Final Technical Report
CRRP2017-04MY-BALT

ECOLOGICAL VULNERABILITY ASSESSMENT FOR ADAPTATION STRATEGY FORMULATION AT DIFFERENT SPATIAL SCALES IN WESTERN MONGOLIA AND CHINA

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Project Overview

Project Duration	**:**	September 2017- September 2019
Funding Awarded	**:**	US$ 43,352 for Year 1; US$ 42,000 for Year 2
Key organizations involved	**:**	1. Sustainable Development Institute for the Western Region of Mongolia 2. Keio University, Japan 3. Northwest Institute of Eco-environment and Resource, Chinese Academy of Sciences, China 4. University of Tokyo, Japan 5. Institute of Geography and Geoecology, Mongolian Academy of Sciences, Mongolia 6. Sustainable development institute, National University of Mongolia, Mongolia 7. Institute of General and Experimental Biology, Mongolian Academy of Sciences, Mongolia 8. Institute for Strategic Studies under National security council of Mongolia, Mongolia 9. Information and Research Institute of Meteorology, Hydrology and Environment, Mongolia 10. Nagoya University, Japan 11. Institute of Grassland surveying and Planning Inner Mongolia, China

Project Summary

The main objective of the research project was to develop the conceptual framework for the integrated pastoral vulnerability assessment and contribution of scientific inputs to the effective adaptation strategies using advanced geospatial techniques merging with scientific data and community knowledge at the multi-level governance in Mongolia and China. The project analysis process consisted of using geospatial techniques to assess the pastoral vulnerability; using statistical correlation analysis to assess the impacts of vulnerability on the socio-economic conditions of herding societies; using qualitative document analysis (QDA) to evaluate policy documents; and engaging in policy formulation, which included active participation by multiple academic researchers, policymakers, and representatives of local communities. The research project was implemented in three case areas in two countries, covering various geo-climatic and ecological zones with different managements and policies. The pastoral vulnerability assessment results reveal that climate change-related drought and aridity, as well as human activity related active pasture, uses and farming are being main driving forces. The pastoral vulnerability may affect the socioeconomics of the herder community, devaluing herders' labour and influencing on men`s life expectancy. The project activities have educated young scientists and local herder communities, practitioners and governors through climate change impact, its risks, pasture vulnerabilities, and the local development scenarios tied to regional and national issues, and application of spatial planning tools. The flexibility of the local pastoral adaptation strategy process has allowed the application of geovisualisations in place-based problem solving and decision-making process

in the specific socio-political context of municipal and regional governments. The adaptation options and policy recommendations are identified to enhance the resilience of livelihoods to climate change and adaptation activities to potentially reduce vulnerability to the anthropogenic and climate change, and advance development.

Keywords: *Pastoral vulnerability, Adaptation strategies, Geovisualisation, Local authorities*

Project outputs and outcomes

Project outputs:

- Completion of international project proposal development training for young and early career researchers at the Mongolian Academy of Sciences.
- Involved local authorities from local government (sub-province and province) offices and herding groups to study linkages of socio-ecological governance and climate adaptation.
- Local government officers, herders, farmers, young researchers, NGOs and professors exchanged their knowledge, and learned from each other and collaborating countries.
- Young researchers learned mechanisms to implement a joint project under different cultural and location conditions.

Project outcomes:

- Trained 27 young and early career researchers about international project proposal development from institutes of Mongolian Academy of Sciences.
- Increased the number of young and early career researchers to know about APN activities and therefore more proposals were submitted than previous years.
- Improved local governors capacity to formulate local pastoral adaptation plan through research-based activities.
- Involved 13 young scientists in the project research progress for their PhD research and facilitated them to learn about future professional collaboration.
- 11 local government officers and 8 herding groups, 5 farmers, 13 young researchers, NGO, and 12 professors exchanged their knowledge, learned from each other and experiences from collaborating countries.
- Held 2 dissemination workshops and 2 site visits on the pastoral vulnerability research and adaptation activities involving a total of 58 participants.
- Produced 2 peer-review publications, several conference papers, 2 research reports with an offset of recommendations, and 2 workshop proceedings.

Key facts/figures

- 4 working teams, 6 research institutes, 14 researchers (5 professors and 9 young scientists), 6 local government offices and 8 herding groups participated from Mongolia.
- 2 working teams, 2 research institutes, 5 researchers (3 professors and 2 young scientists), 1 NGO with 6 staffs for adaptation and replanting, 3 local government officials, 4 farming and replanting groups participated from China.
- 3 research institutes, 5 researchers (3 professors and 2 young researchers), 1 NGO and 1 expert from Japan were actively involved.
- Trained 27 young and early career researchers about international project proposal development from institutes of Mongolian Academy of Sciences.
- 41787 sq.km pasture land, 3149 thousand livestock, and 32 thousand people are living under high pastoral vulnerability in Khovd and Gobi-Altai provinces of western Mongolia.

- The assessment reveals that only 3.1% of the total pastureland has not been degraded, 66.3% low degraded, 13.4% medium degraded, and 17.1% heavily degraded in Chandmani soum (sub-province) of Khovd province, Mongolia.
- The non-degraded area decreased by 30.5%, whereas degraded area expanded: low degraded area increased by 8%, medium degraded area by 17.6%, high degraded area by 3.4%, and the most degraded area increased by 1.5% from the 1981 value.
- The pasture lands in the research areas have been shifting from mountain steppe ecosystem to desert steppe and desert steppe ecosystem to desert pasture, which is not a good condition.
- The difference in 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 herding societies.

Potential for further work

– To increase the training workshops on international project proposal development for young and early career researchers to foster further applicants for the collaborative project proposals.
– The participatory research approach improved local governors capacity on pastoral adaptation plan through research-based activities and GIS applications, and trained herders in adaptation activities from China`s experiences which can be applied for the future policy making and adaptation activities in the local areas.
– Herders from Mongolia visited and learned about a combination of animal husbandry with crop farming in Tongliao, China. In 2019, 3 soums of Mongolia has started the pilot activity, where experts and friends from Tongliao come to teach about greening and cropping. It will be one of the big adaptation potentials for future in the case areas.
– The research results on the impact of pastoral vulnerability for the herders` social-economic characters suggested further detailed studies especially on life expectancy of men and their social service needs.

Publications

Peer-review publication

Kherlenbayar.B, Suvdantsetseg.B, & Altanbagana.M. (2019). Impact of pastoral vulnerability on socio-economy: case of Gobi-Altai province, Mongolia. *Khurel togoot-2019,* pp 92-100. Soyombo printing.(*in Mongolian language*)

Altanbagana.M, & Kherlenbayar.B. (2018). Geo-Spatial Analysis for Human Settlement and Regional Development Issues along with Economic Corridors. *The Scientific Journal on Economic Analytica* 2(03), pp 9-29. Admon Printing Co.l.t.d. *(In Mongolian Language)*

Suvdantsetseg.B, Kherlenbayar.B, Nominbolor.Kh & Altanbagana.M. (2019). Assessment of pastoral vulnerability on socio-economy of local communities using geospatial analysis. *Modern Environmental Science and Engineering,* under review. [*under review*]

Balt Suvdantsetseg, Bolor Kherlenbayar, Khurel Nominbolor, Myagmarsuren Altanbagana, Yan Wanglin, Toshiya Okuro, Togtokh Chuluun, Takafumi Miyasaka, Shaokun Wang, Zhao Xueyoung (2019). Assessment of pastoral vulnerability and its impacts on socio-economy of

herding community and formulation of adaptation options. *APN Science Bulletin*, under review. [*under review*]

Conference papers

Year 2019

B.Suvdantsetseg, B.Kherlenbayar, M.Altanbagana, Kh.Nominbolor. (2019). "Geovisualizations for Adaptation Strategy Formulation at Western Mongolia". *Proceedings of the 40th Asian Conference on Remote Sensing*. October 14-18. Daejuong city, Korea. http://acrs2019.sigongji.com/

B.Kherlenbayar, B.Suvdantsetseg, M.Altanbagana, Kh.Nominbolor. (2019). "Assessment of pastureland vulnerability on socio-economy of local communities using Remote sensing and GIS". *Proceedings of the 40th Asian Conference on Remote Sensing*. October 14-18. Daejuong city, Korea. http://acrs2019.sigongji.com/

B.Kherlenbayar, B.Suvdantsetseg, M.Altanbagana. (2019). "Impact of pastoral vulnerability on socio-economy: case of Gobi-Altai province, Mongolia". *Proceedings of Khurel togoot-2019 scientific conference*. 92-100. October 14-18. Ulaanbaatar Mongolia

Suvdantsetseg. B, Yan. Wanglin, Toshiya. Okuro., and Xueyong Zhao (2019). Ecological vulnerability assessment for adaptation strategy formulation at different spatial scales in western Mongolia and China. *Proceedings of the 2nd workshop on social-ecological systems governance for sustainability*. August 23-24. Ulaanbaatar. Mongolia.

Kherlenbayar.B. (2019). Impact of pastureland vulnerability on socio-economy: case of Govi-Altai. *Proceedings of the 2nd workshop on social-ecological systems governance for sustainability*. August 23-24. Ulaanbaatar. Mongolia.

B.Kherlenbayar, B.Suvdantsetseg, M.Altanbagana, T.Chuluun and Kh.Nominbolor. 2019. "Impact of Pastoral Ecological Vulnerability on Animals Miscarriage: Case of Gobi-Altai Province, Mongolia". *Proceedings of Environmental Science and Technology the second international conference*. June 13-14. 171-176, Ulaanbaatar, Mongolia. http://est.igg.ac.mn/.

Kherlenbayar Bolor, Altanbagana Myagmarsuren. 2019. "Spatial Analysis on Socio-Economy of Mongolian Eastern Zone and Development Resource". *Erina Report Plus* No. 148. Pp 15-21. https://www.erina.or.jp/en/publications/er/er-2019/

Year 2018

B.Suvdantsetseg, Erdenebileg.B, M.Altanbagana, B.Kherlenbayar, Nominbolor.Kh, Gunjargal.B, Mandari.D. 2018. Monitoring grassland Degradation in central and western part of Mongolia using remote sensing and expert knowledge. *Proceedings of international conference on science application and development solution of Mongolia*, 27-28, Sapporo, Japan.

Kherlenbayar.B, B.Suvdantsetseg, M.Altanbagana, Gomboludev.P, and T.Chuluun. 2018. Ecological vulnerability assessment in khovd province, Mongolia. *Proceedings of international conference on science application and development solution of Mongolia*, 60-61, 23-24 November, Sapporo, Japan.

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M.Altanbagana, D.Battogtokh, B.Kherlenbayar. 2018. “Geo-Spatial Analysis for Human Resources and settlement based National Development Policies in Mongolia along with Economic Corridors”. *Proceedings of International Geographic Conference on Economic Corridor “China-Mongolia-Russia”: Geographical and Environmental Concerns and Spatial Development Perspectives*. pp 212. August 20-26, 2018, Irkutsk, Russia.

Books

- “Proceedings of the 2nd workshop on social-ecological systems governance for sustainability (2019 Ulaanbaatar, Mongolia)” Ulaanbaatar: Sod Press. http://en.sd-institute.mn/publications.
- “Booklet of the 1st discussion workshop on Pasture ecological vulnerability Assessment (2018 Tongliao, Inner Mongolia, China)” http://en.sd-institute.mn/publications.
- Suvdantsetseg, B., & Altanbagana, M. (2019). *Impact of pastoral vulnerability on socio-economy of Gobi-Altai province, Mongolia.* Ulaanbaatar: Sod Press.

News media

- Suvdantsetseg, Balt. (2018, February 27). APN supported project and training workshop introduction. (Dorjsuren. Tsogzolmaa, Interviewer), Mongolian radio, SBN television and MN Mongol TV.
- Balt, S. (2019, October 30). Pastoral vulnerability for herders` socio-economic conditions. (Orgil, Interviewer), uploaded in http://peak.mn/news/.

Awards and honours

- Research paper, “Spatial analysis on Social Economic of Mongolian Eastern region and transportation corridor,” is awarded 3rd place in scientific conference of "Khureltogoot-2018" of Mongolian young scientists
- Research paper, “Spatial analysis on Social Economic of Mongolian Eastern region and Development Resource”, is awarded by best paper in scientific conference of BEST PAPER AWARDS: MASTER & DOCTORATE STUDENTS-2019 among young scientists.

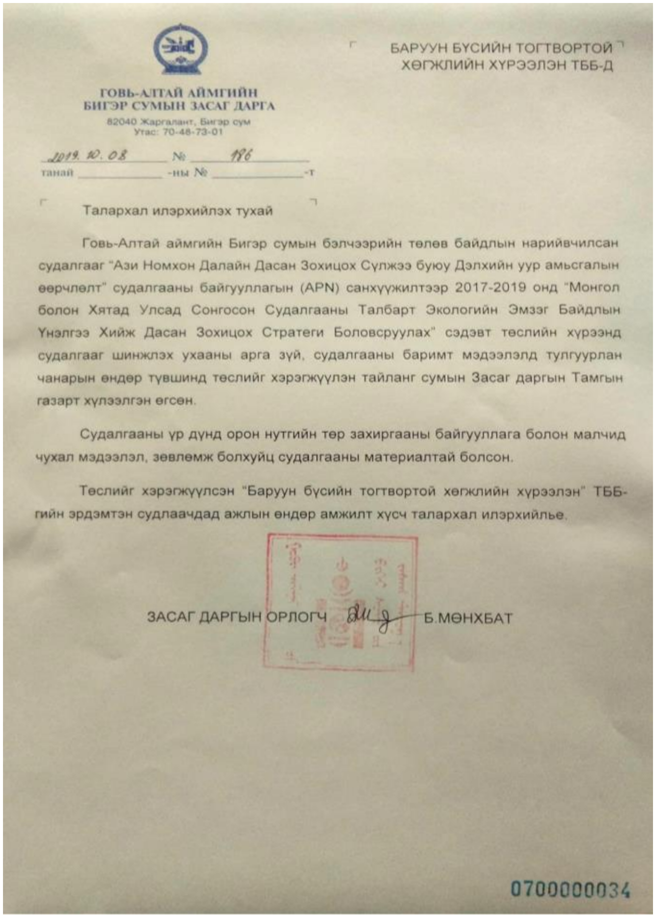
Pull quote

Bolor KHERLENBAYAR is junior research at Institute of Geography and Geoecology, Mongolian Academy of Sciences.

First of all, thanks to the project leader and other team members who teach me a lot under "Ecological vulnerability assessment for adaptation strategy formulation at different spatial scales in western Mongolia and China" (CRRP2017-04MY-BALT) project activity.

I learned and expanded my knowledge on the issues including environmental degradation, livelihoods of local people, and as well as seeking efficient activities with local people and cooperating institutions. The project activity has given me various opportunities to improve my research methodology and barriers for the PhD research and also expanded international friends, and exchanged my experience with many scientists working in different fields which were great opportunity. In finally, pastoral vulnerability assessment will ensure early warning to local communities due to the adverse effect of dzud.

The government office of Biger soum, Gobi-Altai province is expressing their collaboration gratitude to the project team and APN.



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БАРУУН БҮСИЙН ТОГТВОРТОЙ
ХӨГЖЛИЙН ХҮРЭЭЛЭН ТББ-Д

Талархал илэрхийлэх тухай

Говь-Алтай аймгийн Бигэр сумын бэлчээрийн төлөв байдлын нарийвчилсан судалгааг "Ази Номхон Далайн Дасан Зохицох Сүлжээ буюу Дэлхийн уур амьсгалын өөрчлөлт" судалгааны байгууллагын (APN) санхүүжилтээр 2017-2019 онд "Монгол болон Хятад Улсад Сонгосон Судалгааны Талбарт Экологийн Эмзэг Байдлын Үнэлгээ Хийж Дасан Зохицох Стратеги Боловсруулах" сэдэвт төслийн хүрээнд судалгааг шинжлэх ухааны арга зүй, судалгааны баримт мэдээлэлд тулгуурлан чанарын өндөр түвшинд төслийг хэрэгжүүлэн тайланг сумын Засаг даргын Тамгын газарт хүлээлгэн өгсөн.

Судалгааны үр дүнд орон нутгийн төр захиргааны байгууллага болон малчид чухал мэдээлэл, зөвлөмж болохуйц судалгааны материалтай болсон.

Төслийг хэрэгжүүлсэн "Баруун бүсийн тогтвортой хөгжлийн хүрээлэн" ТББ-гийн эрдэмтэн судлаачдад ажлын өндөр амжилт хүсч талархал илэрхийлье.

ЗАСАГ ДАРГЫН ОРЛОГЧ Б.МӨНХБАТ

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Acknowledgements

The project team acknowledges the supports and contributions by various academic and governmental organizations of Mongolian Academy of Sciences, local government officers from Gobi-Altai and Khovd provinces of Mongolia for their assistance in identifying local issues, the herders who participated for the focus group discussions, and experience sharing of greening activities and managements of Tongliao local government office, local staff members of the Green Network in China for their in-kind support of workshop facilitation, and Dr Tuvshintogtokh, Dr Gomboluudev, and Chao Lu Mengqiqige's teams for conducting the field survey and meteorological data collections.

We want to acknowledge the Asia-Pacific Network for Global Change Research (APN) for its financial support to complete the research. We also sincerely thank APN team including Dr Linda Anne STEVENSON, Yukihiro IMANARI, Nafesa ISMAIL all of whom strongly backed-up the research team throughout the study from its design to the report submission stage by providing their guidance, regular feedback and smooth logistical support critical to the successful completion of the study.

1 Introduction

The 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 (Turner et al., 2003). The social-ecological system under non-equilibrium environment is most vulnerable to changes under climate and land use activities (Okuro, 2019).

Mongolia is an agriculture-based country where pastoral livestock production contributes 10.52% of GDP using 72.1% of Mongolia's total land area and employing 21.6% of the total workforce. Nomadic pastoralism is a complex human-environmental system in Mongolia that includes livestock, grazing pasture and herding society which are interdependent (Bazargur, 2005; Chuluun, 2014). The western region of Mongolia is a non-equilibrium environment where the ecological system is arid with harsh temperature, low precipitation and high variability. Social systems in this region predominantly depend on pastoral grazing labor. The pastoral vulnerability causes reduction or loss of the livelihood quality and economic productivity resulting from climate pressure and over-grazing. The nomadic pastoralism has been using the grazing land within pasture capacity through traditional nomadic management to preserve ecosystem resources.

After the transition of Mongolia from a centrally planned socialist economy to a free-market economy in 1990, the limitation on livestock number, supply system of animal raw materials, risk protection system and pasture management on animal husbandry sector were all lost.

Due to rapid increase in the number of livestock and changes of climate condition, 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 & Bat-Oyun, 2002) further reducing the sustainability of nomadic animal husbandry. Some research findings warn that pasture land for livestock grazing will decrease in future (JICA & Almac.corp, 2016).

However, grazing strategy is opportunistic as traditional nomadic and risk management are not well formulated. As usual, policies at the national, regional and local level set out guidelines to prepare winter forage and hay, other than that; they have no special plan or strategy to adapt to climate change in the mid and long term period.

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 the 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 were included in the "inactive and observer" group and that the capacity of social adaptability and pastoral ecosystems was poor. To effectively align adaptation policies and prioritize implementation measures, policymakers require comprehensive information on regional and various sectors vulnerability assessments (O'Brein et al., 2004; Ciscar et al., 2011;

Preston et al., 2011). Therefore, it is a challenge to develop traditional pastoralism adapting to climate change in the vulnerable arid regions.

This research project is proposed that pastoral socio-ecological vulnerability assessment based adaptation strategy at the regional and local levels in Mongolia may have the suitable approach to achieve sustainable pastoral ecological systems of livestock, people`s livelihood and pasture productivity through set of assessment, monitoring, policies, practices and activities.

The collaborative project has enabled participation of several regional and local governments, communities, and multiple academic teams working collaboratively using participatory advanced geospatial techniques merged with scientific data and community knowledge in the development of assessment modelling and policy formulation on adaptation and sustainability of the grazing pasture. A pasture social-ecological vulnerability framework was developed to evaluate the main components of exposure, sensitive factors and adapting/coping responses of pastoral communities.

This research project was implemented in spatially different case areas from Mongolia and China. Due to the difference in research areas, pastoral system and management, as well as advances in the research studies in China, different research method and research component was used in the Chinese case area.

1.1 Objectives of the project

The main objective of this research project is to develop the conceptual framework for the integrated pastoral vulnerability assessment and contribution of scientific inputs to the effective adaptation strategies using advanced geospatial techniques merging with scientific data and community knowledge at the multi-level governance in Mongolia and China. The specific goals are as follows:

- To develop an integrated pastoral vulnerability assessment model with merging of scientific data, holistic and systematic composition, advanced methods, and expert knowledge.
- To identify the most pastoral vulnerable areas by using an integrated ecological vulnerability assessment model in the case areas.
- To contribute scientific outputs to the local-centred, specific adaptation measures and concepts for local development and decision making at the case areas.
- To build up the local stakeholders’ capacity through participation in the research process, training, events, output contribution activities, facilitate knowledge and technology sharing to develop their skills and understanding of scientific importance.
- To develop scientific, user-friendly data-sharing platform for future studies.
- To link local stakeholders’ partnership and strong friendship between local, regional and international level through kind of common communication language at the same level diplomatic meeting and activities.

2 Methodology

The general framework of the project applied a combination of geo-visualisation techniques and a participatory approach for all levels of data collection, integrating method development and assessment, as well as policy-scenario development, during group meetings, training and discussion workshops, and documents review. The analysis process consisted of (1) using geospatial techniques to assess the pastoral vulnerability; (2) using statistical correlation analysis to assess the impact of vulnerability on the herding societies' socio-economic conditions; (3) using qualitative document analysis (QDA) to evaluate policy documents; and (4) engaging in policy formulation, which included active participation by multiple academic researchers, policymakers, and residents of local community in the case areas.

