Risk framework and indicators

The necessary data for calculating each indicator were collected at the soum level (Table 1). Monthly average air temperature, total precipitation, and biomass data were obtained from the Information and Research Institute of Meteorology, Hydrology and Environment of Mongolia (IRIMHE). Meteorological data were collected at 24 stations in Khovd, Bayankhongor, and Dundgovi province between 1994-2024. Each dataset was interpolated using Inverse Distance Weighting (IDW) interpolation method to estimate the meteorological conditions at the center of each soums. To calculate long-term temperature and precipitation change, ERA5 reanalysis data was used [12]. Biomass data were used to calculate the pasture carrying capacity with the methodology provided by the National Statistics Office of Mongolia (NSO) [13]. All relevant statistical data between 2011-2023 were obtained from the NSO [14]. These data were averaged or aggregated over 10-30 years depending on their characteristics. As for the social indicators of vulnerability, data from 2023 were used to reflect current conditions.

Table 1. Indicators of risk and their description

Climate hazard		
Summer temperature change	*Tsum*	Average temperature of May-Aug since 2000 compared to the base year (1970-1999)
Summer precipitation change	*Psum*	Average total precipitation of May-Aug since 2000 compared to the base year (1970-1999)
Winter precipitation change	*Pwin*	Average total precipitation of Nov-Feb since 2000 compared to the base year (1970-1999)
Drought	*drought*	Frequency of years with drought index (Ped index of May-Aug) higher than 1.5
Dzud	*dzud*	Frequency of years with dzud index (Ped index of Nov-Feb) lower than -1.5
Exposure		
Pasture use index	*pas_use*	The ratio of existing livestock number compared with pasture carrying capacity
Livestock mortality rate	*ls_mort*	Percentage of adult livestock loss
Water availability	*water*	Percentage of pastureland with close distance to water source
Ratio of seasonal pastureland	*sea_ter*	Ratio of pastureland suited for four season usage
Vulnerability		
Poverty	*poverty*	Percentage of herder households with less than 200 livestock
Bank saving	*saving*	Bank saving per person
Dependency ratio	*d_ratio*	Percentage of population under 15 and over 65 years old
Education	*edu4*	Percentage of herders with elementary or lower education
Response		
Index-Based Livestock Insurance	*IBLI*	Percentage of herder households taking up index-based livestock insurance
Prepared hay and fodder	*hay_fod*	Hay and fodder preparation per sheep unit
Number of barns	*barn*	Number of barns per herder household

Principal Component Analysis (PCA) was used to aggregate the factors within 4 components of risk, and the composite risk index (RI) was calculated using the component scores of each soums. The Kaiser–Meyer–Olkin (KMO) test was conducted to ensure the suitability of the dataset for PCA. Principal components with eigenvalues greater than 1.0 were used for the assessment. The signs of the principal component scores were adjusted based on the relationship to the overall risk. To facilitate comparability and eliminate negative values, a constant was added to the risk indexes.

The study areas are Khovd, Byankhongor, and Dungovi provinces of Mongolia. These provinces represent different natural regions, climates, and socio-economic characteristics. The assessment was conducted on a total of 49 soums excluding provincial center soums.

3. RESULT AND DISCUSSION

3.1. PCA

Climate hazard

Based on the PCA on the climate hazard component, the first principal component (PC1) was used for risk assessment. The eigenvalue of PC1 was higher than 1, which explained 56.8% of the total variance. Summer temperature increase had the highest positive contribution to PC1, while summer and winter precipitation change had the highest negative contribution to PC1. The first component represents the warming and drying trends in summer, as well as an inrease in winter precipitation (Figure 2).

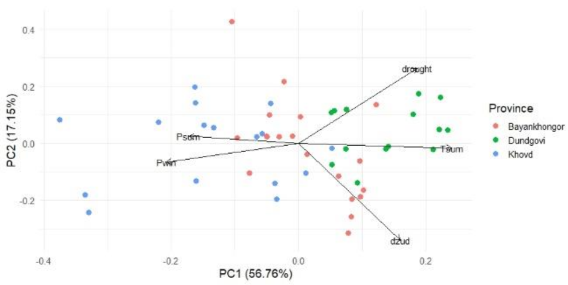

Figure 2. PCA biplot of climate hazard component

Exposure

Based on the PCA on the exposure component, PC1 was used for risk assessment. The eigenvalue of PC1 was higher than 1, which explained 44.4% of the total variance. Water availability had the highest positive contribution to PC1, while livestock mortality and the ratio of seasonal pastureland had the highest negative contribution to PC1. The first component represents relatively higher water availability, lower livestock loss and better availability of seasonal pastureland (Figure 3).

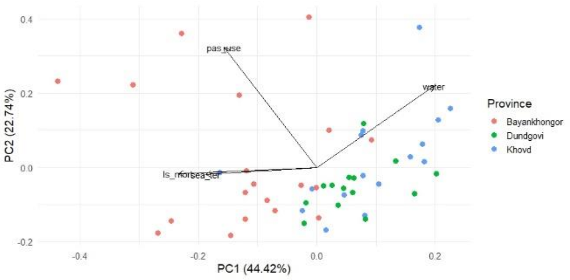

Figure 3. PCA biplot of exposure component

Vulnerability

Based on the PCA on the vulnerability component, PC1 and PC2 were used for risk assessment. The eigenvalue of PC1 and PC2 were higher than 1, which explained 60.1% of the total variance. Poverty and dependency ratio had the highest negative contribution to PC1, while saving had the highest positive contribution to PC2. The first component represents a lower poverty and a lower fraction of child and elderly in the population, the second component represents a higher savings (Figure 4).

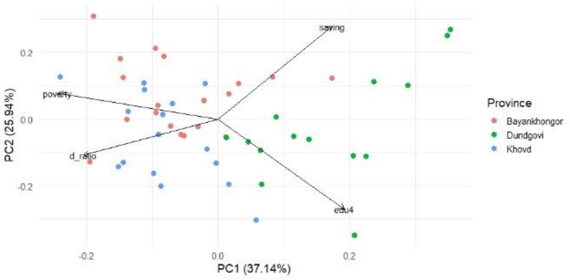

Figure 4. PCA biplot of vulnerability component

Response

Based on the PCA on the response component, PC1 was used for risk assessment. Eigenvalue of PC1 was higher than 1, which explained 60.9% of the total variance. Index-based livestock insurance had a positive contribution to PC1, while hay and forage preparation and barn number had a negative contribution to PC1. The first component represents a higher take-up rate of index-based livestock insurance, while a lack of hay forage preparation and barns. Hay forage preparation and barns are relatively constant compared to livestock-based insurance which can fluctuate depending on the year (Figure 5).

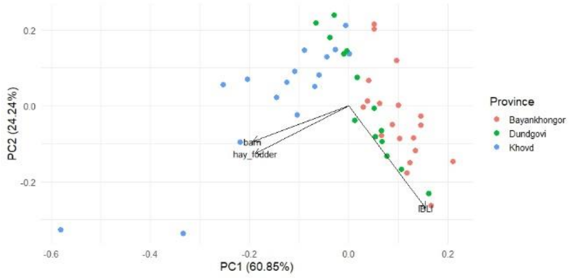

Figure 5. PCA biplot of response component

3.2. Risk assessment

The average risk index (RI) was 19.2 in Bayankhongor, 14.2 in Khovd, and 17.0 in Dundgovi province. Categorizing each soums into low risk (RI ≤ 15.0), moderate risk (15<RI≤20), and high risk (RI>20), 64.7% of the soums in Khovd were low risk, while 73.7% of soums in Bayankhongor and 64.3% of soums in Dundgovi fell under moderate risk category (Table 2). One of the primary factors contributing to this difference was hay and forage preparation, which was relatively high in Khovd province.

Table 2. Indicators of risk and their description

Province	Low risk (%)	Moderate risk (%)	High risk (%)
Khovd	64.7	23.5	11.8
Bayankhongor	0.0	73.7	26.3
Dundgovi	28.6	64.3	7.1

The risk assessment identified the following soums as having the highest risk index: Bayantsagaan, Galuut, Erdenetsogt, Bayangovi, Bumbugur, and Jinst in Bayankhongor province; Adaatsag, Bayanjargalan, and Delgertsogt in Dundgovi province; and Durgun, Chandmani, Myangad, and Mankhan in Khovd province. These soums exhibited high scores across all four risk components, indicating a combination of climate, pasture, and social conditions are increasing the risk in these soums.