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 pastoral vulnerability to drought and dzud disaster, the majority of studies applied in Mongolia referred to Dryland Development Paradigm (DDP) (Reynolds et al., 2007). Natsagdorj and Sarantuya (2004) assessed impact of drought and dzud on livestock loss due to extreme weather, while 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 two main drivers consisting of drought-dzud index and pasture use. Preventing the dzud disaster risks is vital. However, the vulnerability of pastoral ecosystem is not much related to dzud disaster. Therefore, the interaction of pastoral social-ecological system is significant to examine how pastoral ecosystem services are vulnerable to human and climate change, and which soum's 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 (Turner et al., 2003; Brooks et al., 2005).

The research project is implemented at three vulnerable provinces in two countries, covering various geo-climatic and ecological zones and different management policies. The research methodological framework consists of three main parts of assessment of pasture ecological vulnerability, effectiveness assessment for socio-economics of pasturing society, and evaluation of policy documents and policy formulation. Data sets were collected to assess pastoral vulnerability in two provinces, Khovd and Gobi-Altai, in Mongolia and vegetation changes in Tongliao, China in the first part of the project. During this period, we organized field surveys for data collection in 3 case areas and discussed the research framework between project collaborators, local communities, policymakers and researchers. In the second part, we assessed the impacts of pastoral vulnerability on socio-economy of the pastoral communities and evaluated the policy documents related to grazing pasture and animal husbandry management by sustainable development criteria in 2 provinces. The third part is to disseminate research results and develop policy scenario and recommendations (Figure 1).

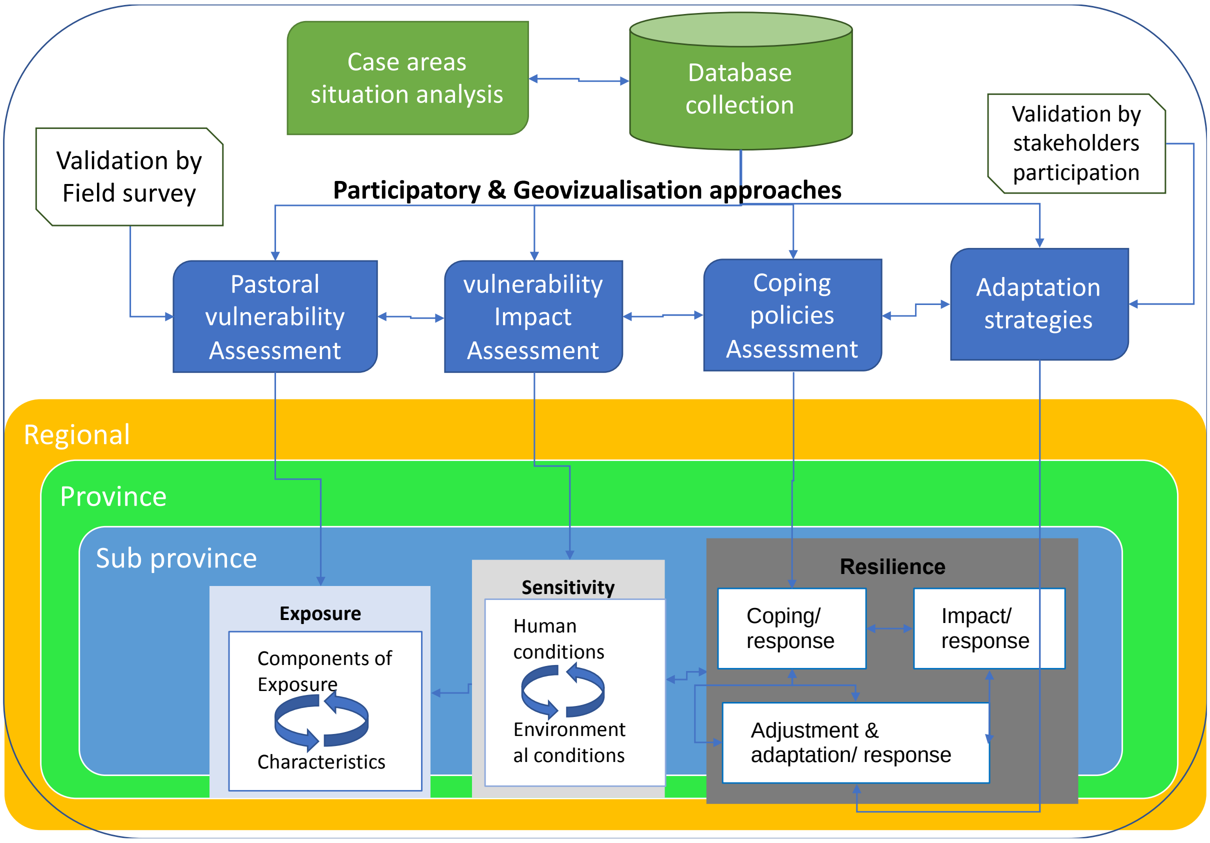


Figure 1. General framework of the project

2.1 Used data sources, data collection and database sharing system

The data during the period of 1998-2017 covering the component index of pastoral vulnerability were derived from various sources: observed precipitation and temperature data were derived from National Agency of Meteorology and Environmental Monitoring (NAMEM), the Normalized Difference Vegetation Index (NDVI) images derived from SPOT, eMODIS satellite data (https://earthexplorer.usgs.gov/), the pasture carrying capacity data was derived from the Mongolian National Atlas of 1990, statistical data sets were obtained from the National Statistical Office (http://www.1212.mn) and other relevant data were collected from local and regional government offices.

During the first year, we collected statistical, observation, meteorological, field survey and remote sensing data sets in the case research areas. All of our database, output documents, publication, experiences, process and reports were uploaded to the project web portal (http://en.sd-institute.mn/spatial-data-and-maps, http://en.sd-institute.mn/statistical-data). We are considering the APN's policy on "Data Sharing and Data Management", in particular, the standardized data collection, data management and data sharing policy. According to the APN data sharing regulation we prepared to make open all datasets collected during this project.

The data collection process consists of three main parts: a) Statistical, remote sensing and observational data collection in Mongolia; b) Field survey and data collection in China; and c)

Field survey and sample collection in Mongolia. In the following lines, we briefly explain the processes for each of them.

a. Statistical, remote sensing and observational data collection in Mongolia

This is the most difficult part of our research. Our research is based on time series analysis; therefore we needed good quality and time-series datasets. In this part, we have cooperated with several partners, institutions and stakeholders from December 2017 to date. Under the good communication of collaborators we collected following data sets (Table 1).

Table 1. Used remote sensing, meteorological and observational data sets in 3 case areas

		Statistical			
No	***Name of data***	***Time range***	***Units***	***Spatial range***	***Source***
1	Livestock	1998-2017	Number	All soums	NSOM[1]
2	Livestock by types[2]	1998-2017	Number	All soums	NSOM
3	Livestock loss by type	1998-2018	Number	All soums	NSOM
4	Barren female animals by type	1998-2018	Number	All soums	NSOM
5	Miscarriage female animals by type	1998-2018	Number	All soums	NSOM
6	Breeding stock by type	1999-2018	Number	All soums	NSOM
7	Migration	1990-2018	Number	Province	NSOM
8	Poverty rate	2010	Percentage	All soums	NSOM
9	Life expectancy	1998-2017	Number	Province	NSOM
10	Well	2012, 2015, 2018	Number	All soums	NSOM
11	Cereals	2000-2018	Ton	All soums	NSOM
12	Potatoes	2000-2018	Ton	All soums	NSOM
13	Vegetables	2000-2018	Ton	All soums	NSOM
14	Fodder crops	2000-2018	Ton	All soums	NSOM
15	Insured livestock	2010-2018	Number	All soums	NSOM
16	Insured households	2010-2018	Number	All soums	NSOM
17	Bank loan	2010-2018	Tugrug	All soums	NSOM
18	Bank deposit	2010-2018	Tugrug	All soums	NSOM
19	Herder household	2012-2018	Number	All soums	NSOM
		Meteorological observation			
No	***Name of data***	***Time range***	***Units***	***Spatial range***	***Source***
1	Annual temperature	1970-2017 Monthly	Celsius	All soums	NAMEM[3]
2	Precipitation	1970-2017 Monthly	Mm	All soums	NAMEM
3	Pastoral area	1990	Hectare	All soums	NAM[4]
4	Pasture carrying capacity	1990	Sheep/per hectare	All soums	NAM
		Raster			

[1] National statistics office of Mongolia (NSOM)
[2] 5 types as Horse, Cattle, Camel, Sheep & Goat
[3] National Agency of Meteorological and Environmental Monitoring (NAMEM)
[4] National Atlas of Mongolia (NAM)

No	Satellite name	Product name	Time range	Units	Spatial range	Source
1	SPOT VEGE	NDVI data 2nd ten days of August	1998-2000	1 km	2 provinces	https://earthexplorer.usgs.gov/
2	eMODIS	NDVI data 2nd ten days of August	2001-2017	250 m	2 provinces	https://earthexplorer.usgs.gov/
3	Administrative boundry	GIS vector	2017		2 provinces	
	Tongliao, prefecture, Inner Mongolia, China					
1	eMODIS	Moisture data	2005-2016	250m	Tongliao prefecture	Institute of Grassland surveying and Planning Inner Mongolia, Hohhot, China
2	eMODIS	Net Primary Production	2005-2016	250m	Tongliao prefecture	
3	eMODIS	NDVI	2005-2016	250m	Tongliao prefecture	
	Field survey					
No	**Name of data**	**Date**	**Unit**	**Number of sites**	**Sampling size**	**Collected site**
1	Biomass data	16 July to 5 August 2018	Hectare	103	1m x1m	Chandmani & Biger

Document reviewed

No	Name of data	Implementation period	Policy area	Implementing area
1	Comprehensive development policy	2012-2020	Development	Gobi-Altai province
2	Governor's Action Program	2016-2020	Development	Gobi-Altai province
3	Pasture management program	2012-2020	Land & Environment	Gobi-Altai province
4	Sub-program to combat desertification	2012-2020	Land & Environment	Gobi-Altai province
5	Environmental master plan	2012-2020	Land & Environment	Gobi-Altai province
6	Development strategy	2015-2020	Development	Khovd province
7	Green development policy	2016-2026	Development	Khovd province
8	Governor's Action Program	2016-2020	Development	Khovd province
9	Pasture use improvement program	2016-2020	Land & Environment	Khovd province

b. Field survey and data collection in China

The team from the Institute of grassland surveying and planning Inner Mongolia has been working on the grassland degradation and Net primary productivity (NPP) analysis in Tongliao prefecture, Inner Mongolia, China under sub collaborator contract. The team collected data sets from Tongliao prefecture and did a field survey and computational research analysis report.

Grassland degradation monitoring and field survey took place in 18 days from 15 June to 2 July 2018 in Tongliao prefecture.

Photo 1. Tongliao prefecture, Inner Mongolia Autonomous Region, China

c. *Field survey and data collection in Mongolia*

This study is part of the pastoral vulnerability assessment research. As a result of the initial study of pastoral ecological vulnerability assessment, two most vulnerable sub-provinces in terms of pastoral and grassland degradation were selected from two case provinces for further study by using field survey and maps comparison. The main purpose of this field survey was to identify the main reasons and conditions of the grassland changes including changes in vegetation types, degradation of grassland, biomass and volumes by comparing field survey data and mapping in 2018 with the map in 1981.

The objectives of the field survey were:

- To assess vegetation condition of two sub-provinces: Biger from Gobi-Altai province and Chandmani from Khovd province, Mongolia
- To create a new vegetation map with 1:200 000 scale at the sub-provinces
- To identify pasture changes by comparing new pasture map in 2018 with the old pasture map made in 1981

The field survey was done in 20 days from 16 July to 5 August 2018 in 2 sub-provinces, Biger from Gobi-Altai province and Chandmani from Khovd province. The field survey used a Geobotanical reviewing method including aboveground biomass measurement (1m*1m area) and vegetation releves (25m*25m area) in a total of 103 sites, 51 points in Biger (Figure 2) and 52 points in Chandmani sub-province (Figure 3). This work was done under subcontract between Sustainable development institute for western region of Mongolia and Institute of General and Experimental Biology (IGEB), Mongolian Academy of Sciences with Dr I.Tuvshintogtokh`s team.

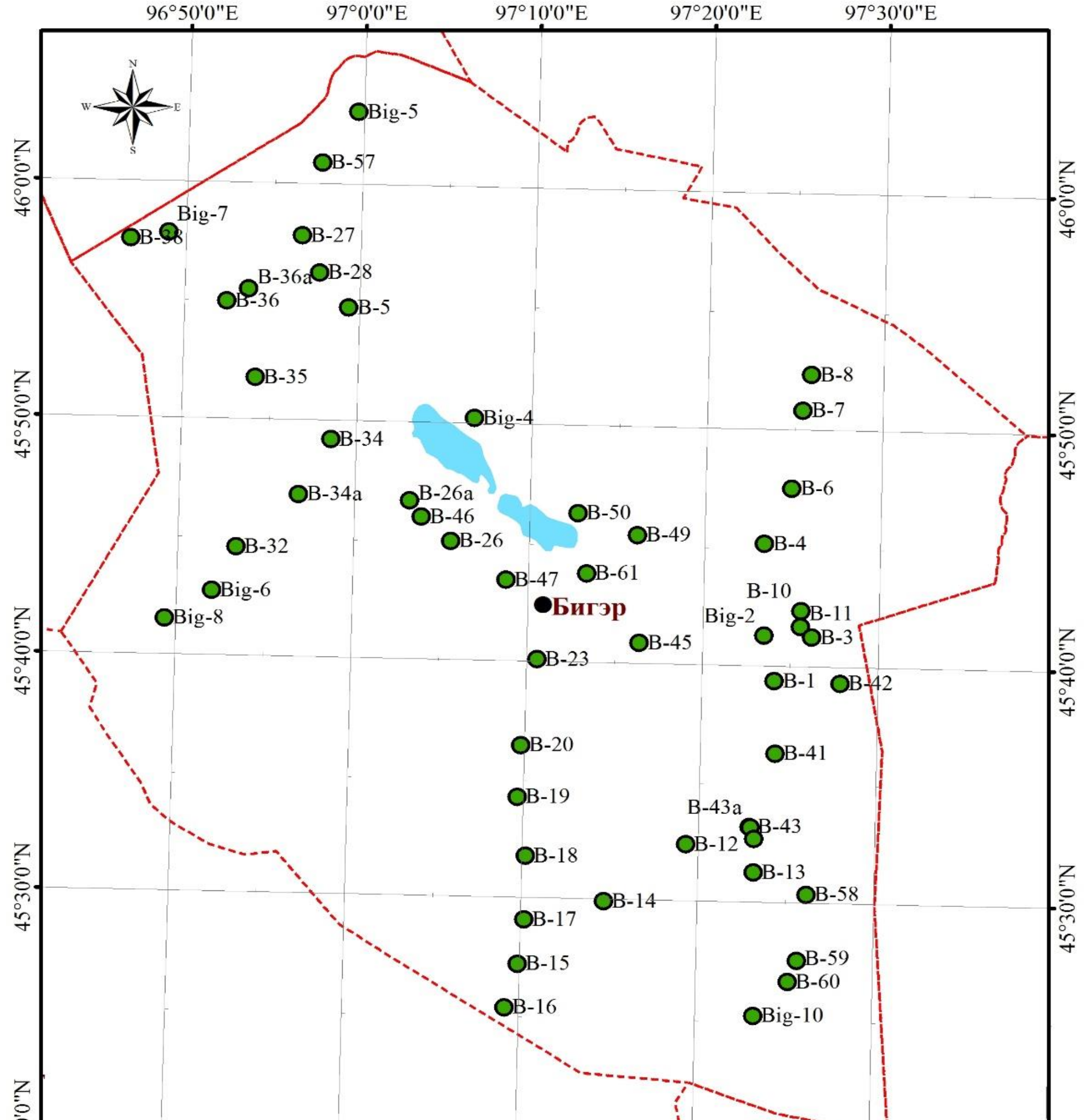


Figure 2. Field survey sites at Biger sub-province, Gobi-Altai province, Mongolia

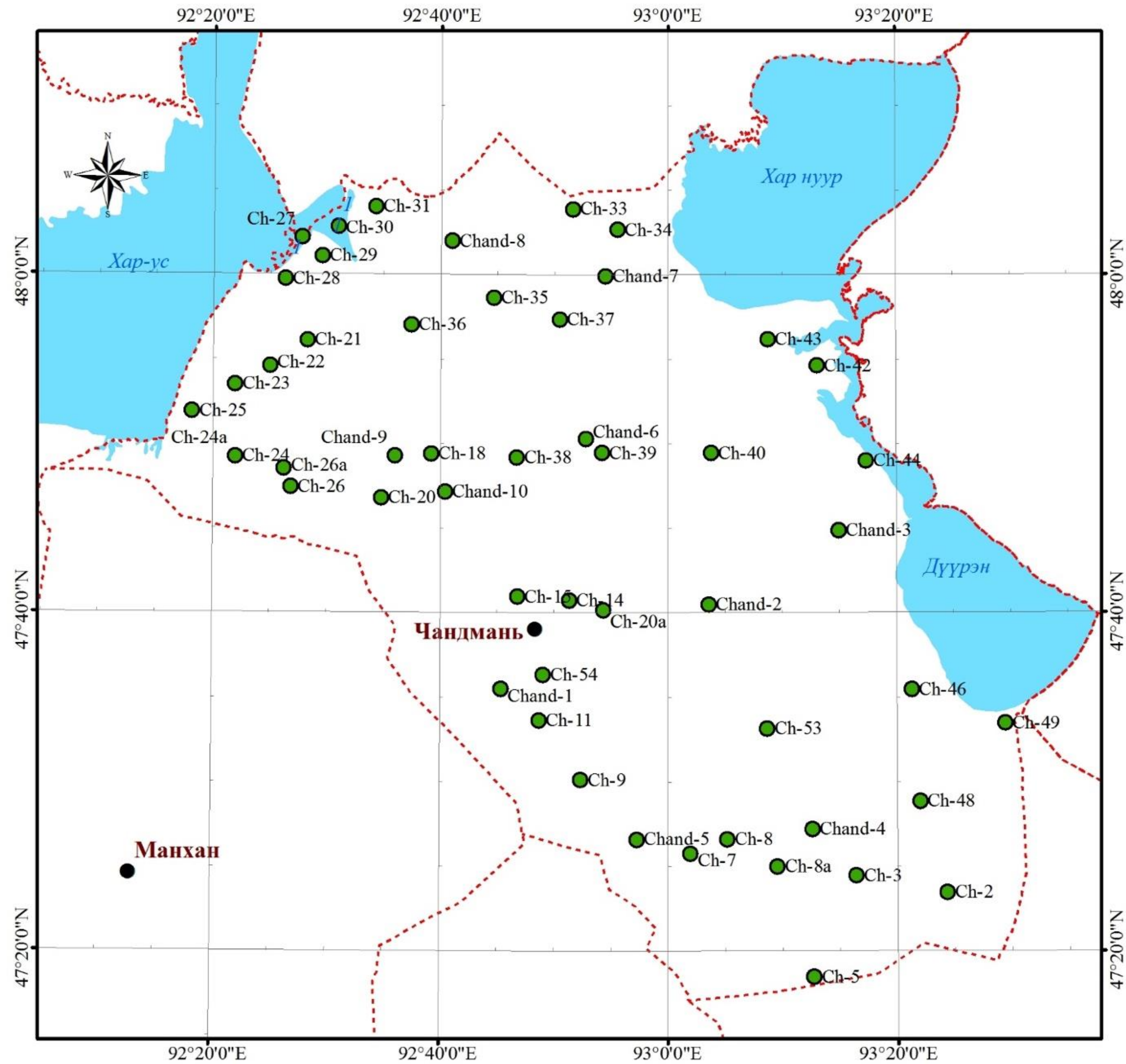


Figure 3. Field survey sites at Chandmani sub province, Khovd province, Mongolia

Photo 2. Ch-8a site. Aboveground biomass measurement (1m*1m area) at Chandmani sub province, Khovd province, Mongolia

Photo 3. B-35 site. Aboveground biomass measurement (1m*1m area) at Biger sub province, Gobi-Altai province, Mongolia

Photo 4. Fieldwork team at Biger sub province, Gobi-Altai province, Mongolia

2.2 Project research sites

The project was implemented in 2 provinces from Mongolia and 1 Prefecture from China, covering Asian arid desert, desert steppe ecological and various geo-climatic regions. Each of the provinces has specific differences for the cases of pasture grazing system due to implementing policies and management. In this regard, research studies used different research methodology and indicators under project activity. The research activities were done differently in Mongolian case area for the pastoral vulnerability; and in China case, we did a grassland degradation and Net primary productivity (NPP) analysis, as well as Isolation of efficient cellulose decomposer in sandy cropland and its application in straw turnover in agro-pasture ecotone of northern China.

Khovd and Gobi-Altai provinces in the western region of Mongolia were selected. Both of those provinces are taking traditional nomadic animal husbandry and living under direct impact of climate variability and human activity impacts. In practice, various policy regulations have been made to balance the conservation of grasslands, production of livestock and the livelihoods of local communities in agricultural societies. However, the validity of existing policies must be examined in terms of sustainable grassland use and management, given that grassland degradation is still ongoing and rural poverty is deepening in these pastoral areas.

The khovd province is promoting green development policy (Galsandondog, 2016), however its instalment on disaster risk reduction, and pastoral adaptations and alignment with Sustainable Development Goals (SDG`s) were not reviewed. Gobi-Altai province is ecologically most vulnerable province affected by climate change-related extreme disasters, water resource shortage and cultural changes while trying to keep its nomadic rangeland systems, and is adversely affected by overgrazing in the Gobi Desert ecological region.

The case research site from China is Tongliao prefecture in the Inner Mongolian autonomous region of China. The Tongliao is the most vulnerable site ineffective use of agro-pastoral system which naturally located at desert zones with high risk of human and climate effect. In traditionally this prefecture was used traditional nomadic animal husbandry, however due to the transition system in China and impact of climate change that area affected much for the desertification. Currently in this province, farmers and herders are taking combination of animal husbandry with crop farming and bird or pork farming in the limited fenced area. Also in the area many of replanting activities are raising to promote greening and reforesting with the socio-economic development of the region.

China promises to embrace "green" development in its 13th Five-Year Plan (2016-2020) by reducing climate change impacts and exacting environmental protection system because China's economic diversification is leading to high risks on its ecology. In order to produce high efficiency of products that ecosystems and natural resources are degrading that may also leading and influencing on climate changes.

Both countries are actively participating in contributing to the global sustainable development goals through developing their national policies, programs and raising activities. In order to implement national policies that local level governments required to develop a short and midterm strategic plan through a new framework of policy research conducted to study the current and future condition of social, economic and ecological vulnerability of the spatial regions.

Figure 4. Project research sites in Mongolia and China

2.2.1 Study Area in Mongolia

Gobi-Altai province, Mongolia is located in the southwestern part of Mongolia and bordered by the People's Republic of China in the southern part, Khovd province in the western part, Zavkhan province in the northern part and Bayankhongor province in the eastern 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. The whole territory of the province belongs to arid and semi-arid zone, the mountain steppe and alpine zones are distributed in the high altitude of Mongol Altai mountain range, with four seasons. The annual average precipitation is 80-135mm, most of the rainfall is during the summer season.

This province is the ecologically most vulnerable province affected by climate change-related extreme disasters, water resource shortage and cultural changes while trying to keep its nomadic rangeland systems. The province is adversely affected by overgrazing in the Gobi Desert ecological region.

Photo 5. Livestock grazing lifestyle in Gobi-Altai province. By B.Suvdantsetseg

Gobi-Altai province consists of 18 sub-provinces (soums) sheltering 3513370 livestock; the livestock sector generates 43.8% of the province's GDP. As of 2018, the population has reached 58.4 thousand, decreasing by 18.4% compared to 1998 value. Of the total population, 32.1% is settled in the center of Gobi-Altai province, while 21% are herders, totalling 16711 householders, and 66.6% of whom live in rural areas practising nomadic herding. It is among the provinces with highly vulnerable ecosystem and largest population out-migration.

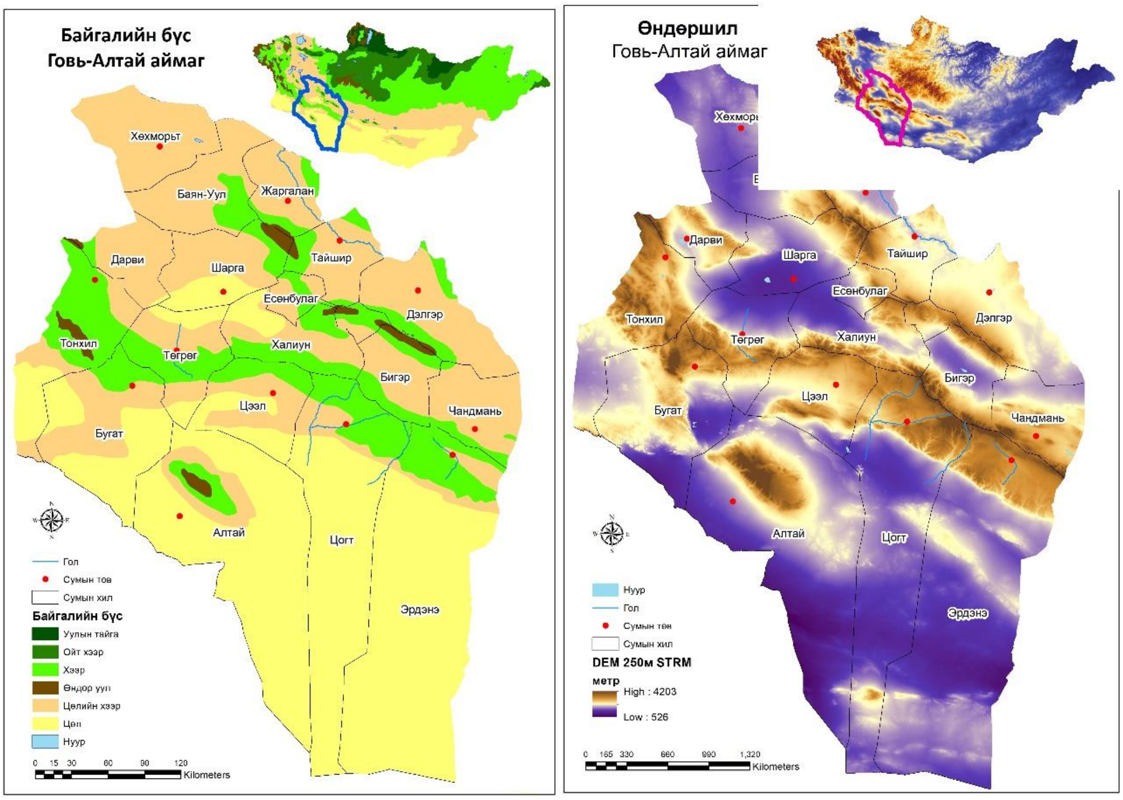


Figure 5. Ecological zones and elevation map, Gobi-Altai province

Table 2. Socio-economic statistics, Gobi-Altai province

No	Soum names	Natural zone	Land size (km²)	Population	Livestock number
1.	Altai	Desert	20431	2,063	134,765
2.	Erdene	Desert	25188	2,219	280,443

3.	Tsogt	Desert	16860	3,579	307,558
4.	Bayan-Uul	Desert Steppe 1	5922	3,002	232,089
5.	Darvi	Desert Steppe 1	3558	1,844	172,056
6.	Huhmorit	Desert Steppe 1	6419	2,373	160,598
7.	Sharga	Desert Steppe 1	5792	1,937	171,439
8.	Biger	Desert steppe 2	3881	2,211	194,444
9.	Chandmani	Desert steppe 2	4637	2,218	228,507
10.	Delger	Desert steppe 2	6679	3,127	287,930
11.	Tseel	Desert steppe3	5668	2,164	213,628
12.	Bugat	Desert steppe3	10124	2,168	178,720
13.	Tonhil	Desert steppe3	7701	2,197	269,886
14.	Tugrug	Desert steppe3	5478	2,054	174,258
15.	Ysunbulag	Mountain steppe	2357	18,469	223,744
16.	Jargalan	Mountain steppe	3716	1,802	191,599
17.	Khaliun	Mountain steppe	5223	2,407	247,833
18.	Taishir	Mountain steppe	3778	1,606	132,154

Khovd province, Mongolia is promoting green development policy of the country. Khovd province has a territory of 76.1 thousand square kilometres, covering Mongolia's Altai Mountains, Great Lakes Depression and Altai Gobi. Desert steppe elevation is 530 m above sea level, reaching 4200 m in Altai mountain range. There exist many of the snow-capped mountains of Mongol Altai mountain range, and originating from these mountains, the rivers of Buyant, Khovd, and Chonokharaih (Bulgan and Tsenkher rivers) drain into Khar-Us, Khar and Durgun lakes.

Photo 6. Livestock grazing lifestyle in Khovd province. By B. Hurelbaatar

In this study, an ecological vulnerability assessment is based on the pastoral ecosystem, therefore, Jargalant soum of Khovd city is not included in the assessment given the size of its land and the source of livelihood of the population.

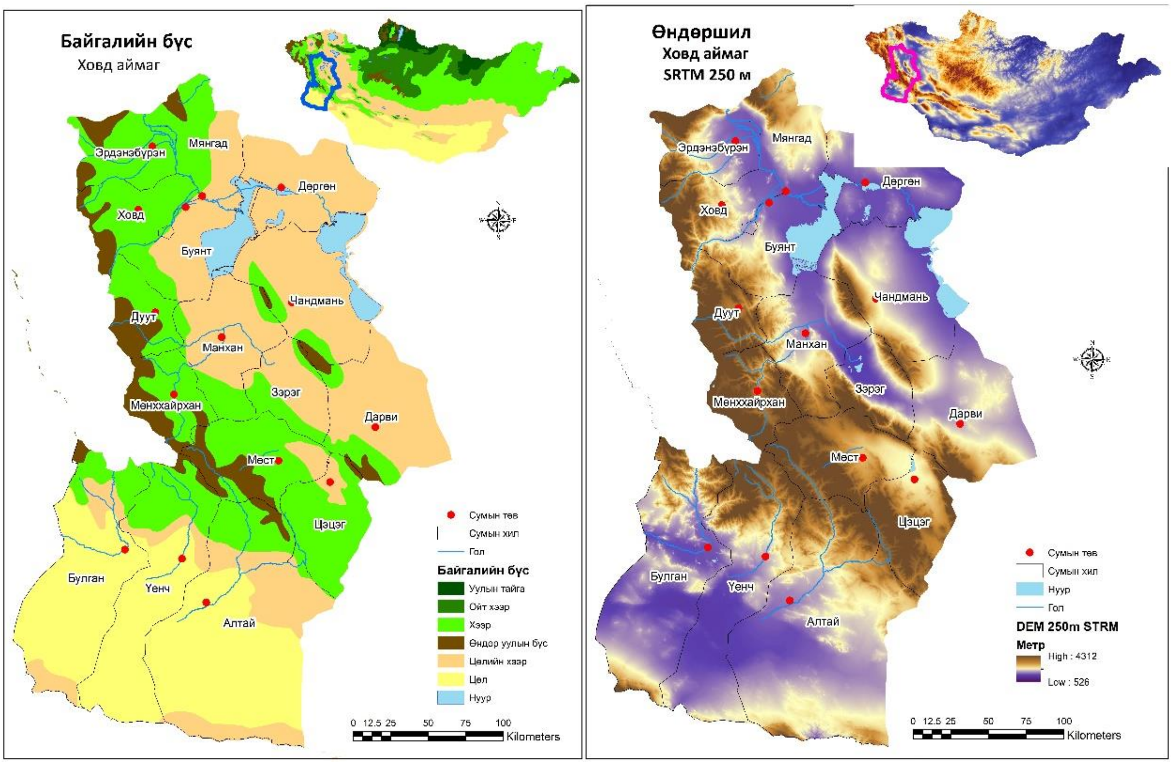


Figure 6. Ecological zones and elevation map, Khovd province

Khovd province has a population of 87.3 thousand, which has decreased by 3.8% since 1998. Of the total population, 34.1% is living in Jargalant soum, the center of Khovd province, 74% of the rural population in 16 soums are living in grazing areas, and 26% of them live in soum (town) centers (NSOM, 2018). The province has experienced an uneven and unstable population growth rate since 1991, which is associated with out-migration. Most (67%) of the land is used for agriculture (Munkhdulam, Avirmed, Jonathan & Renchinmyadag, 2018), pasturing 6,890 thousand livestock and generating 36.9% of Mongolia's GDP.

Table 3. Socio-economic statistics, Khovd province (as of 2017)

No	Soum names	Natural zone	Land size (km^2)	Population	Livestock number
1.	Altai	Desert	13438.7	3,219	181,783
2.	Bulgan	Desert	8335.26	10,126	258,503
3.	Uench	Desert	7591.37	4,091	140,985
4.	Darvi	Desert steppe 2	5646.39	3,013	249,839
5.	Zereg	Desert steppe 2	2578.52	3,245	196,071
6.	Buyant	Desert Steppe 1	3759.54	3,644	215,823
7.	Chandmani	Desert Steppe 1	6183.29	2,937	254,717
8.	Durgun	Desert Steppe 1	4221.73	3,044	151,069
9.	Mankhan	Desert Steppe 1	4426.15	4,217	298,812
10.	Myangad	Desert Steppe 1	3350.33	3,630	261,343
11.	Duut	Mountain steppe	2201.46	2,058	167,138
12.	Erdeneburen	Mountain steppe	2837.79	2,374	212,223
13.	Khovd	Mountain steppe	2885.6	3,554	197,597
14.	Munkhkhairkhan	Mountain steppe	2625.53	2,216	140,604
15.	Must	Mountain steppe	4066.61	3,144	228,660
16.	Tsetseg	Mountain steppe	3554.63	3,051	178,317
17.	Jargalan		69.26	29,800	113,133

2.2.2 Study Area in China

In this regional research project, we selected Tongliao prefecture from Inner Mongolia Autonomous Region (IMAR), China. Tongliao is the most vulnerable site ineffective use of agro-pastoral system naturally located in the desert zone with high risk of human and climate effect. Currently, in this province, many replanting activities are happening to promote greening and afforesting together with socio-economic development of the region.

Tongliao is located in the eastern part of IMAR and the western part of Tongliao plain (E119°14′- 123°43′, N42°15′-45N59′). The topography is high in the south and north, and low in the middle. Altitude: 120-1300m. Annual average temperature of 0 to 6℃, the average annual sunshine hours 3000 h, or 10℃ accumulated temperature of 3000-3200℃, frost-free period 140-160days, annual average rainfall of 350-400 mm, evaporation is about 5 times higher the precipitation, annual average wind speed of 3-4.4 m/s, 20-30 days more than 8 level winds days all the year-round. Tongliao subordinates 1 urban district, 1 development zone, 1 county, 5 banners, and the agency of 1 county-level city.

Table 4. The area of each county or banner, IMAR, China

Name of the City (County, Banner)	Area (Km^2)
Horqin District	3,212
HulinGol	585

Kailu	4488
Kulun	4650
Naima	8120
Zhalute	17,193
Kezuo-Zhongqi	9,811
Kezuo-Houqi	11,476
Total	59,535

China has around 392 million hectares of grasslands, the second largest area in the world after Australia, accounting for 12% of the world's grasslands and 41.7% of the national land area (Fan et al., 2008). Nearly 80% of these grasslands are in arid and semi-arid regions, which are characterised as most vulnerable to degradation, desertification and salinization (Feng et al., 2008; National Bureau of 5 Statistics of China, 2009). Approximately 17 million people maintain their livelihoods on the grasslands of China (Li et al., 2014).

The extensive grasslands of China are concentrated in six provinces and autonomous regions: Xinjiang, Tibet, Qinghai, Sichuan, Gansu and Inner Mongolia. They account for 75% of grasslands and accommodate 70% of the grazing livestock of China (Suttie et al., 2005). These areas maintained traditional pastoralism over hundreds of years, before undergoing thorough land tenure reform since the 1980s and a series of Ecological Construction Programs since 2000. These policy interventions have been implemented widely in favour of transforming traditional pastoral practices.

The grasslands of China are mainly distributed on the Inner Mongolia Plateau, the Loess Plateau and the Qinghai-Tibetan Plateau. The four types of grasslands have a combined distribution ranging from the northeast plain adjacent to Mongolia to south of the Tibetan Plateau (Kang et al., 2007). The meadow steppes and typical steppes are the most commonly used grasslands for grazing and other economic activities related to livestock production, and most of them are located on the Inner Mongolian Plateau (Kang et al., 2007). The grassland types in Tongliao city are mainly warm steppe and warm meadow.

The distribution is shown in Figure 7. As is shown in the figure, due to the topography condition Zhalute County, the northern part of Tongliao, the main grassland type is warm meadow. In most areas, the main grassland type is warm grassland. There are also some lowland meadows in lower areas.

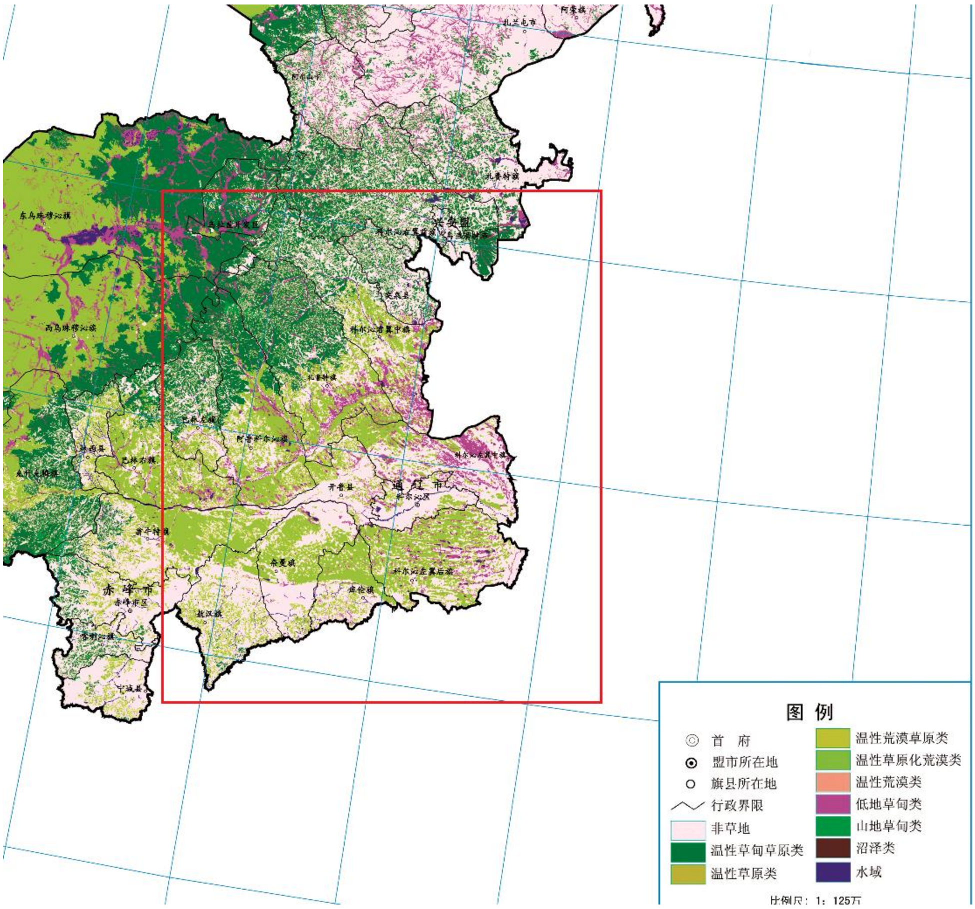


Figure 7. Distribution of grassland types in Tongliao

2.3 Assessment of pastoral vulnerability in Mongolia

Scientific collaborators worked together based on their expertise areas to develop integrated pastoral vulnerability assessment model within the scientific framework for each case area. Main collaborators decided to develop and use their analysis methods suited for Mongolia and China case areas. The Mongolian team was divided into 3 working groups to achieve the goal of this part of the project. The Sustainable Development Institute for western Region of Mongolia (SDiWoM), Institute of Geography and Geoecology, MAS, Sustainable Development Institute, National University of Mongolia and Information and Research Institute of Meteorology, Hydrology and Environment has worked on the integrated pastoral vulnerability assessment.

As seen from previous studies, the assessment model of ecological vulnerability used different indicators based on case area situation. For instance, Li et al. (2016) used eight indicators, and Altanbagana et al. (2015) used eight ecological indicators for the assessment of socio-ecological vulnerability at the regional level in the Mongolian case.

This time we focused on pastoral vulnerability at 2 case research areas in Mongolia, therefore, we decided to use 4 indicators (Drought index, Aridity index, Pasture use index, and Vegetation index) in the case areas. The main method of the research used multivariate statistical analysis and the weighted summation analysis for rescaling different index values. The model structure is partly based on spatially explicit ecological model (Pastorok, et.al 2003), which is one of the most advanced ecological and landscape analysis models. In order to combine individual indexes into an integrated pastoral vulnerability index, variables were calculated into same range from 0.0 to 1.0 by rescaling the weighted summation of values for long term data.

The methodology of ecological vulnerability assessment due to climate change (Chuluun, Altanbagana, Davaanyam, Tserenchunt & Dennis, 2014), is modified for Pastoral vulnerability assessment in this research. Also, DDP application (Reynolds et al., 2007), 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 index, vegetation cover changes and pasture use. However, if each variable exceeds the vulnerability threshold value, it will reduce pasture productivity.

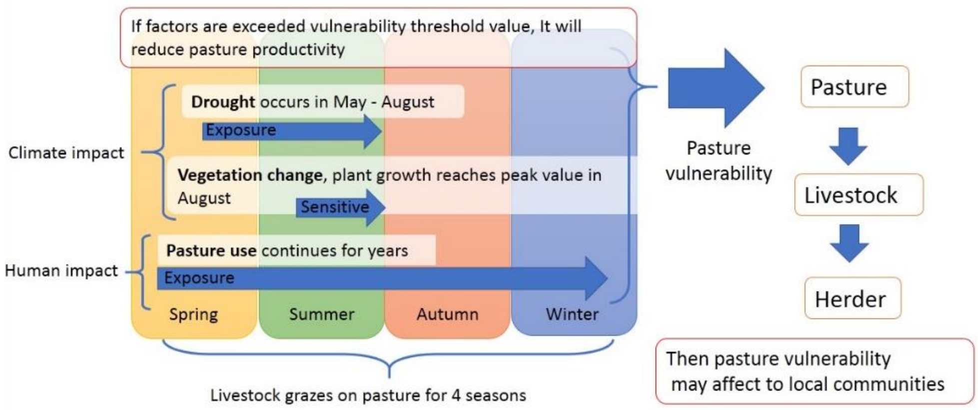


Figure 8. Pastoral vulnerability framework

Pastoral 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, $V_{t,i}^{eco}$ – 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

Ecological vulnerability mainly defines drought risk rather than the frequency and severity of weather anomalies (Downing & Bakker, 2000; Yanqiang, 2017). Drought estimates are calculated by using the Ped's index, which represents long-lasting atmospheric degradation. The Ped index value means that 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 the drought index, S = 3 value is chosen as the threshold value for pastoral vulnerability.

The Ped's index and share of the area affected by drought were calculated by Equation 2 and 3 respectively:

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

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.