On the other hand, soums with the lowest risk index included Bulgan, Uyench, and Erdeneburen in Khovd province; Govi-Ugtaal, Undurshil, and Luus in Dundgovi province; and Bayan-Undur, Hureemaral, and Bogd in Bayankhongor province. The response component differed greatly for these soums, particularly in Bulgan and Buyant soums of Khovd province, where a higher amount of hay and fodder preparation per sheep unit and a higher number of barns per household were present.

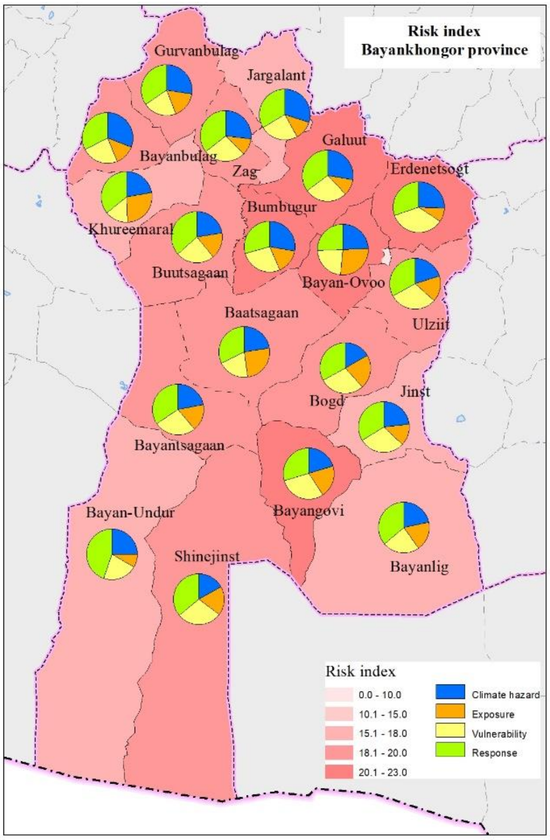

Figure 6. Risk map of Bayankhongor province

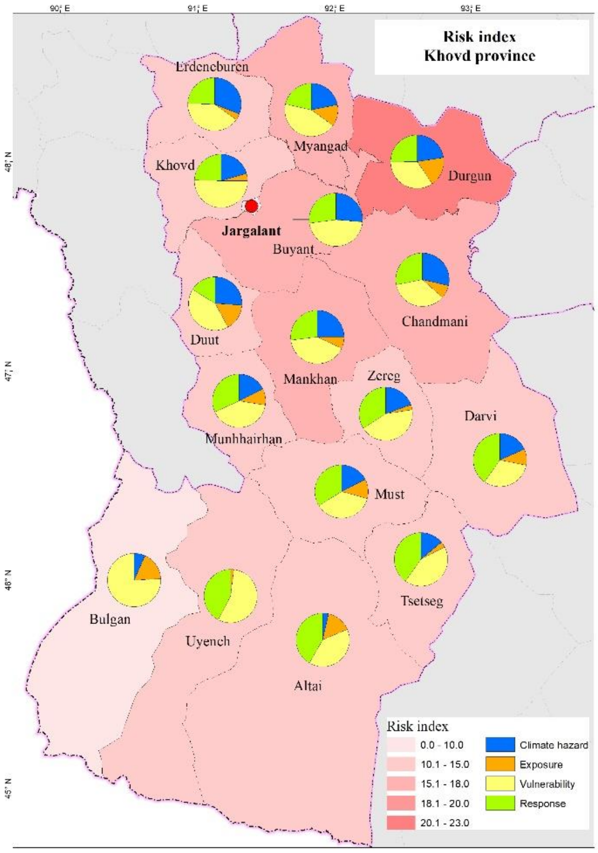

Figure 7. Risk map of Khovd province

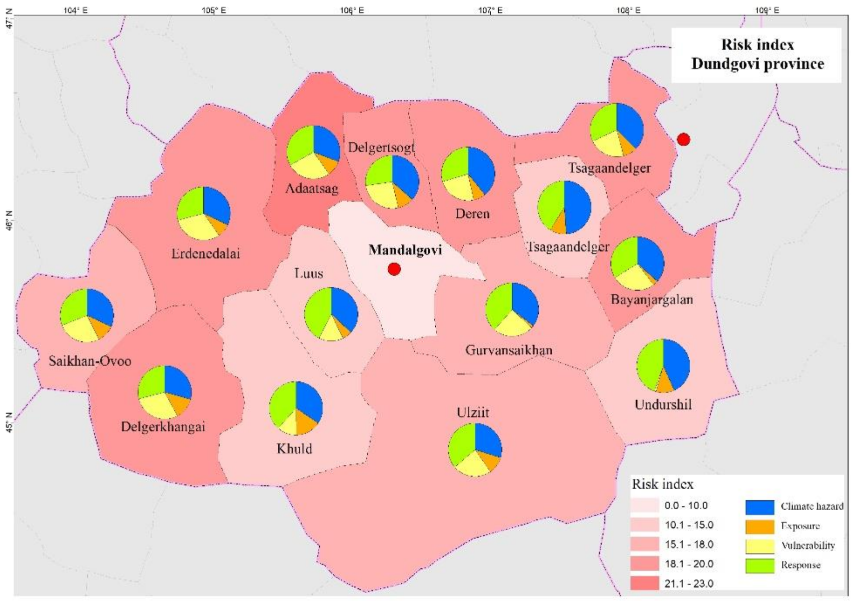

Figure 8. Risk map of Dundgovi province

In terms of risk distribution, the soums most affected by climate-related hazards were located in the northern regions of Khovd and Bayankhongor provinces and the northeastern regions of Dundgovi province. The soums most affected by the exposure component were Durgun, Duut, Myangad soums of Khovd province, Bayan-Ovoo, Baatsagaan, Hureemaral soums of Bayankhongor province, Delgerkhangai, Khuld, Adaatsag soums of Dundgovi province. Therefore, in these soums pasture management plays a key role in decreasing the risk and improving adaption measures. The soums most affected by the vulnerability component were Myangad, Buyant, Khovd soums of Khovd province, Erdenetsogt, Bayangovi, Ulziit soums of Bayankhongor province, Erdenedalai, Adaatsag, Delgerkhangai soums of Dundgovi province. Thus, it is important to focus on improving the social and financial support mechanisms for vulnerable herder households. Lastly, the soums where the response component was weakest include Darvi, Altai, Tsetseg, Durgun soums of Khovd province, Galuut, Buutsagaan, Bayan-Undur soums of Bayankhongor province, Adaatsag, Bayanjargalan, Undurshil soums of Dundigovi province. Here, securing long-term, stable winter preparation is crucial for improving resilience to dzud events.