2.3.2 Pasture use

In 1990, the Mongolian government determined a suitable number of livestock per hectare of grazing field for all soums in Mongolia (National Atlas of Mongolia, 1990). Those values were selected as the threshold value for the vulnerability of pasture use and Tserendash's (2006) pasture use index was modified to calculate pastoral 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):

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

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

Livestock	*Camel (a_1)*	*Horse (a_2)*	*Cattle (a_3)*	***Sheep (a_4)***	*Goat (a_5)*
Sheep	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 at soum level 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 in sheep; N_0– The pasture carrying capacity, suitable number of livestock per hectare in soum pastureland in sheep

2.3.3 Vegetation cover change

The peak level of vegetation biomass in the pastureland, Mongolia is mainly in the middle of August. However, it spatially depends on natural zones, 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 the pastoral vulnerability through pasture land degradation and reduction of suitable area for livestock grazing (Zhou, Gang, & Jianlong, 2014), (Miyasaka, Okura, Zhao, & Takeuchi, 2016).

In order to calculate the vegetation cover and biomass changes Normalized Difference Vegetation Index (NDVI) was used (Equation 5). The NDVI value itself cannot provide sufficient condition to pastoral vulnerability assessment. Therefore, we considered both multiyear average NDVI values and the coefficient of the linear trend equation of NDVI changes for the last 20 years, which might express trends of vegetation changes. Here, we used SPOT Vege satellite within 1 km spatial resolution with the second 10 days of August from 1998-2000 and eMODIS within 250 m spatial resolution and the second 10 days of August from 2001-2017.

$$NDVI = (NIR - Red) / (NIR + Red) \quad (6)$$

The annual vulnerability assessment estimates what percentage of the area in the soum has significantly changed when compared with the average annual average. Based on the results of this analysis, we selected 2 sub-provinces (Biger from Gobi-Altai province and Chandmani from Khovd province) for the detailed pasture change and vegetation surveys.

Alternatively, the degraded grazing area was calculated whether it exceeds the threshold value of vegetation vulnerability for each pixel. The threshold value of the vegetation vulnerability was selected by the difference of the mean value and standard deviation in the biomass peak time data derived by satellite images from 1999-2017 and determined for each of the pixels by the following equation.

Changed vegetation cover and share of decreased vegetation cover area in the total area were calculated by Equation (7) and (8)

$$\Delta V_{ti} = \left(V_{ti} - \left(\frac{\sum_t^n V_{ti}}{n} - \sigma\right)\right) \quad (7) \qquad \Delta V_{ti} < 0 \qquad\qquad \Delta Vci = \frac{Vst,i}{Vsi} \quad (8)$$

Here, 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

2.3.4 Aridity index

Aridity index was calculated by Dr Gomboluudev`s team at Information and Research Institute of Meteorology, Hydrology and Environment under the subcontract. This team also provided all necessary data sets for the calculation.

Aridity is measured by comparing long-term average water supply (precipitation) to long-term average water demand (evapotranspiration). If demand is greater than supply, *on average*, then the climate is arid. Drought refers to the moisture balance that happens on a month-to-month (or more frequent) basis. If the water supply is less than the water demand for a given month, then that month is abnormally dry; if there is a serious hydrological impact, then drought is occurring that month. Aridity is permanent, while drought is temporary

Aridity index=P/PET, (UNEP, 1992) (9)

where, P is precipitation and PET is potential evapotranspiration estimated by Thornthwaite method or another method

2.4 Correlation analysis to assess the impact of vulnerability on the herding societies' socio-economic conditions society

In this part, we assessed the impacts of Pastoral vulnerability on socio-economy of the pastoral communities. The interaction of pastoral social-ecological system is significant to examine how pastoral ecosystem services are vulnerable to human and climate change, which areas are most affected and which indicators are more sensitive to affecting herders socio-economy. This part used Pearson correlation analysis (Lane, 2019) to measure the strength of the relationship between variables. A correlation analysis among the 19 indicators from social, economic, and environmental groups were conducted. As a result of the analysis, the most affective and correlative indicators were are highlighted in this report. Results of the analysis shown can be found in GIS maps, infographics and table. .

2.5 Evaluation of policy documents

Climate adaptation and sustainable development are linked in several ways: first, many of the determinants of adaptive capacity to respond to climate impact and indicators of sustainable development overlap; second, adaptive capacity building may critically contribute to the well-being of both social and ecological systems; and third, building adaptive capacity within a sustainable development framework may require transformational changes (Denton et al., 2014). Transformational change is a fundamental change in a system, its nature, and/or its location that can occur in human institutions, technological and biological systems, and elsewhere. For climate-resilient pathways for development, transformations in social processes may be required to get voluntary social agreement to undertake transformational adaptations that avoid serious disruptions of sustainable development. These may involve adaptations at a larger scale or greater intensity than previously experienced; adaptations that are new to a region or system; or adaptations that transform places or lead to a shift in the location of activities (Kates et al., 2012).

This part used Qualitative Document Analysis (QDA) to facilitate analysis of policy documents. QDA was utilised to understand the extent to which policy documents of two provinces, Khovd and Gobi-Altai, incorporated the SDGs. The QDA process uses subjective scoring and we ensured consistency by following explicit steps aimed at providing in-depth analysis. These include: (i) collecting documents; (ii) identifying main areas of analysis; (iii) coding the documents; (iv) analyzing findings.

The building blocks for the QDA were informed by the Synergy of climate change adaptation and mitigation response and sustainable development (Nhuan, 2019): climate adaptation, mitigation, and transforming capacity. Appropriate indicators for the building blocks were selected based on the SDGs aligned with National Green Development Policy of Mongolia and the Sustainable development vision of Mongolia 2030 (SDV). For adaptation in terms of social resilience, the indicators included income diversification and poverty reduction (SDG1), health and wellbeing (SDG3), water and sanitation including sustainable water management (SDG6), full and productive employment and sustainable tourism development (SDG8). Other indicators of adaptation in terms of enhancing natural resilience included the ecosystem and biodiversity conservation (SDG15). Indicators of mitigation included reducing GHG emissions and renewable energy (SDG7). For transforming the capacity, we adopted indicators such as quality education (SDG4), industry, innovation and infrastructure (SDG9), and climate action (SDG13).

Table 5. Building blocks for local sustainable development based on SDGs

Building blocks	Indicators	SDGs
Adaptation	Diversification of income and poverty reduction. Measures directed at diversified livelihood and reduced poverty *(eg.: programs to encourage employment)*	SDG 1
(Social resilience)	Healthy lives and wellbeing for all ages. Measures to improve quality and accessibility of health services, reduce maternal and child mortality and malnutrition; reduce the prevalence of non-communicable diseases and their risk factors and reduce possible deaths; Strengthen the capacity of surveillance, prevention, preparedness and response to infectious diseases, and make the essential vaccines available to everyone	SDG 3
	Safe drinking water and sanitation, and sustainable water management . Measures to increase the number of population connected to safe water supply and sanitation	SDG 6
	Full and productive employment and decent work. A variety of economic activities can be developed that are connected to pastoral livestock-keeping, including input delivery, veterinary services, trading, transport, processing and infrastructure. As also emphasised in SDG8, such productive activities need to be supported by policies that support entrepreneurship, enterprise development, job creation and access to financial services.	SDG 8
	Environmentally friendly, sustainable tourism development. Measures aimed at promoting sustainable tourism by developing eco-tourism products and services that meet environmental and health requirements based on natural and cultural resources.	SDG 8
	Sustainable pasture management and protection of pastoral ecosystems. Measures to improve herd composition and breed in compliance with pasture carrying capacity, to improve pasture land use through seasonal pasture rotation and provision of water supply in remote and water-scarce pastures	SDG 15
(Natural resilience)	Sustainable forest management. Measures against forest fire and pests, breeding, protecting and sustainable management	SDG 15

	Combating desertification and halting land degradation. Soil rehabilitation, introduction of new methods of protection against pollution, prevent cross-roads, introduction of proper management and technology for soil protection, support for cultivation with forested land, establish sustainable land management suitable for the local area, take degraded land into local protection, restrict and limit certain types of activities up to 5 years is strongly degraded and desertified lands, and restoration of abandoned land	SDG 15
	Biodiversity conservation. Measures to protect biodiversity gene pool and to prevent habitat loss, to maintain reserves, to set up salt and marshes, and water points.	SDG 15
	Sustainable management and conservation of protected areas. Identify activities that can be implemented that support proper protection and use management in buffer zones of state and local protected areas. Eg: Use as motorcycle in case of need, take fee from tourists, improve protection management	SDG 15
Mitigation	Energy supply with stable and reliable sources. Increase production of pure technology and renewable energy in energy production; reduce energy consumption and loss; investment in heat loss, reduction of air emissions, investments in energy savings and green building	SDG 7
Transforming capacity	Inclusive and quality education and skills. Measures aimed at enhancing coverage of preschool education, general education and vocational training that meet the standards	SDG 4
	Improved infrastructure including road networks to have access to markets and enabling services	SDG 9
	Inclusive, safe and resilient human settlements. Measures aimed at promoting environmentally-friendly nomadic culture, with the capacity to sustain resilience in dry or non-equilibrium ecosystems, and to preserve traditional cultural heritage	SDG 11
	Capacity building on adaptation to climate change, natural disaster and risk prevention. To strengthen the adaptive capacity of herders and farmers, to support ecological education and sound practices, to improve the early warning and reporting systems of natural hazards and emergencies, to establish *otor* zones and reserve areas, and hay making plants, and to construct road and telecommunications infrastructure	SDG 13

A scoring system was developed (Table 6) based on the work of Gouais & Wach (2013). To determine the extent to which the policy documents align with the "building blocks", each of the policy documents was analysed separately. All assessments of alignment were supported by explanations and quotes from the policy to ensure the rationale for each assessment.

Table 6. Scoring criteria for alignment of the policy documents with the building blocks (Modified from Gouais &Wach, 2013)

Type of alignment	Description of alignment	Score
High alignment	The policy aligns strongly with the indicators of adaptation, mitigation and transforming capacity (A/M/Tc). Policy devotes attention to the particular building block and includes specific activities for achieving the particular block.	3
Partial alignment	Although the policy supports the various indicators of A/M/Tc, it is less clear and distinct in terms of how the indicators and each particular building block could be achieved. There is limited evidence present of how the specific indicators, as well as the building blocks, could be achieved in practice.	2
Limited alignment	The policy supports a particular indicator of the A/M/Tc building block but there is a lack of evidence to support alignment with it.	1
No alignment	There is no evidence in the document to suggest that the policy supports the implementation of the building block or even encourages it.	0

Table 7. Policy documents reviewed

Policy area	Khovd province	Gobi-Altai province
Development	1. Development strategy 2015-2020 2. Green development policy 2016-2026 3. Governor's Action Program 2016-2020	1. Comprehensive development policy 2012-2020 2. Governor's Action Program 2016 – 2020
Land & Environment	1. Pasture use improvement program	1. Pasture management program 2. Sub-program to combat desertification 3. Environmental master plan 2012-2020

2.6 Development of policy recommendations

In this part, we used three types of survey instruments for data collection including focus groups discussions, interviews with herders or governors, and workshops with multi-stakeholders. Focus group discussions in each soum gathered qualitative information at the local community level such as important stakeholders in pastoral herding, natural resources users and risk reduction management, levels of their collaboration, seasonal locations of herders, pasture use, understanding of pastoral vulnerability and its impacts on their livelihood including herding groups, local, and provincial governors, academics and civil societies. Interviews with local officials were a semi-structured tool to collect soum and province-level policy information on pasture use, and climate change adaptation together with a qualitative assessment of the respondent on local pasture use patterns, and resource coordination, conflicts and pasture users' participation in decision-making. The study team facilitated discussion with the local people using participatory tools such as initial results of pastoral vulnerability maps, pasture use poster, diagrams of pastoral vulnerability impacts on some social and economic factors.

Three participatory focus group discussions were organized at the local project areas (Biger soum and province center of Gobi-Altai province, and Zereg soum of Khovd province) from 19-30 July 2019.

Photo 7. Focus group discussions among herders and interviews with local governors

The group discussions covered the issues including increasing pastureland degradation from the locals' view and living experiences, visible impacts of Pastoral vulnerability on their livelihoods, and barriers to formulate and implement policy documents.

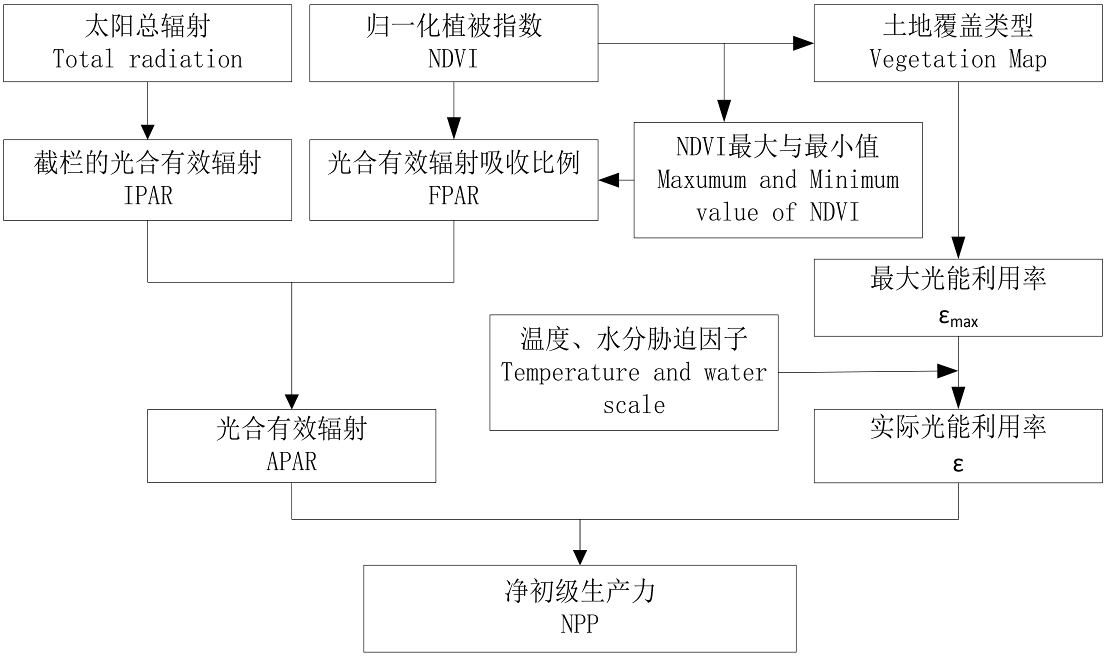
We also organized several group meetings among project collaborators to identify the key indicators of pastoral vulnerability, main affecting factors for herding society, main barriers for the adaptation strategy of the policy documents and ways to overcome these issues from the academic side. In these meetings, all of our research collaborators participated and presented findings and outputs of research via the internet and face to face.

Finally, a participatory workshop entitled "The 2nd workshop on social-ecological systems governance for sustainability" was organized in Ulaanbaatar, Mongolia on 23-24 August 2019 to conclude all activities and discuss policy recommendations.

Photo 8. Team group meetings and policy development workshop discussions

2.7 Vegetation Coverage and Net Primary Productivity (NPP) distribution of Tongliao, Inner Mongolia, China

The Carnegie-Ames-Stanford Approach (CASA) model used remote sensing technology to obtain FPAR to obtain Absorbed Photosynthetically Active Radiation (APAR) that the part of radiation energy absorbed by plants in photosynthetic effective radiation absorbed by vegetation, and then estimated NPP. The parameters in the model vary with time (t) and place (x) and are regulated by temperature and moisture factors. As APAR of photosynthetic effective radiation absorbed by plants can be obtained through remote sensing technology, the parameter model based on APAR is highly valued. CASA model is the most widely used model in global NPP estimation.



净初级生产力（NPP）估算模型总体框架
Frame of net primary productivity (NPP) Estimation Model

Figure 9. Frame of net primary productivity (NPP) Estimation Model

The estimation of NPP in CASA model can be expressed by two factors, namely photosynthetic active radiation (APAR) and actual solar energy utilization (turned). The estimation formula is as follows:

$$NPP(x,t) = APAR(x,t) \times \varepsilon(x,t) \qquad (10)$$

Where, *APAR(x,t)* is the photosynthetic effective radiation absorbed by pixel x in the month of t (g C·m^{-2}·month^{-1}), and ε(x,t) represents the actual light energy utilization rate of pixel x in the month of t (g C· mj^{-1}).

The value of APAR is determined by the proportion of solar effective radiation absorbed by vegetation and photosynthetic effective radiation absorbed by vegetation.

$$APAR(x,t) = SOL(x,t) \times FPAR(x,t) \times 0.5 \qquad (11)$$

Where, *SOL(x,t)* is the total solar radiation amount at pixel x of t month (g C·m^{-2} mont^{-1}), FPAR(x,t) is the absorption ratio of the incident photosynthetic effective radiation of vegetation layer, and the constant 0.5 represents the proportion of solar effective radiation (wavelength 0.4-0.7 solar m) utilized by vegetation to the total solar radiation.

Within a certain range, there is a linear relationship between FPAR and NDVI (Ruimy & Saugier, 1994), which can be determined according to the maximum and minimum values of a certain type of NDVI and the corresponding FPAR maximum and minimum values.

$$FPAR(x,t)=\frac{(NDVI(x,t)-NDVI_{i,\min})}{(NDVI_{i,\max}-NDVI_{i,\min})}\times(FPAR_{\max}-FPAR_{\min})+FPAR_{\min} \tag{12}$$

Where, $NDVI_{i,Max}$ and $NDVI_{i,min}$ correspond to the maximum and minimum values of NDVI of type I planting.

$\varepsilon(x,t)$ is the ratio of the chemical potential of the dry matter produced per unit area in a given period to the photosynthetic effective radiation energy projected on that area at the same time. Environmental factors such as air temperature, soil moisture, and atmospheric water vapor pressure difference regulate vegetation NPP by affecting the photosynthetic capacity of plants.

$$\varepsilon(x,t)=T_{\varepsilon 1}(x,t)\times T_{\varepsilon 2}(x,t)\times W_{\varepsilon}(x,t)\times\varepsilon_{\max} \tag{13}$$

In the formula, $T\varepsilon 1(x,t)$and $T\varepsilon 2(x,t)$ represents the stress effect of low temperature and high temperature on light energy utilization. $W\varepsilon(x,t)$ is the influence coefficient of water stress, reflecting the influence of water condition. ε_{max} is the maximum light energy utilization under ideal conditions (g C/MJ).

2.8 Isolation of efficient cellulose decomposer in sandy cropland and its application in straw turnover in agro-pasture ecotone of northern China

2.8.1 Introduction

The boundary line of the agricultural and pastoral area is approximately consistent with the 400 mm isohyet in China. The land use in the southeast part of the isohyet is cropping dominant, and the northwest part is pasture dominant. The agro-pasture transitional ecotone is in between the agricultural and pastoral area, in which both cropping and grazing are flourishing spatially and temporally. The agro-pasture transitional ecotone of northern China starts from Hulun Buir of western Great Khingan, southwards to Tongliao and Chifeng of Inner Mongolia, then goes to northern Hebei, Shanxi and Shaanxi provinces, ends at eastern Gansu province (Zhao et al., 2002). The annual precipitation of the transitional ecotone is ranging from 300 mm to 450 mm. Precipitation, which fluctuates significantly, is the main limiting factor for both cropping and grazing in this area. The vegetation changes variably in consequence with the precipitation, which makes this transitional area a very vulnerable ecotone (Zhao et al., 2003).

Horqin Sandy Land is located in the southeast part of Inner Mongolia, which is one of the most vulnerable and the most typical area for an ecological and environmental study of semiarid agro-pasture transitional ecotone. The last few decades saw a large area of grassland were converted into farmland, mostly due to the rapid growth of population and the communities' easgernedd for a better life. Therefore, maize (*Zea mays L.*) became the best choice, because of its higher productivity and better income. However, maize consumes much more water than the local vegetation, and the overuse of water for irrigation resulted in desertification of this vulnerable sandy land ecosystem for desertification (Wang et al. 2016; Zhao et al. 2015).

Soil microorganisms play a very important role in sandy farmland ecosystem. They participate actively in straw turnover, nutrient uptake, as well as pest control (Jaiswal et al., 2017; Jin, 2004; Wang et al., 2016). Straw turnover could enhance soil fertility in cropland. However, the low precipitation and temperature make the straw decompose much slower in winter and spring, remaining a large amount of undecomposed cellulose in and/or upon the surface soil of the cropland in Horqin sandy cropland. The undecomposed straw residual will lead to pests and viruses break out in this area. So many farmers prefer burning the maize straw after harvest, which causes heavy air pollution, in consequence of respiratory infections, and also a waste of organic resource in the semiarid area (Qu et al., 2012; Zhang et al., 2014). Cellulose is one of the most renewable bioenergy material, producing alcohol, carbohydrate, single-cell protein, organic fertilizer during its enzymatic decomposition procedure (Lynd et al., 2002). Therefore, the efficient treatment and suitable utilization of cellulose could not only supplement bioenergy shortage but also relieve environmental pollution from agricultural waste. It is an efficient and environmentally friendly approach to decompose cellulose by cellulolytic decomposers (Panagiotou et al., 2003). The cellulose decomposers isolated from terrestrial ecosystems are mostly fungi, and most of them could be categorized into Trichoderma, Penicillium, Aspergillus and Fusarium (Lu et al., 2011; Panagiotou et al., 2003; Wang et al., 2015; Wen et al., 2005). Cellulose decomposers play an important role in straw decomposition after its turnover. The study on the functional cellulose decomposers and their ecological service is fundamental and essential in sustainable agricultural management (Qin & Wei 2007). However, it is seldom reported on the isolation of efficient cellulosed decomposers in semiarid sandy cropland. We demonstrated that isolation of highly efficient cellulose decomposers in Horqin sandy cropland soil could not only enrich soil functional microbial bank, but also accelerate maize straw turnover and sustainable agricultural development in the agro-pasture ecotone of northern China.

2.8.2 Materials and methods

Study area: This study was conducted in Naiman Desertification Research Station of the Chinese Academy of Sciences (NDRS), which is located in Naiman County of Inner Mongolia, northern China (120º55'E, 42º41'N; 360 m a.s.l.) (Figure 10). The climate in this area is characterized as a temperate, semiarid continental monsoon, with a hot summer and cold winter. The mean annual precipitation is 366 mm, with 70-80% falls during the growing season from June to September. The annual mean open-pan evaporation is around 1935 mm, five times greater than annual precipitation. The annual mean temperature is around 6.4 °C, ranging from a monthly maximum of 23.5 °C in July to a monthly minimum of -16.8 °C in January. The annual mean wind velocity ranges from 3.6 to 4.1 m/s, and the dominant wind is southwest in summer and autumn and northwest in winter and spring. The zonal soil is classified as sandy chestnut, which is sandy in texture, light yellow in colour and loose in structure, and is vulnerable to wind erosion (Wang et al., 2016; Zhao et al., 2003). The original landscape was dominated by sandy grassland with scattered trees (mostly elms, Ulmus spp.). However, the grassland has been replaced by farmland, due to the increase of population and development of irrigation. Maize (*Zea mays L.)* monoculture dominates the cultivated land because of its higher productivity and easier management (Wang et al., 2016).

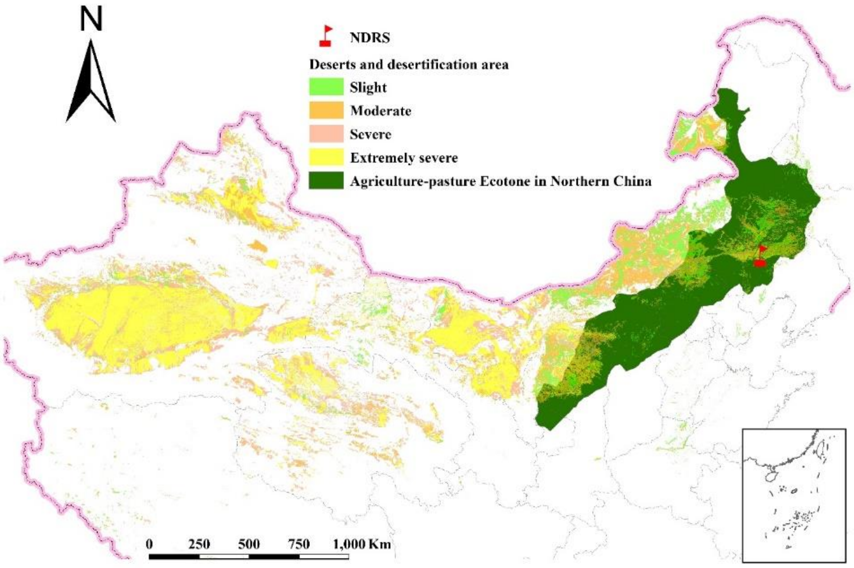


Figure 10. Study area of Naiman Desertification Research Station (NDRS), in the southeastern part of Inner Mongolia, typical area in agro-pasture ecotone of northern China

2.8.3 Experimental design

Soil collection: We collected soil samples for isolating cellulose decomposers in the comprehensive observation cropland field in NDRS. This long-term observation field was established in 1997, covering 20 000 m2 and planting maize. This field is a typical irrigated sandy cropland in Horqin sandy cropland of agro-pasture ecotone in northern China. We randomly set up 10 quadrats (1 m × 1 m) in the observation field, took five replications of soil cores in each quadrate and mixed the five cores as a pooled sample. Every pooled sample was sieved (< 2 mm) to remove rocks and plant material, and stored separately in sterilized ziplock bags at 4 °C, prepared for laboratory isolation of cellulose decomposers. The basic characteristics of the observation field were shown in Table 8.

Table 8. Characteristics of the cropland

Crop	Species	*Zea mays* L.
	Yield (g/m^2)	998.37±38.32
	Aboveground biomass (g/m^2)	2288.73±156.71
	Underground biomass (g/m^2)	77.45±9.16
Soil	pH	8.20±0.21
	C ($g.kg^{-1}$)	7.56±0.30
	N ($g.kg^{-1}$)	0.85±0.04
	P ($mg.kg^{-1}$)	28.76±4.01
	K ($mg.kg^{-1}$)	95.31±7.83
	Bulk density ($g.cm^{-3}$)	1.41±0.11
Microbe	Bacteria abundance (10^3 /g. dry soil)	1032.44±50.97

Actinomycete abundance (10^3 /g. dry soil)	495.20±44.16
Fungi abundance (10^3 /g. dry soil)	21.07±3.38
Soil Microbial biomass carbon (mg kg^{-1})	462.17±35.08

Note: Data were from the long-term observation database in NDRS (http://nmd.cern.ac.cn/meta/metaData)

2.8.4 Culturable medium for cellulose decomposing fungi isolation

The medium used for isolating and selecting efficient cellulose decomposing fungi includes CMC medium, PDA medium, Congo Red CMC medium, litter medium and liquid medium. The detailed recipe for each medium was shown in Wang et al., (2015).

2.8.5 Procedures for isolation and screening

Isolation: 10 g fresh soil was mixed into 90 ml sterilized water until the soil was totally suspended. 1 ml supernate was added into 9 ml sterilized water and shaked to produce 1% and 10% soil microbial suspensions. 1 ml suspensions were transferred into CMC medium plates with five replicates for both 1% and 10% suspensions, separately. The plates were incubated at 30 °C for 10-15 days until different colonies grew big enough to be picked for purification.

Purification: Single colonies were picked and transferred into PDA medium plates, and incubated at 30 °C for 3-5 days. Colonies without any infection were selected as purified fungi for advanced screening.

Screening for efficient cellulose decomposing fungi: Pure colonies were transferred into litter medium plates at 30 °C for 5-10 days. Pure colonies with long mycelium and abundant spore were chosen as cellulose decomposing fungi. Separated colonies were scraped by vaccinating lancet, placed into Congo Red CMC medium plates and incubated at 30 °C for 10 days to select efficient cellulose decomposing fungi. Colonies with faster growth and larger transparent rings in the Congo Red CMC medium plates were screened as highly efficient cellulose decomposing fungi. The selected fungi strains were stored in Congo Red CMC medium tubes for morphological and molecular identification and further experiment.

2.8.6 Morphological and molecular identification

Morphology: The selected fungi strains were transferred into PDA medium plates, and incubated at 30 °C for 3-5 days. Microscopic examination was performed to observe the characteristics of the mycelium and spore for each strain. “Manual of Fungi Taxa Identification” (Wei 1979) and “Illustrated Genera of Imperfect Fungi” (Barnett and Hunter 1998) were used for the fungi taxa identification.

Molecular biology: DNA was extracted from a small portion of the selected fungi mycelium (Zhang et al. 2008). Primers of ITS1 (5'-TCCGTAGGTGAACCTGCGG-3') and ITS 4 (5'-TCCTCCGCTTATTGATATGC-3') were used for PCR, and the PCR products were sequenced. The DNA sequences were aligned with GenBank database in NCBI to determine the taxa of the selected fungi.

2.8.7 CMC enzyme activity

Take a small amount of the final selected fungi and dipped it into the conical flasks with the liquid medium. Shake (150 r/min) the flasks at 30 °C for 7 days, and then centrifuge it at 4 000 r/min for 15 min. The supernate was used for determining the CMC enzyme activity. 0.5 ml of supernate was placed into a tube with 1.5 ml citrate buffer (0.05 mol/l, pH 5.0, containing 0.5% CMC-Na). The tube was water-bathed at 50 °C for 30 min. Then 1 ml DNS was added into the tube and boiled the tube at 100 °C for 5 min. Constant the volume at 5 ml when the tube cooled at room temperature. Determine the absorbance at 540 nm in a spectrophotometer. The glucose content was calculated based on the standard curve (Bayer et al. 2013; Fang et al. 2007; Sun et al. 2017).

CMC enzyme activity $X=m/(V\cdot t)\cdot n$ (Eq-1)

Where m represents glucose content, V represents supernate volume (0.5 mL), t represents reaction time (30 min) and n represents dilution ratio (5/0.5).

10 g fresh soil was diluted into 90 ml sterilized water, shaking 15 min at 150 r/min, and 0.5 ml of the soil supernate was used to determine soil CMC enzyme activity (Guan 1986).

2.8.8 Decomposition ability

Take a small piece of the strain, and incubate it in the liquid medium conical flasks for 24 h. Then put 5 pieces of filter paper into the flask and shake (150 r/min) incubation at 30 °C for 10 days. Determine the weight loss every day until the weight does not change significantly (Yao and Huang 2006).

Decomposition rate $D = (m_0-m_i)/m_0 \times 100\%$ (Eq-2)

where m_0 is the original weight of the filter paper, while m_i is the weight on the ith day.

2.8.9 Straw decomposition in field experiment

Cut the maize straw into small pieces (< 5 cm) after harvest, and oven-dried the straw pieces at 70 °C for 24 h to a constant weight. 10 g straw pieces were sealed in a 20 cm×25 cm nylon net bag (net hole are 2 mm×2 mm). Soap the net bags with straw into the liquid medium incubated with the selected cellulose decomposing fungi for 30 min. Meanwhile, straw net bags without decomposer infection were set as control. The control net bags were soaped into the liquid medium without any microbes for 30 min to minimize the influence of the liquid medium to straw decomposition. Then 20 net bags with and without the decomposing fungi were buried at 10 cm deep in the cropland soil, respectively. The net bags were set randomly 20 m away with each other in the comprehensive observation cropland field in NDRS in early October. We collected 5 net bags with the impact of the selected cellulose decomposing fungi, as well as 5 control net bags in early December (frozen season, 60th day), next early May (seeding season, the 200th day), next middle August (growing season, 300th day) and next early October (harvest season, 360th day), respectively. The straw in the net bags was cleaned and then oven-dried at 70 °C for 24 h. The straw decomposition rate is calculated as Eq-2 (Qu et al., 2011).

2.8.10 Data analysis

Origin 8.0, SPSS 17.0 and Microsoft excel 2016 were used to analyze the descriptive statistical data and significance tests. Significant differences were assessed by One-way ANOVA and LSD tests at $p<0.05$. All the descriptive data were expressed as means ± SE.

3 Results & Discussion

3.1 Assessment of pastoral vulnerability in Mongolia

The single and integrated pastoral vulnerability assessments were done at two case areas of Khovd and Gobi-Altai provinces in Mongolia using collected datasets and developed methods. The detailed research report was written in the Mongolian language which shared with the local government offices and discussed with all partners. The main results of the research are summarized in this report.

3.1.1 Assessment of pastoral vulnerability in Gobi-Altai province, Mongolia

The estimation of component indexes for the pastoral vulnerability assessment in Gobi-Altai province is reported below in detail by each of the indicators.

Drought: Gobi-Altai province experienced considerable droughts, which covered most of soums in 2001, 2007-2009 and 2017 respectively (Figure 11). During the first ten years, the frequency of the drought was higher, and it was lower in the last ten years. The frequency of the drought within the last 20 years from 1998 to 2017 was low (2 to 4 times) in Altai, Tsogt, Bayan-Uul and Khukhmorit soums, moderate (4 to 6 times) in Tseel, Bugat, Tonkhil, Tugrug, Biger, Darvi and Yesunbulag soums, and high (6 to 9 times) in Chandmani, Jargalan, Delger, Erdene, Taishir, Khaliun and Sharga soums (Figure 12a). In terms of geographical location, soums that are located in the far east have experienced more drought than the others did. Both frequencies of the drought and the spatial distribution coverages were high in Jargalan, Delger and Chandmani soums (Figure 12b).

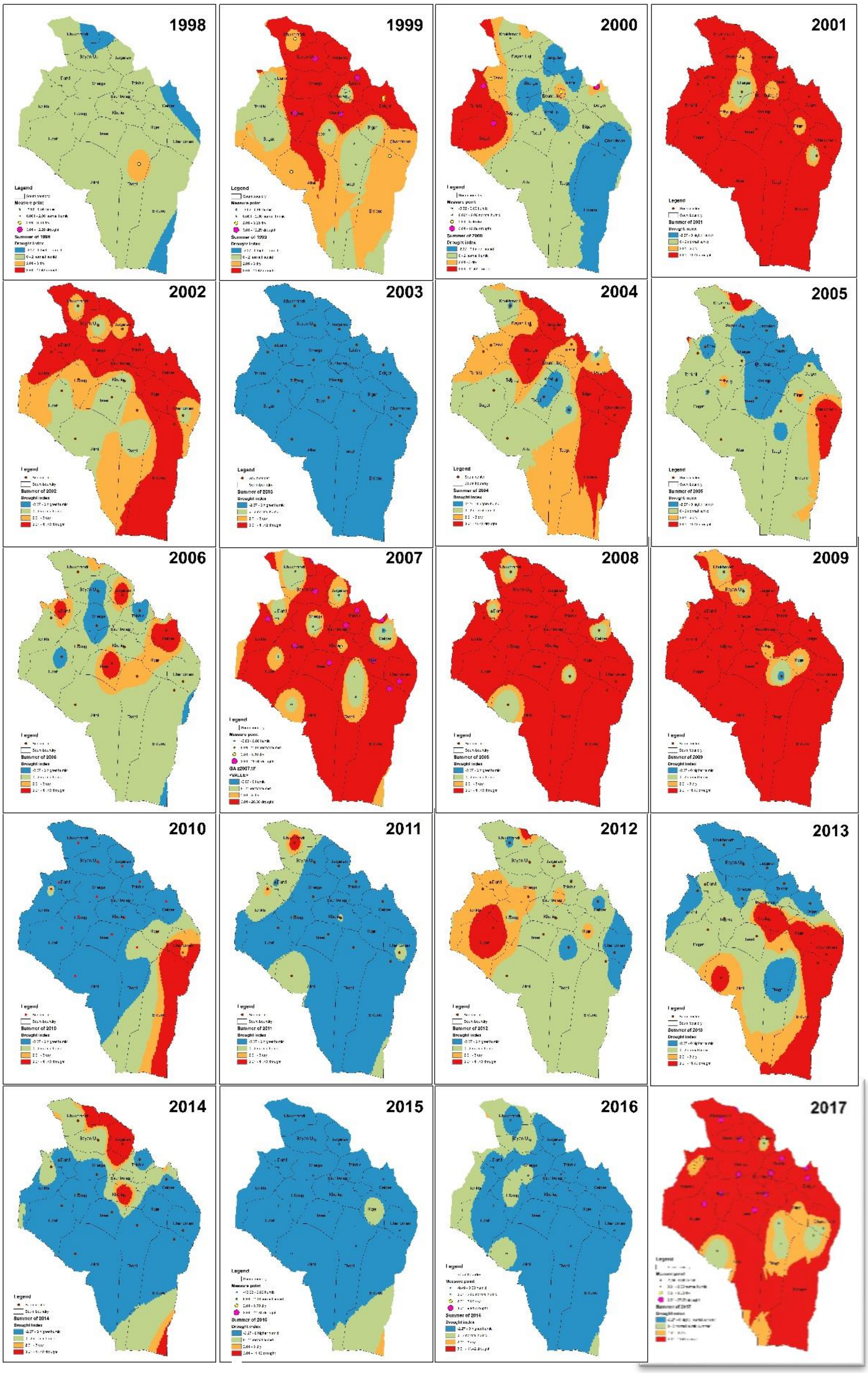


Figure 11. Drought map in Gobi-Altai province

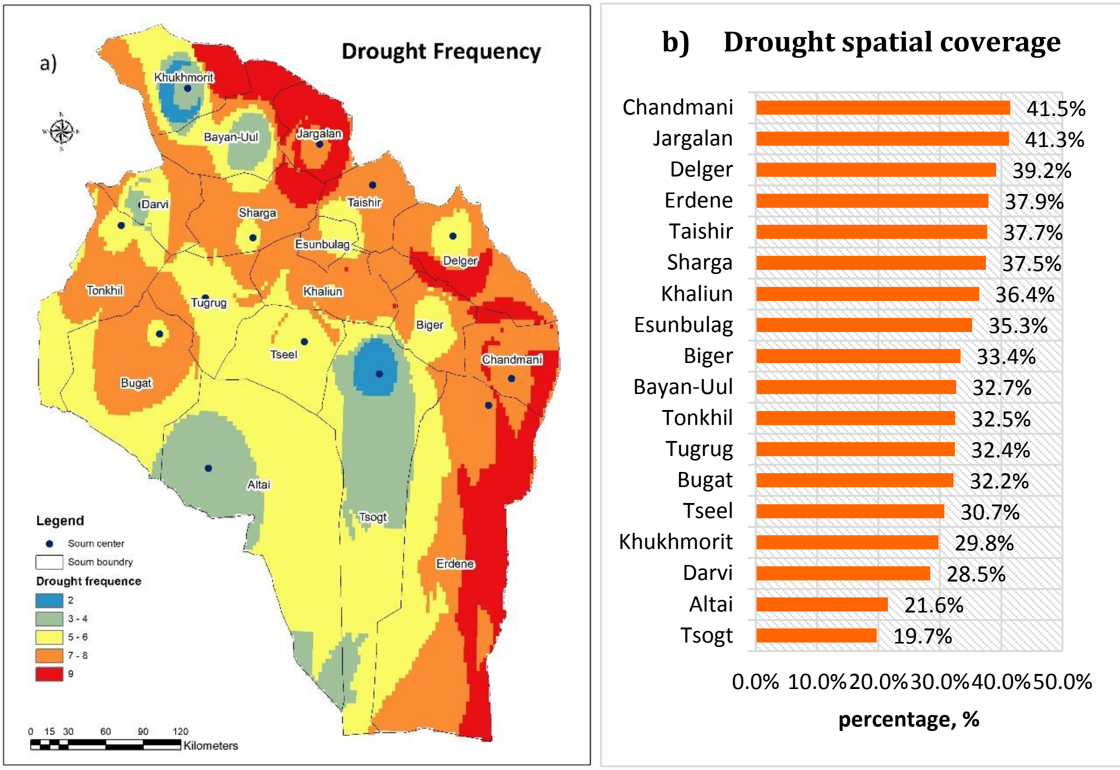


Figure 12. a) Drought frequency map and b) Spatial coverage (%) of drought on average from 1998-2017

Pasture use: With the 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 had collapsed. Also, the loss of control over the number of livestock has resulted in an increase in livestock number throughout the country. In Gobi-Altai province, for instance, the number of livestock has doubled from 1.6 million in 1990 to 3.8 million in 2017 after the collapse of the socialist system. Although the dzud in 2009-2010 claimed half of 2.5 million livestock, it has tripled again within only 6 years following the incident. The average pasture use in the province for the last 20 years is mapped in Figure 13a. It is 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. The carrying capacity of pastureland was determined at the soum level by the Mongolian government (Mongolian Academy of Sciences, 1990), which was used as a reference. Currently, pasture carrying capacity has exceeded in majority of 17 soums, while only Bugat soum is under the capacity level (Figure 13b).