4. CONCLUSION

The purpose of this study is to assess climate hazard risks of herders at the soum level and explore the varying contributions of risk components. Based on a literature review and data availability, 15 factors of risk were selected including temperature and precipitation change, drought and dzud frequency, pasture use index, livestock loss, ratio of seasonal pastureland, water availability, poverty, dependency ratio, education, bank savings, prepared hay and forage, barns, and index-based livestock insurance. Principal Component Analysis (PCA) was used to aggregate the factors within 4 components of risk, and the composite risk index (RI) was calculated using the principal component scores at the soum level in Bayankhongor, Khovd, and Dundgovi provinces of Mongolia.

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ACKNOWLEDGMENTS

This research was supported by the Asia-Pacific Network for Global Change Research (APN) under the project "Strengthening Local Adaptation Plan Through Integrating Socio-Economic Vulnerability Assessment and Policy Gap Analysis in Mongolia and China (CRRP2022-09MY-Myagmarsuren)". Additional support was provided by the Mongolian Foundation for Science and Technology through the project "Vulnerability Assessment of Pasture Industrial System to Global Climate Change and the Optimization Countermeasures of the Typical Case Regions in China and Mongolia, on Mongolian Plateau" jointly implemented by the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. The authors would like to express their sincere gratitude to all institutions, researchers, and stakeholders who contributed their expertise and collaboration to this study.

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