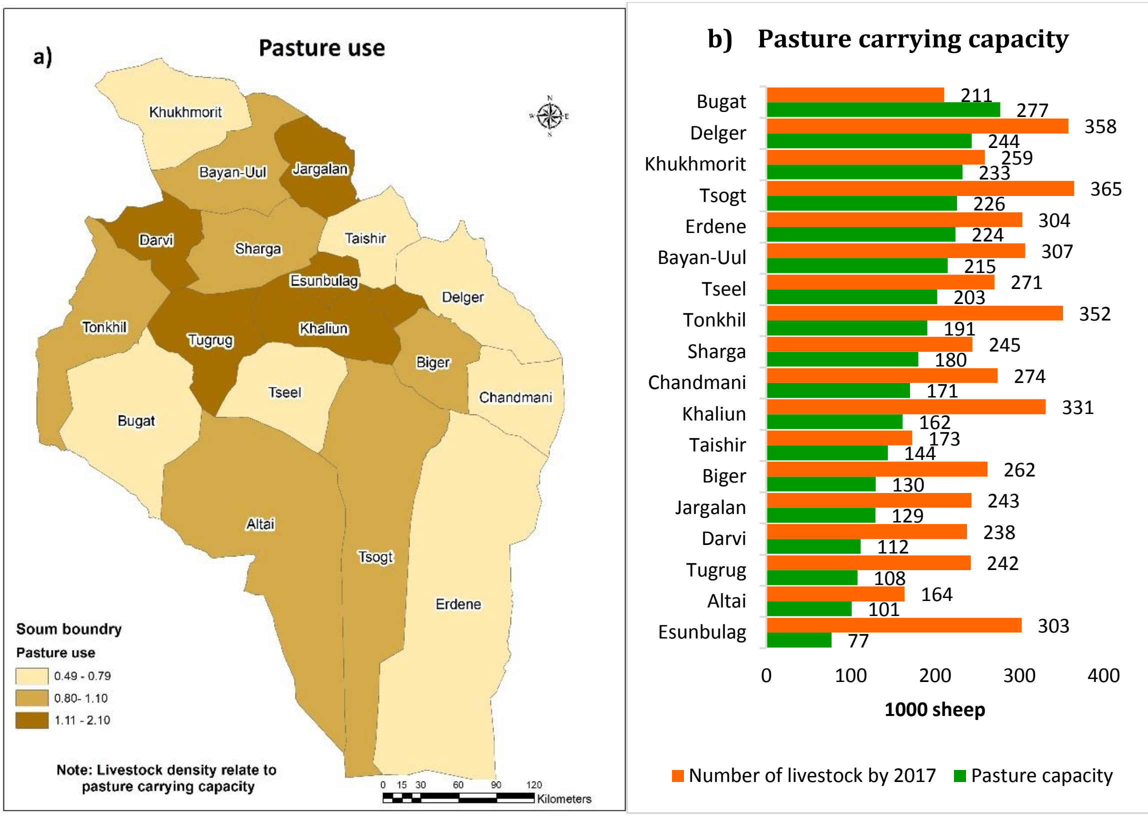
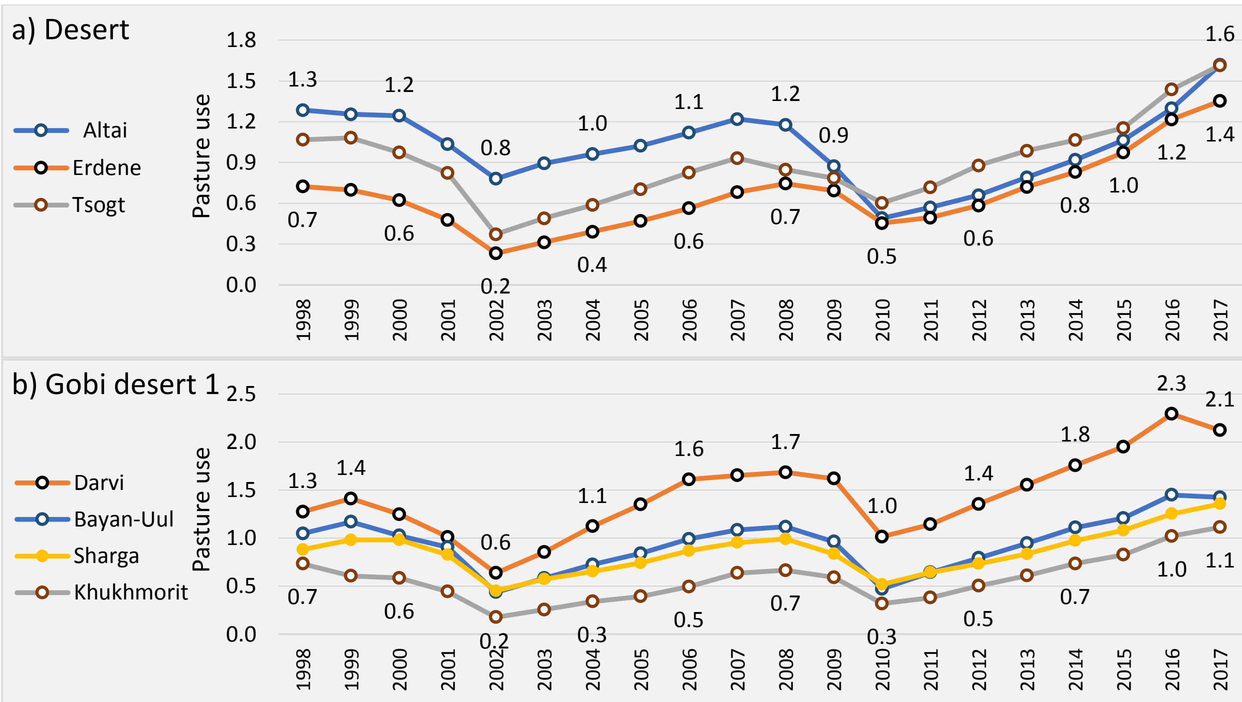


Figure 13. a) Average pasture use, and b) Pasture carrying capacity of Gobi-Altai province

The dynamic changes of pasture use for the last 20 years in 18 soums by natural zones are shown in Figure 14 a-e. Since 2010 pasture use has increased in all types of natural zones. Due to the increased number of livestock in a small size of grazing land, pasture use is particularly high in Yesunbulag soum, the province center, in the mountain steppe zone.



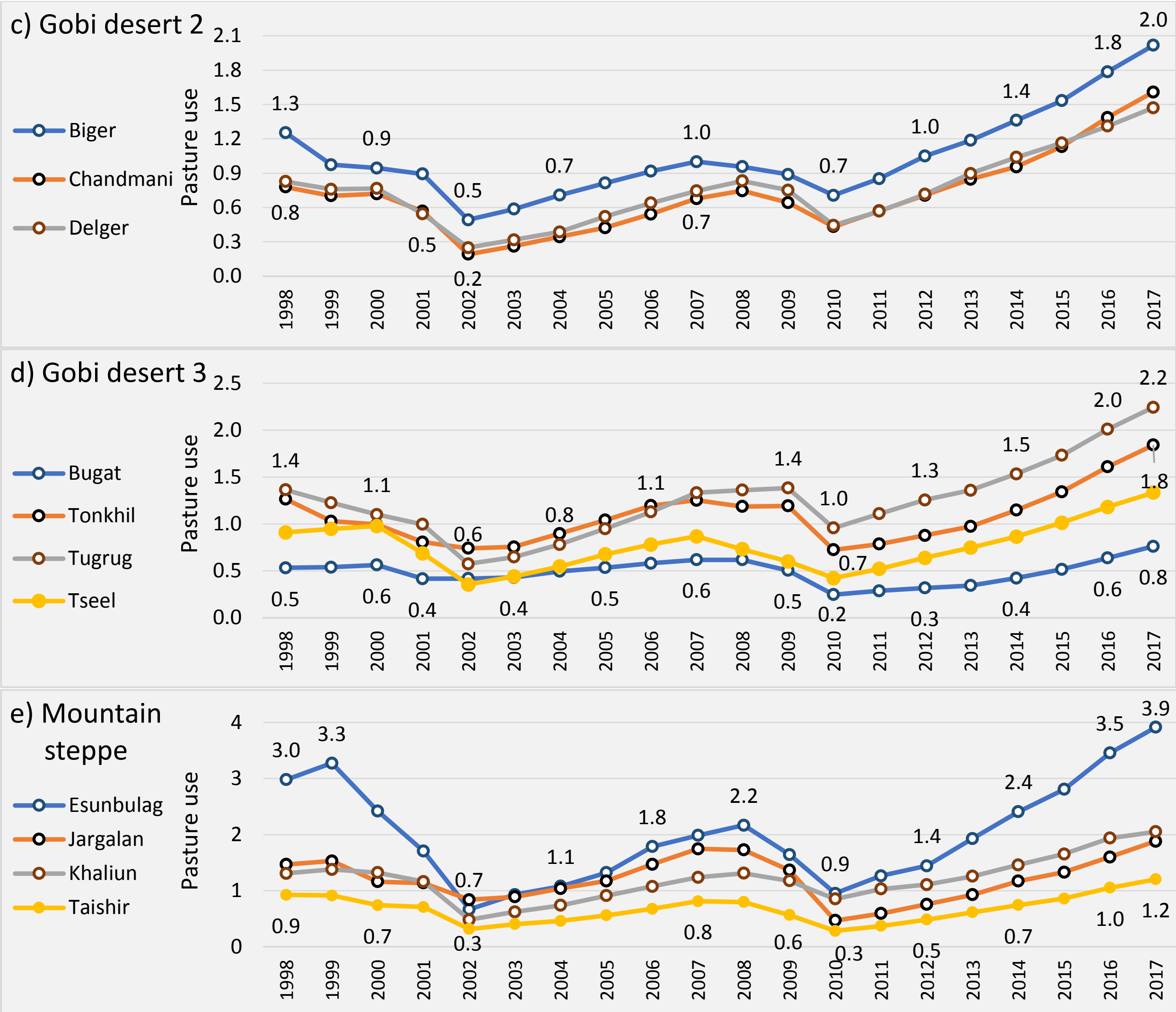


Figure 14. Dynamic changes of pasture use by soums in the natural zones

Vegetation cover change: The average NDVI changes during the last 20 years are shown in Figure 15. The changes of vegetation cover have been relatively high in the mountain steppe zone and low in the desert zone. The changes have occurred, in particular, in the bordering areas between soums. The frequency of changed vegetation cover was relatively high in Tsogt, Darvi, Bugat, Bayan-Uul, Yesunbulag, and Biger soums (Figure 15).

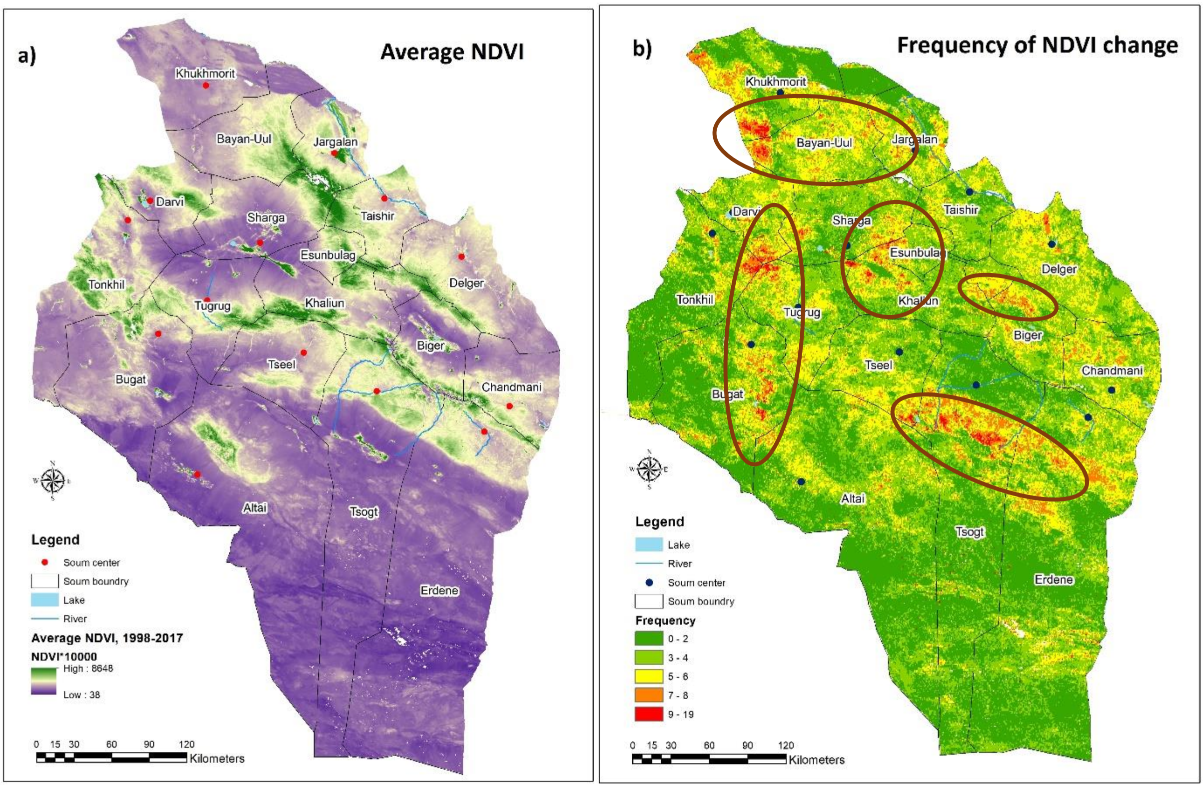
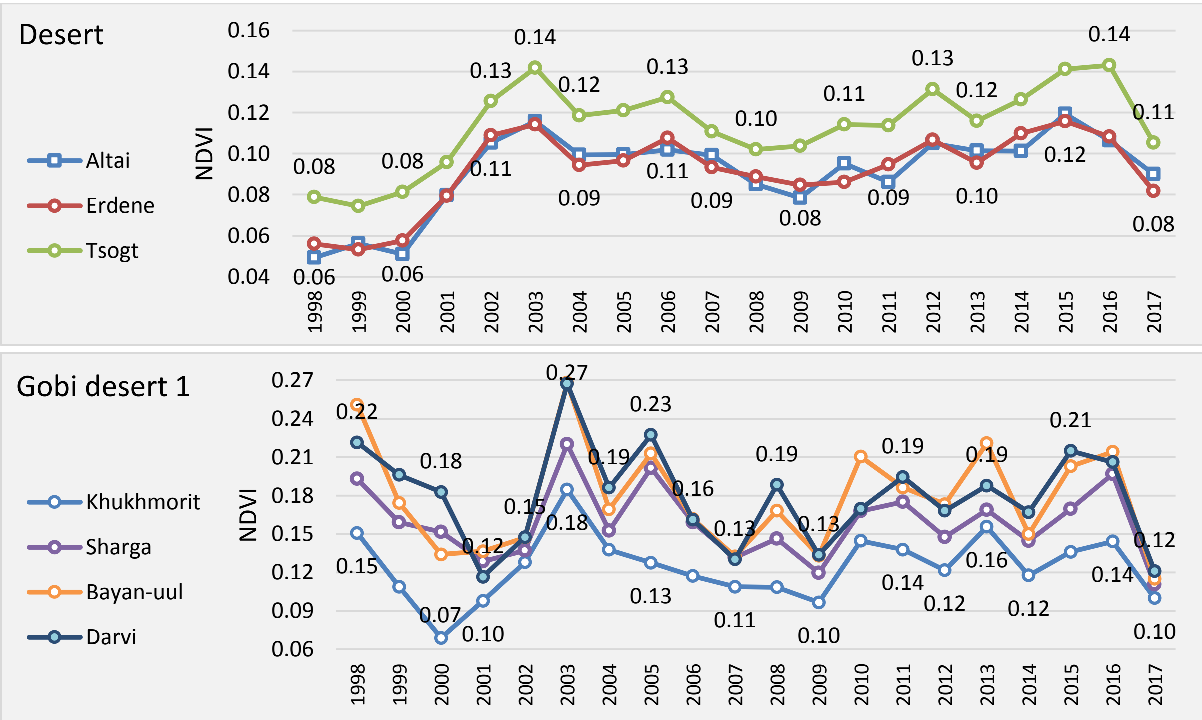


Figure 15. The average NDVI and frequency of changed vegetation cover 1998-2017

The dynamic changes of NDVI during the past 2 decades are shown in Figure 16 by each soum in different ecological zones.



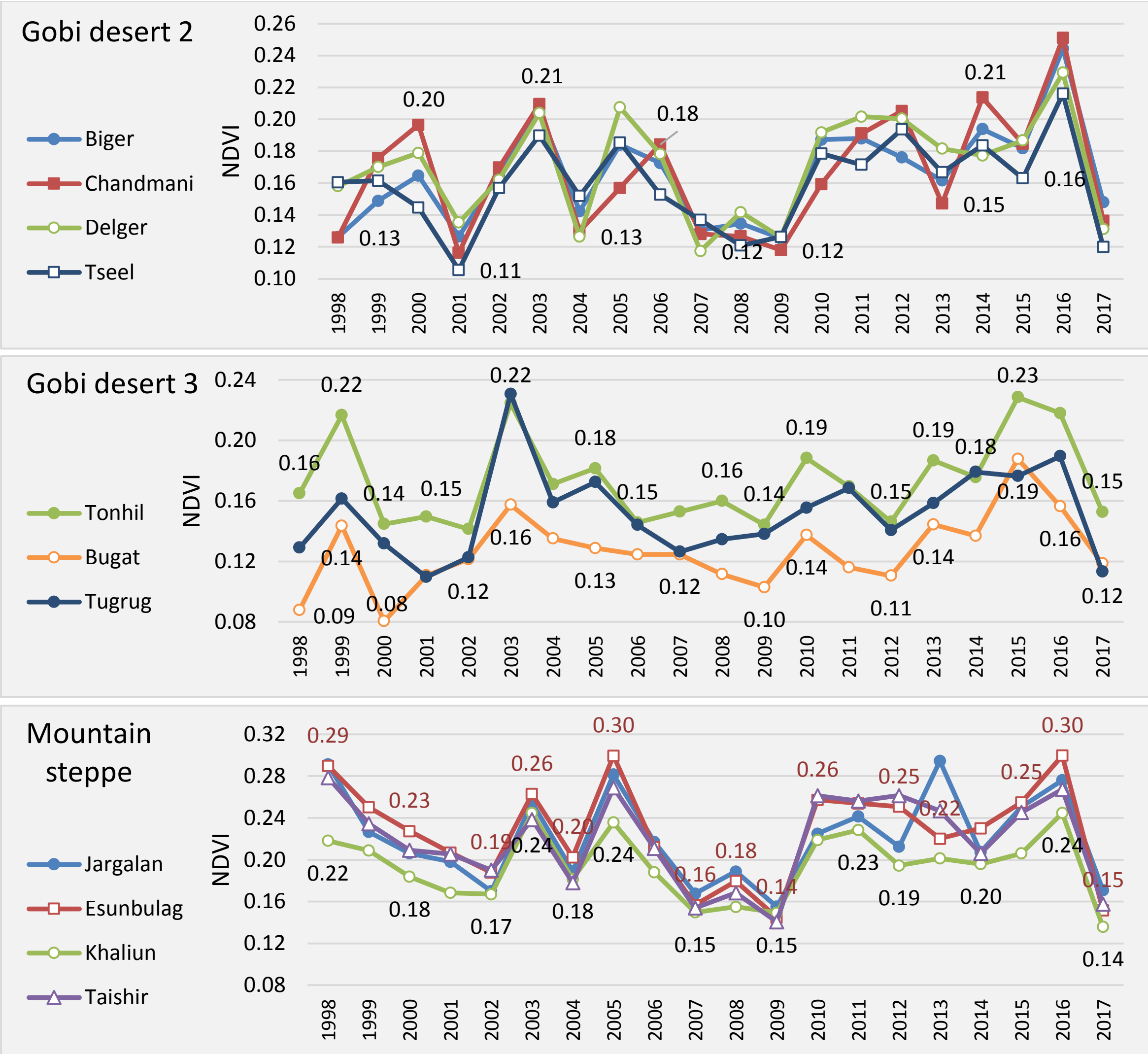


Figure 16. Dynamic changes of NDVI, 1998-2017

Pastoral vulnerability: The pastoral vulnerability during the last two decades is presented in Figure 17. In the map, base colours show the level of pastoral vulnerability and the graph shows the average value of components in each soum. As seen from the results, 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 effective variable is drought followed by pasture. The growing number of livestock and related product market, price, accessibility, water scarcity in the grazing areas, and pasture grazing managements are also considerable issues.

Table 9 presents the affecting level of vulnerability in the case area through 3 indicators on human, livestock and pasture.

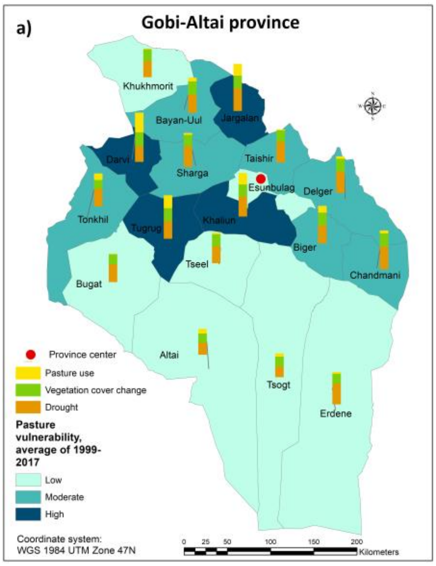


Figure 17. Levels of pastoral vulnerability and component indicators in Gobi-Altai province

Table 9. 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

Assessment of pasture degradation by field survey

This field survey was done at only Biger soum from Gobi-Altai province due to initial vegetation change assessment and research fund limitation. During the field survey, we recorded 109 species of vascular plants belonging to 69 genera and 23 families in Biger sub-province. Pastureland types and changes in areas comparing 1981 value to 2018 value are shown in Table 10.

Table 10. Comparison of pastureland area changes in 1981 and 2018, Biger soum, Gobi-Altai province

	TYPES OF PASTURE	1981		2018	
		Area, ha	Percentage	Area, ha	Percentage
	Mountain pasture	**105909.6**	**27.3**	**126722.9**	**32.6**
1	High mountain	2638.6	0.7	2161.0	0.6
2	Mountain steppe	57636.7	14.8	39225.7	10.1
3	Mountain desert steppe	45634.3	11.8	85336.2	22.0
	Steppe pasture	**281236.5**	**72.5**	**230809.7**	**59.5**
4	Desert steppe	160701.3	41.4	98755.9	25.4
5	Desert	120535.2	31.1	132053.8	34.0
6	River and lake valley		0.0	26545.0	6.8
	Total pasture	**387146.0**	**99.7**	**385157.3**	**99.2**
7	Lake area	991.2	0.3	2979.9	0.8
	Total soum pasture area	**388137.2**	**100.0**	**388137.2**	**100.0**

When we compare this survey result with the pasture-monitoring map in 1981, non-degraded area decreased by 30.5%, whereas degraded area expanded: low degraded area increased by 8%, medium degraded area by 17.6%, high degraded area by 3.4%, and the most degraded area increased by 1.5% from 1981 value (Figure 18). This means there has been a shift in the mountain steppe ecosystem to desert steppe and desert steppe ecosystem to desert pasture, which is not a good condition. The main impacts on the degradation are increasing the number of livestock that was 154,674 sheep in 1981 and 239,232 sheep in 2018. In the south-east part of the soum, *Artemisia adamsii*, *Ajania achilleoides*, *Ephedra sinica* and *Artemisia adamsii* were highly increased and *Nitraria sibirica, Achnaterum splendens, Leymus secalinus* and *Potentilla bifurca*, *Achnaterum splendens* vegetations are increased at Biger valley and lake area which indicates pasture degradation caused by the increased number of livestock.

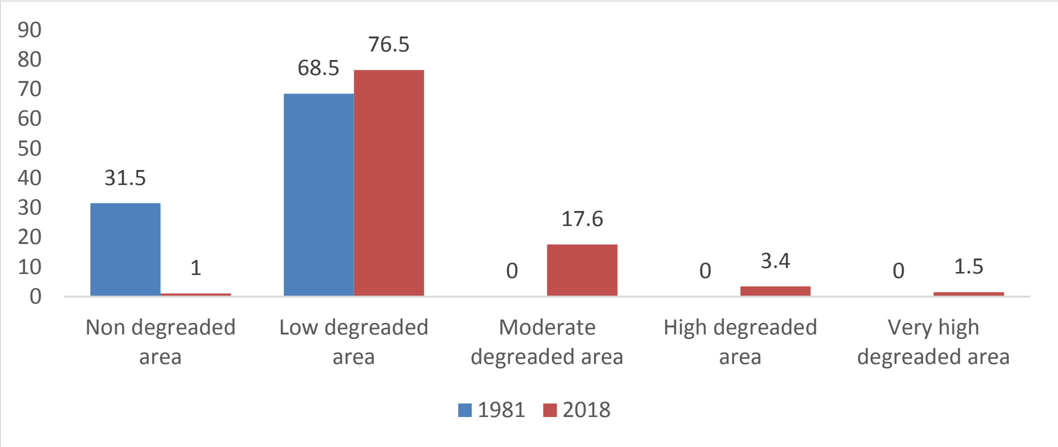


Figure 18. Change in the state of pasture, in percentage, Biger soum, Gobi-Altai province

3.1.2 Assessment of pastoral vulnerability in Khovd province, Mongolia

The results of component indexes for the pastoral vulnerability assessment in Khovd province are reported below in detail by each of the component indicators.

Drought: Khovd province experienced considerable droughts, which covered most of soums in 2000-2002, 2004-2009 and 2017 respectively (Figure 19). During the first ten years, the frequency of the drought was higher, and it was lower in the last ten years except 2017. The frequency of the drought within the last 20 years from 1998 to 2017 was low (2 to 4 times) in Erdeneburen, Munkhhairkan, Must, and Durgun soums; moderate (4 to 6 times) in Chandmani, Bulgan, Myangad, Uench, Duut, Altai, Zereg, Mankhan and Tsetseg soums; and high (6 to 9 times) in Khovd, Buyant and Darvi soums (Figure 20a). Both frequencies of the drought and the spatial distribution coverages were high in Khovd, Buyant and Darvi soums (Figure 20b).

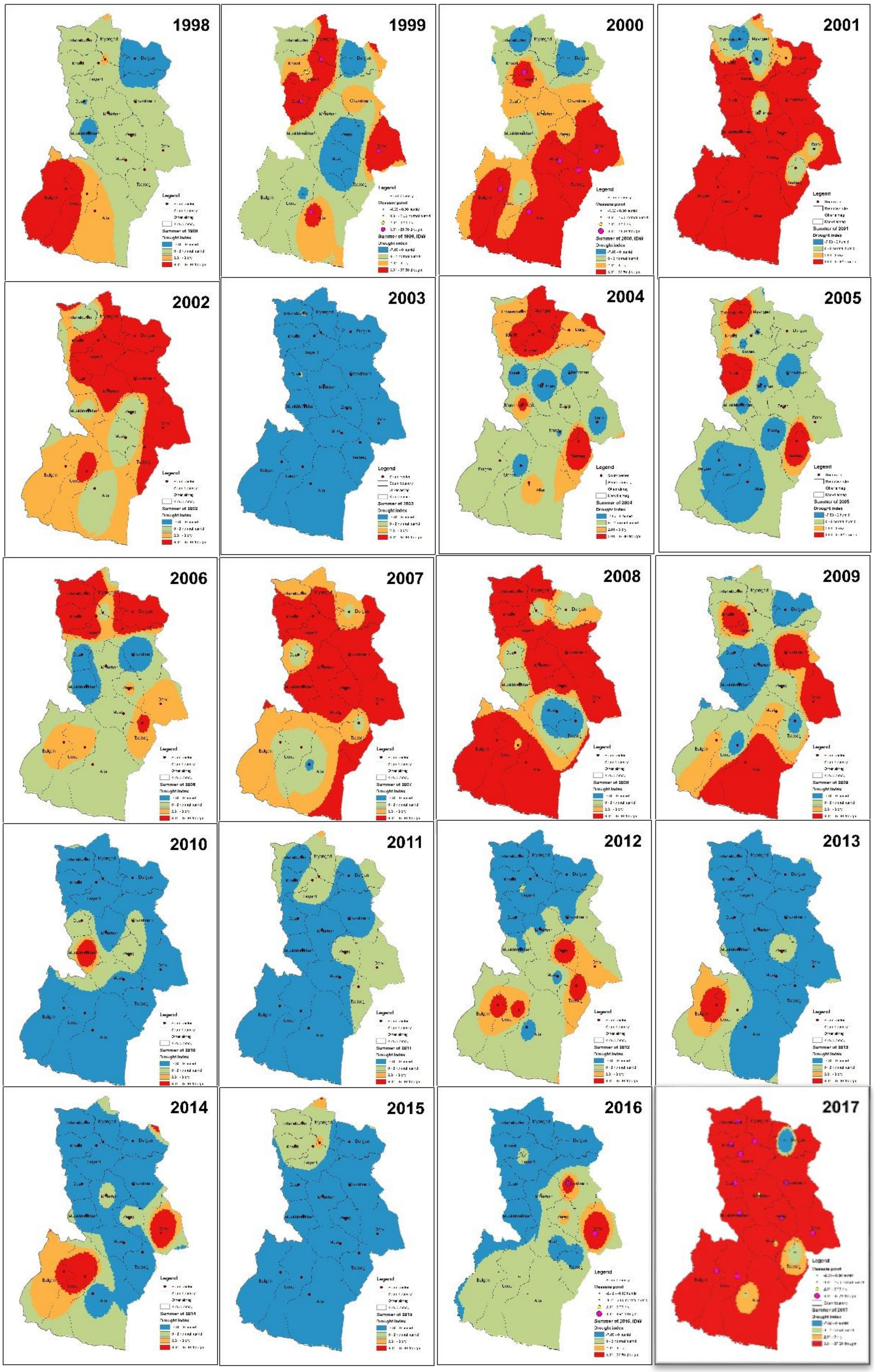


Figure 19. Dynamic changes of drought

Note: Red - drought, orange - Улаан нь гантай, улбар шар нь гандуу, усан ногоон нь чийглэг, цэнхэр нь их чийглэг

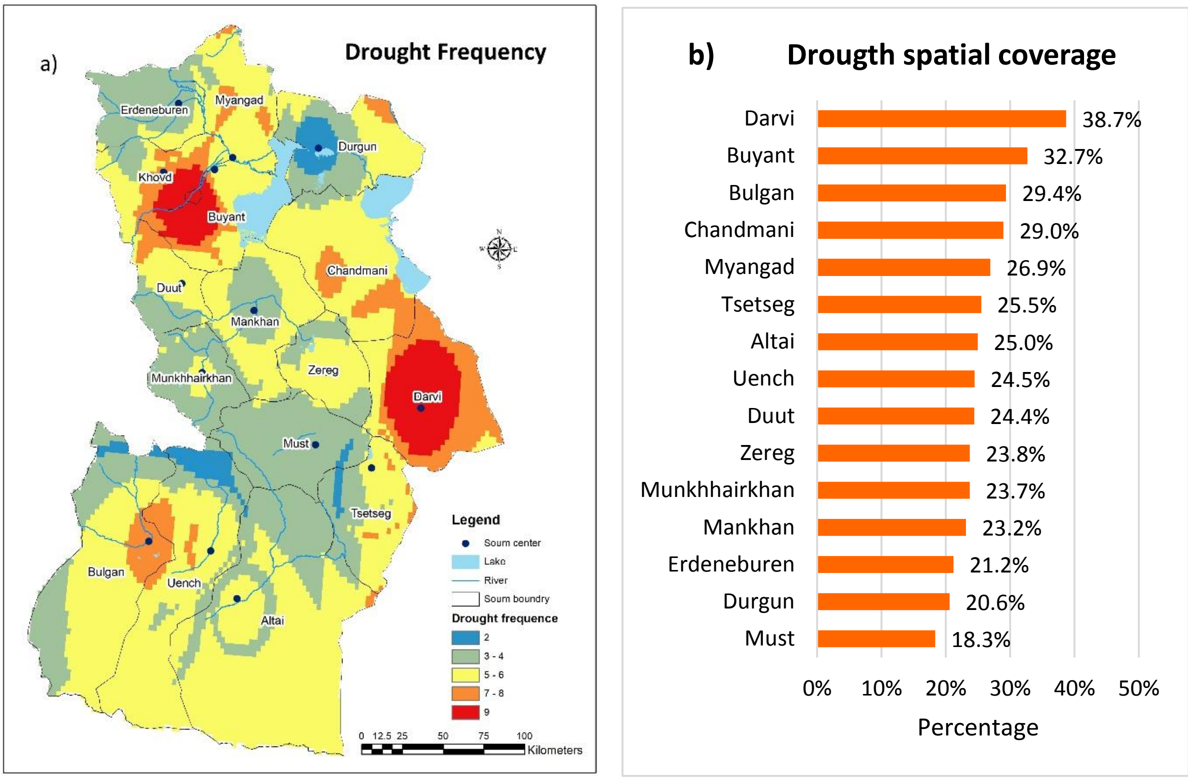


Figure 20. a) Drought frequency map, and b) Drought spatial coverage by percentage average of 1998-2017, Khovd province

Pasture use: In Khovd province, the number of livestock has more than doubled from 1.6 million heads right after the collapse of the socialist system in 1990 to 3.4 million heads in 2017. During the dzud disaster in 2009-2010, the number of livestock dropped out from 2.4 million to 1.6 million, which was the biggest sudden risk. Since then it has doubled again within 6 years becoming the main reason for pasture degradation. The average pasture use in the province is mapped in Figure 21a. During the last 20 years, the pasture use has been high in ten soums, medium in five soums and low in only one soum. Depending on the number of livestock and grazing land size, the pasture use in the majority of the soums is expected to increase in the future. The carrying capacity of the pastureland was determined at the soum level by the Mongolian government (Mongolian Academy of Sciences, 1990), which we used as a reference. Currently, pasture carrying capacity has exceeded in all soums (Figure 21b).

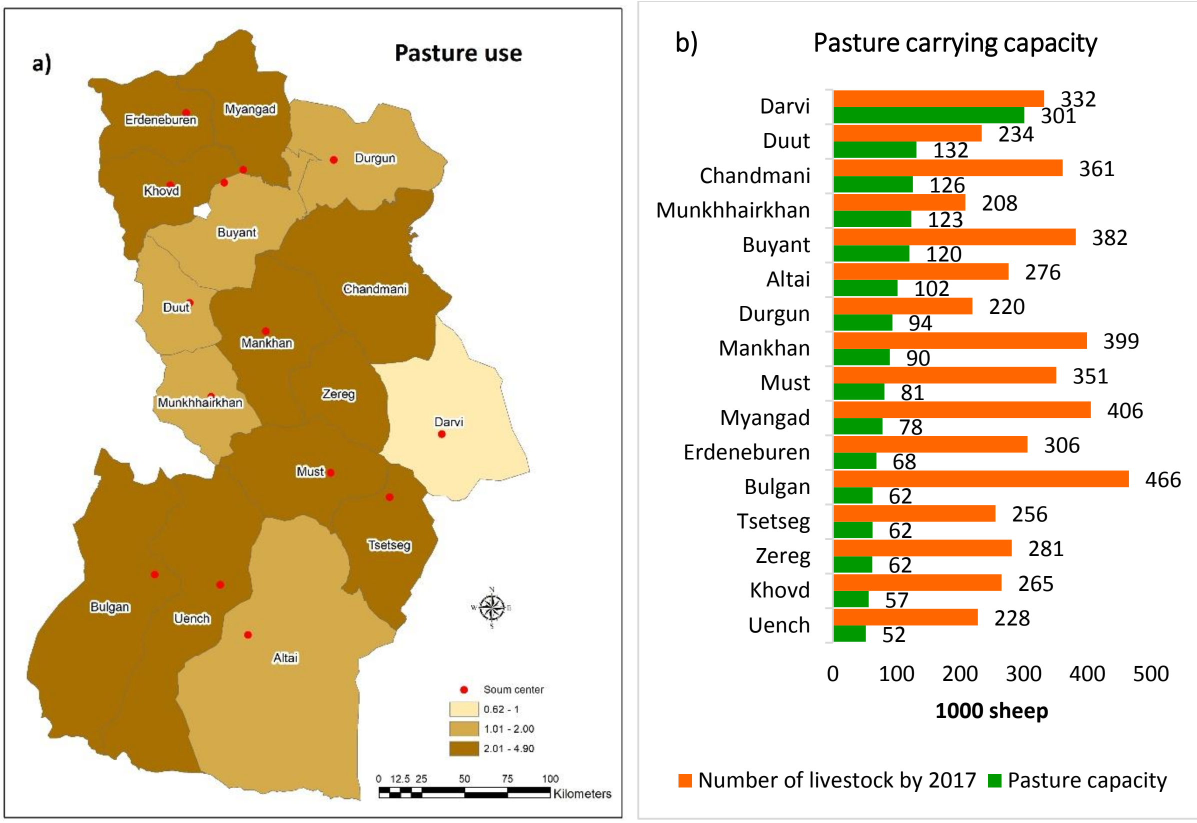


Figure 21. a) Average pasture use, and b) Pasture carrying capacity in Khovd province

The dynamic changes of pasture use for the last 20 years in 17 soums by natural zones are shown in Figure 22 a-d. Since 2010 pasture use has increased in all types of natural zones. Due to the increased number of livestock in a small pasture area, the pasture use is specifically high in Bulgan, Zereg and Myangad soums. There are several reasons for growing number of population and markets in Bulgan and Zereg soums due to rapid changes in recent economic condition.

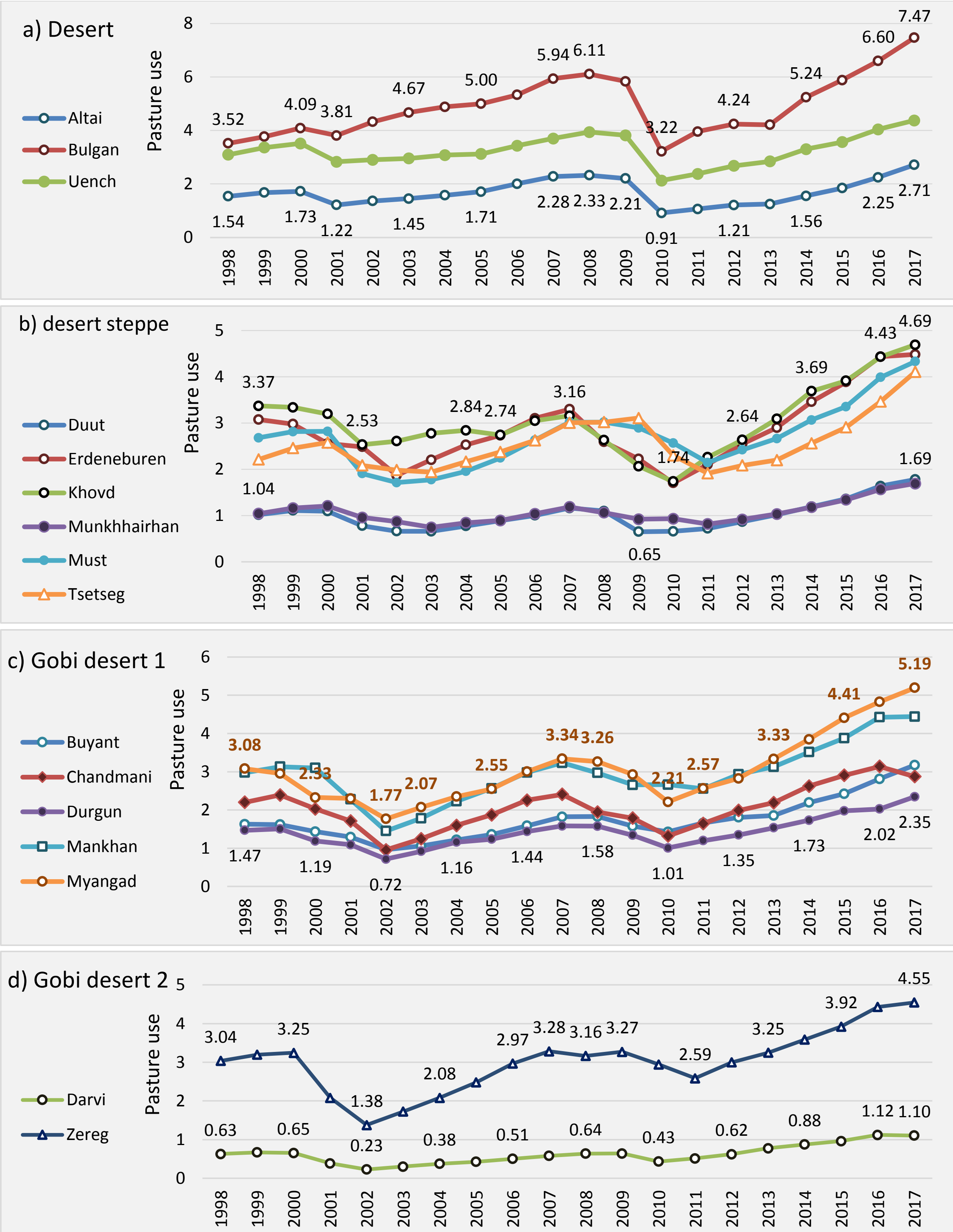


Figure 22. Pasture use by natural zones, Khovd province

Vegetation cover change: The average NDVI changes during the last 20 years are shown in Figure 23a. As seen from the analysis the NDVI value is high in the mountain, near rivers and valley areas, and low in desert areas. The frequency of changed vegetation cover is very high in the Great lakes basin, medium in mountain steppe and low in desert steppe region (Figure 23b). The frequency of changed vegetation cover is high in Chandmani, Zereg and Durgun soums.

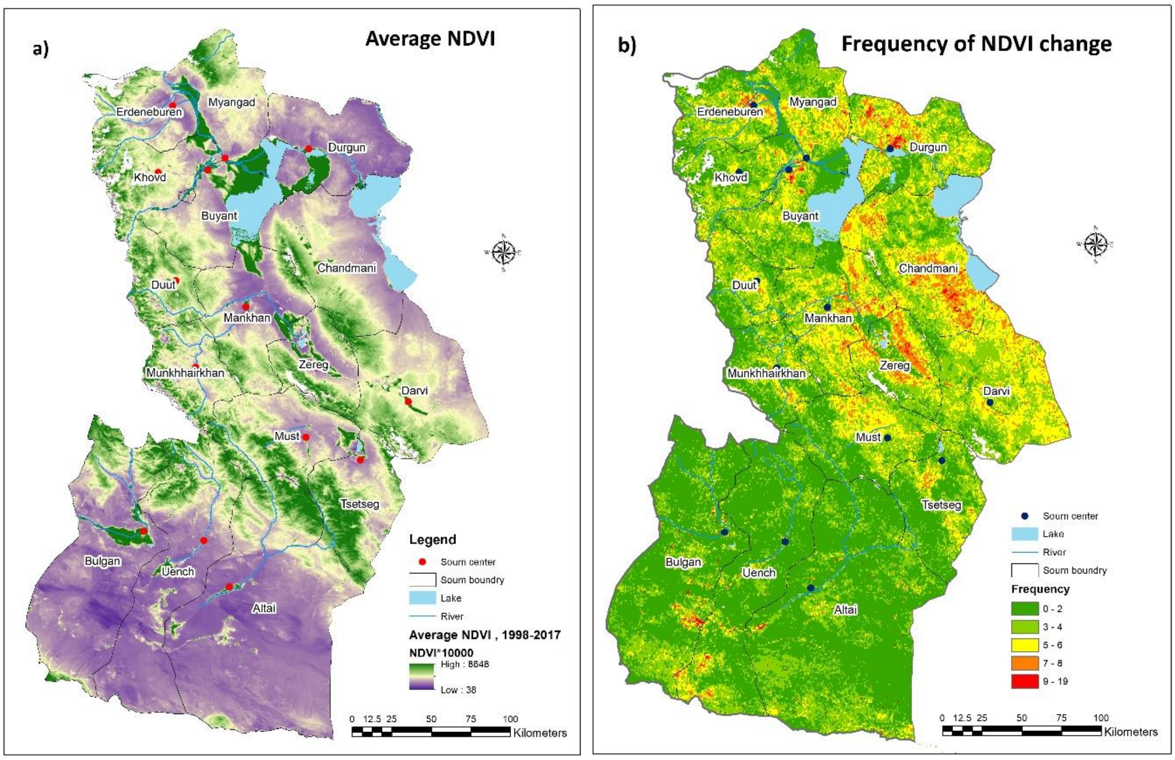


Figure 23. a) The average NDVI, and b) The frequency of changed vegetation cover, Khovd province

The dynamic changes of NDVI for the past 2 decades are shown in Figure 24 by soums in a different group of natural zones.

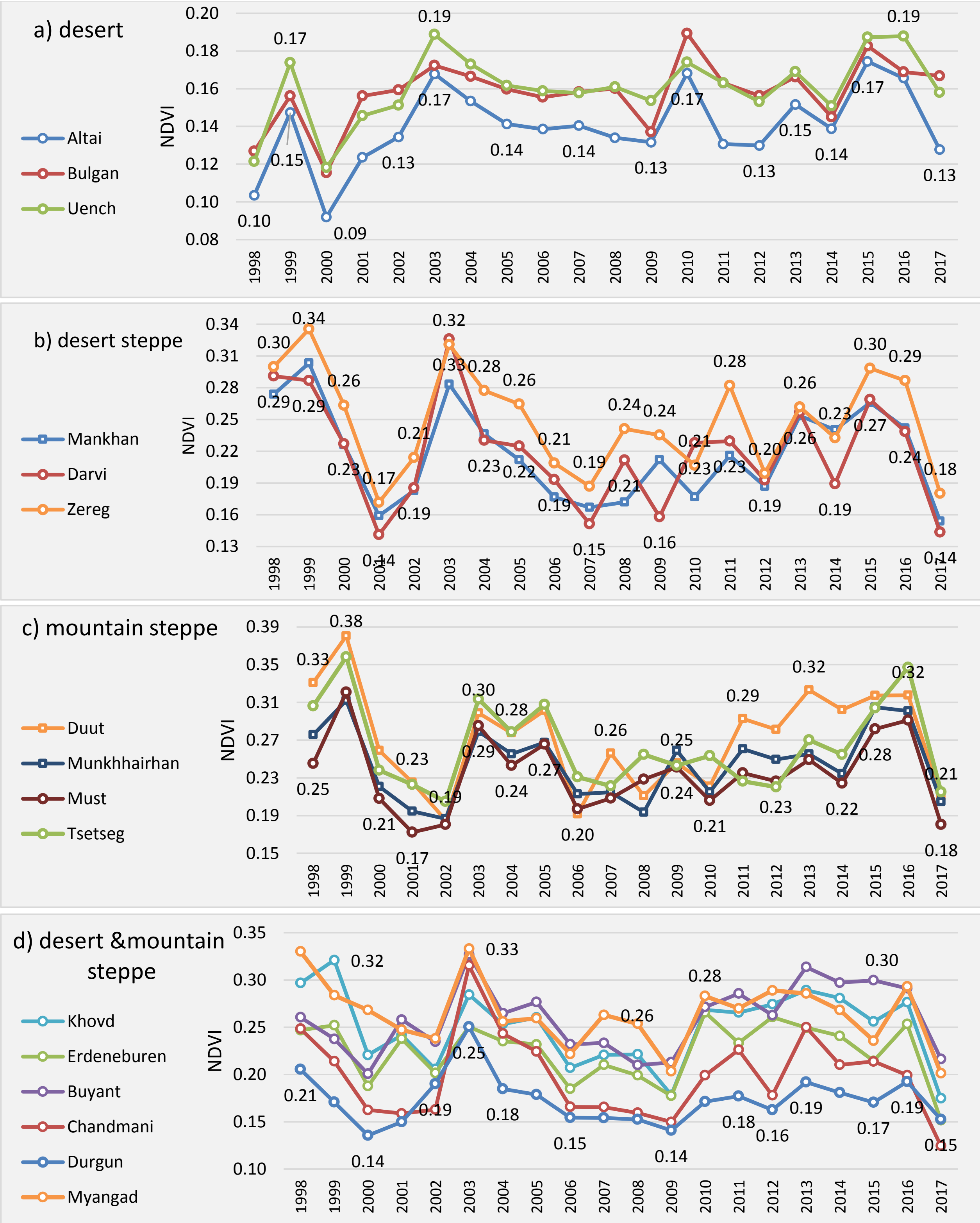


Figure 24. Dynamic changes of NDVI by natural zones, Khovd province

Integrated pastoral vulnerability: The pastoral vulnerability during the last two decades in the case area is presented in Figure 25. In the map, base colours show the level of pastoral vulnerability and the graph shows the average value of components in each soum during the last two decades. The pastoral vulnerability interdepends on each of three indicator values, where the most effective variable is pasture use followed by drought in this province. Five soums, namely Mankhan, Khovd, Chandmani, Bulgan and Zereg, were evaluated to have the highest pastoral vulnerability under climate and human activity related impacts.

Table 11 presents the affecting level of vulnerability through 3 indicators on human, livestock and pasture. Khovd province is in the high risk of affecting people and livestock, where human-related activities are main driving forces. Human related activities, in particular, overgrazing due to the increased number of livestock, shortage of water sources and ineffective pasture managements are the major impacts leading to pastoral vulnerability in this province. Vegetation degradation effectively occurred in the highly vegetated edge of the large rivers and lakes valley due to high livestock density and overgrazing around water sources.

Table 11. Impacts of pastoral vulnerability, Khovd province

Vulnerability level	Khovd		
	People (%)	Livestock (%)	Pasture area (%)
High	27.6	35.1	31.5
Moderate	56.8	23.7	33.4
Low	15.5	41.2	35.1

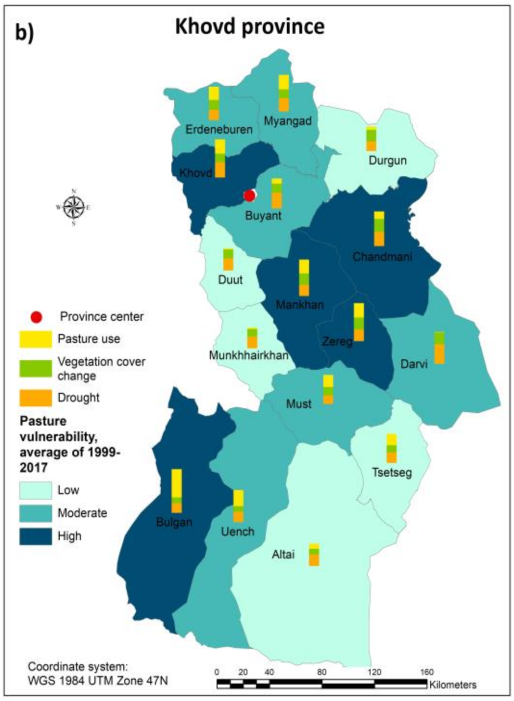


Figure 25. Levels of pastoral vulnerability and component indicators in Khovd province

Assessment of pasture degradation by field survey

This study is part of the pastoral vulnerability research, which was done at Chandmani soum only in this province due to research fund limitation. As a result of initial vegetation change assessment, the most vulnerable soum in terms of pasture degradation was selected for deeper study by using field survey and maps comparison. Pastureland types and changes in the areas comparing 1981 value to 2018 value are shown in Table 12. During the field survey, we recorded 134 species of vascular plants belonging to 84 genera and 29 families in Chandmani soum.

Table 12. Comparison of pastureland changes in 1981 and 2018, Chandmani soum, Khovd province

	TYPES OF PASTURE	1981		2018	
		Area, ha	Percentage	Area, ha	Percentage
	Mountain pasture	**64042.6**	**10.4**	**143760.3**	**23.3**
1	High mountain	8507.9	1.4	4759.1	0.8
2	Mountain steppe	39278.3	6.4	65307.2	10.6
3	Mountain desert steppe	16256.4	2.6	73694.0	11.9
	Steppe pasture	**454836.0**	**73.6**	**352155.8**	**57.0**
4	Dry steppe	40790.6	6.6	-	0.0
5	Desert steppe	237842.3	38.5	290399.2	47.0
6	Desert	147688.3	23.9	61756.6	10.0
7	River and lake vallet	26438.4	4.3	25037.4	4.1
	Total pasture area	**516802.2**	**83.7**	**520953.5**	**84.3**
8	Lake	100884.6	16.3	96733.3	15.7
	Total soum area	**617686.7**	**100.0**	**617686.8**	**100.0**

The assessment reveals that only 3.1% of the total pastureland has not degraded, 66.3% low degraded, 13.4% medium degraded, and 17.1% heavily degraded (Figure 26). When we compare this survey result with the pasture-monitoring map in 1981 the non-degraded area decreased by 34%, while low degraded area expanded by 19% and highly degraded area increased by 17.1%. The main factors leading to pasture degradation are increased temperature and dryness due to climate change, and rapid growth in the number of livestock.

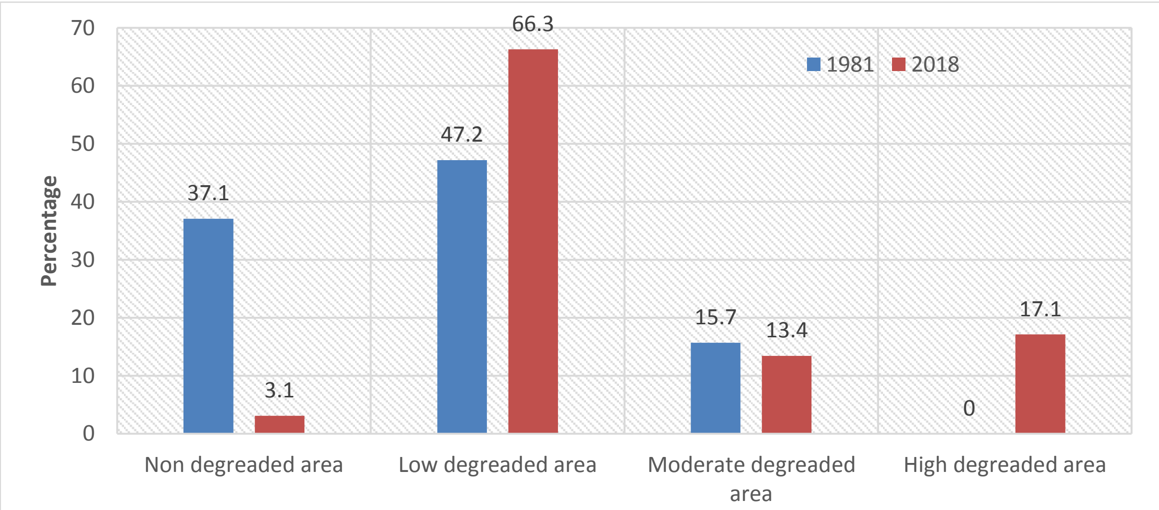


Figure 26. Change in the state of pasture, in percentage, Chandmani soum, Khovd province

3.2 *Correlation analysis of pastoral vulnerability on the socio-economic conditions of herding communities*

3.2.1 Gobi-Altai province, Mongolia

Agriculture and animal husbandry 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 change of total livestock in Gobi-Altai province remained stable. Since 2000, however, the number of livestock has fallen down by 8-44% than the previous year due to the vulnerability of pasture multiplied by the dzud disasters (2000-2002 and 2009-2010). The growth in livestock number fluctuated from 13% to 21% in the post-high mortality years (Figure 27). The herders reduced the number of livestock for consumption per year down to 0.1-0.3 million sheep to increase their herds. After the disaster, the income of herders decreased due to a reduction in the productivity of live animals and the number of slaughtered livestock, ultimately resulting in an 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 to increase their income by increasing the number of slaughtered livestock for consumption.

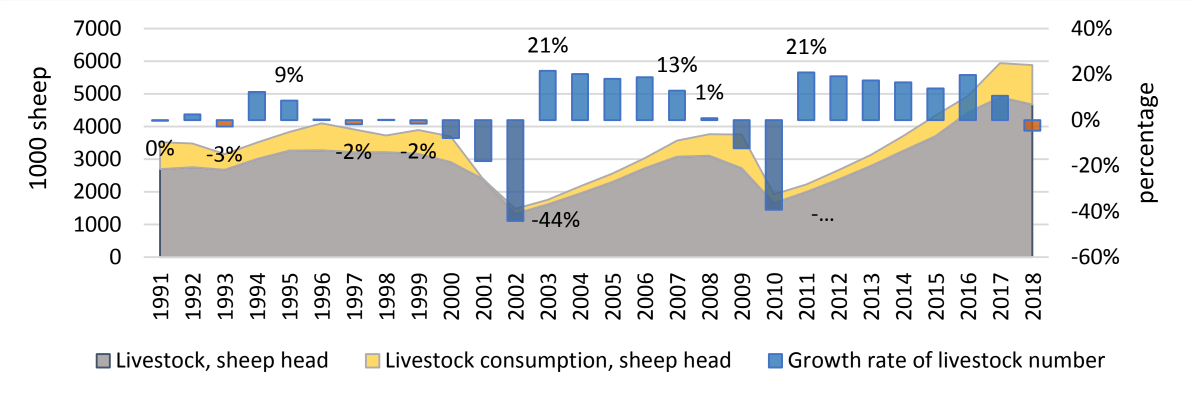


Figure 27. Comparison of dynamic changes in the total number of livestock, number of livestock for consumption and growth rate of livestock number in Gobi-Altai province

As seen from Figure 28, Tonkhil, Tseel, Bugat, Darvi, Erdene and Delger soums have more than 700 livestock per herder household and Bayan-Uul, Sharga, and Tsogt soums have up to 500 livestock per herder household. The base colour shows the total number of livestock, and graph shows the number of livestock per household (Figure 28a) and the number of livestock for consumption per household (Figure 28b) in the soums of Gobi-Altai province. Darvi, Tonhil, and Tugrug soums used over 120 sheep for the consumption per household and Khuhmorit, Jargalan, and Altai soums used under 60 sheep per household for their livelihood and food.

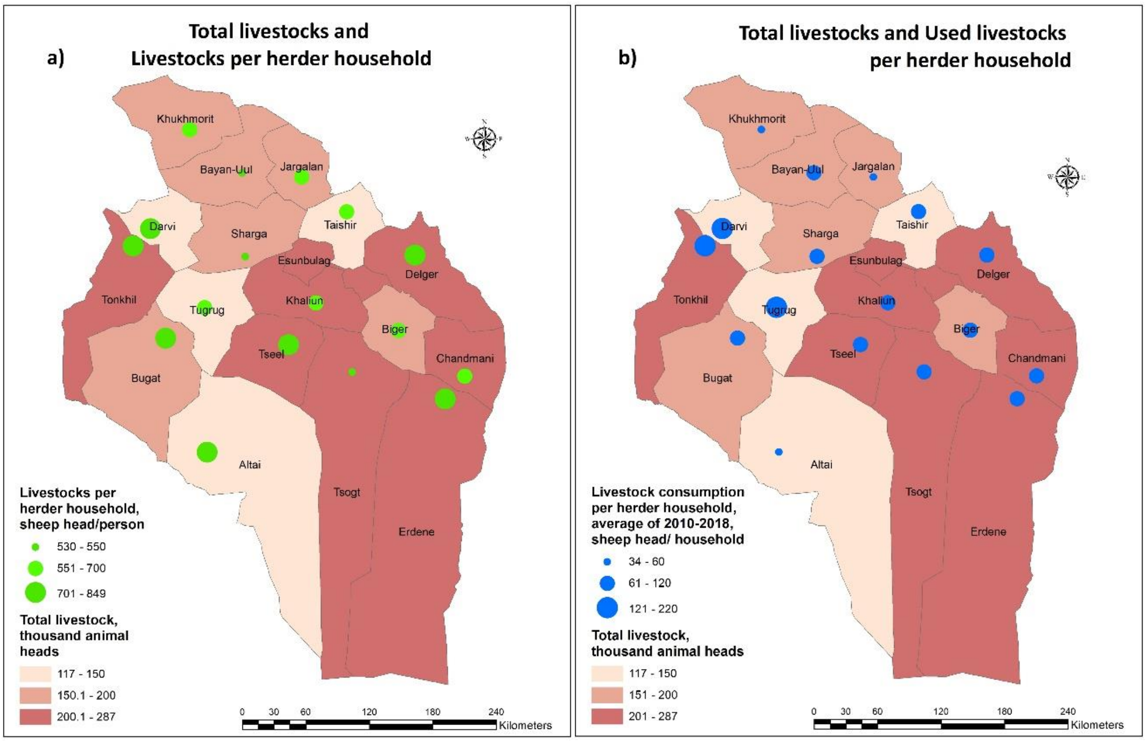


Figure 28. a) Livestock number per herder householder and b) livestock number for consumption per herder household, Gobi-Altai province

Pastoral vulnerability is a key factor for increased livestock miscarriage and loss, which may negatively impact herders' income. Dzud is one of the main causes of livestock loss (Natsagdorj, 2009), but its frequency is low compared to pastoral vulnerability. Livestock miscarriage and loss increased during 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 for the livestock during summer months, negatively impacting their ability to survive the upcoming cold winter months and, ultimately, increasing their mortality rates. In the years with low pastoral vulnerability, the number of livestock increased rapidly (Figure 29).

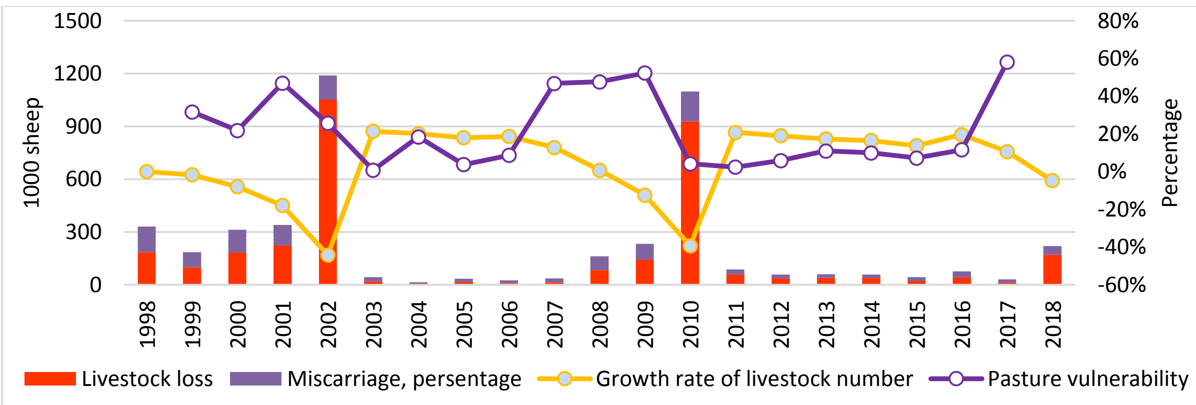


Figure 29. Comparison of pastoral vulnerability, change of livestock number, livestock loss and livestock miscarriage, Gobi-Altai province

Statistical correlations were calculated for pastoral vulnerability and the miscarriage rate among breeding stock for four types of female animals (Table 13). 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 pastoral vulnerability was strongly correlated with the miscarriage rates of female goats in this province. However, no strong correlations were found for other herd types.

Table 13. Correlation analysis of pastoral vulnerability and livestock miscarriage rates among different types of livestock, Gobi-Altai province

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

Crop farming is an important sector for animal husbandry. However, located in the desert, desert steppe and mountainous region under harsh climate and limited surface water resources, Gobi-Altai province is less suitable for cultivation. Figure 30 shows the total harvest of wheat, potato and vegetables in Gobi-Altai province decreased 2 times from 2013 to 2018.

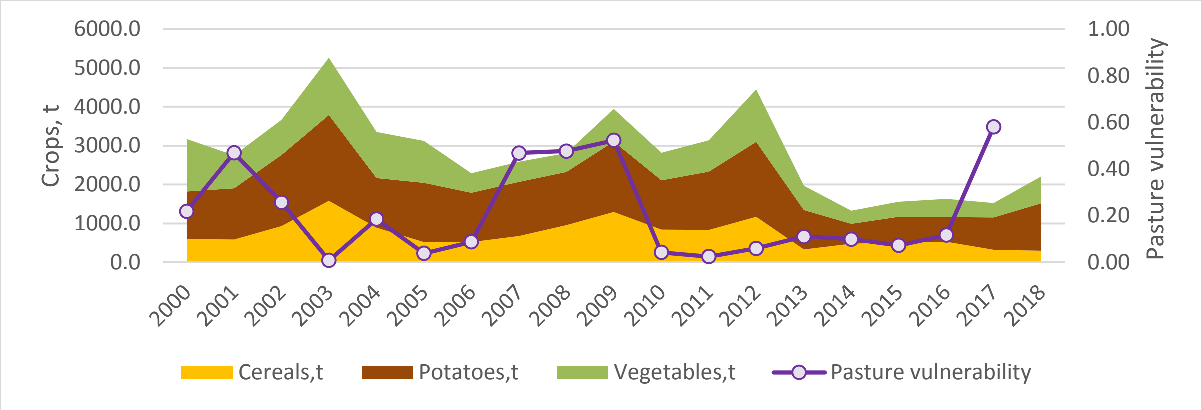


Figure 30. Total harvest of wheat, potato and vegetables with pastoral vulnerability, Gobi-Altai province

The total harvest of wheat, potato and vegetables compared with the population in each soum in Gobi-Altai province is shown in Figure 31. Tsogt, Chandmani, Khaliun, Sharga, Jargalan, Delger soums have increased their crop farming which is an important factor to adapt to pastoral vulnerability.

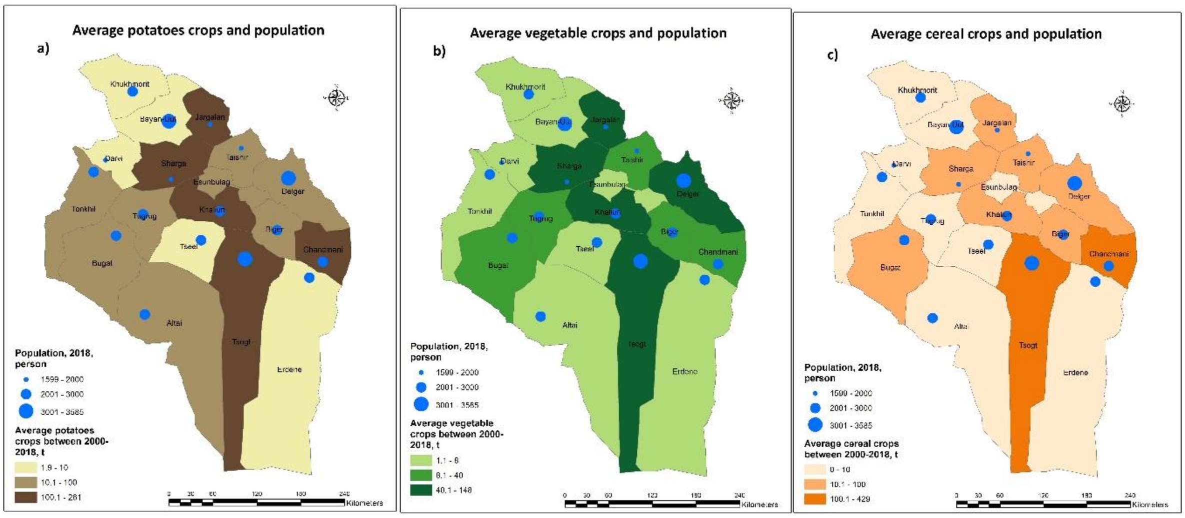


Figure 31. Comparison of the soum population with a) Potato harvest, b) vegetable harvest, and c) wheat harvest, Gobi-Altai province

Preparation of the hay and fodder is crucial to reduce the miscarriage rate and the loss of livestock. However, the largest hay harvest since 1990 was 7.5 tons in 2018, which accounted for only 0.6% of the national level and only 3% of the total hay harvesting in the western region. Gobi-Altai province produces 5.2 tons of hay, 480 tons of handmade fodder and 1200 tons of fodder per year. Due to natural and climate conditions, natural hay harvesting is limited. However, some haymakers prepare a large number of hayfields, and the amount of prepared hay and fodder has increased in recent years (Figure 32).

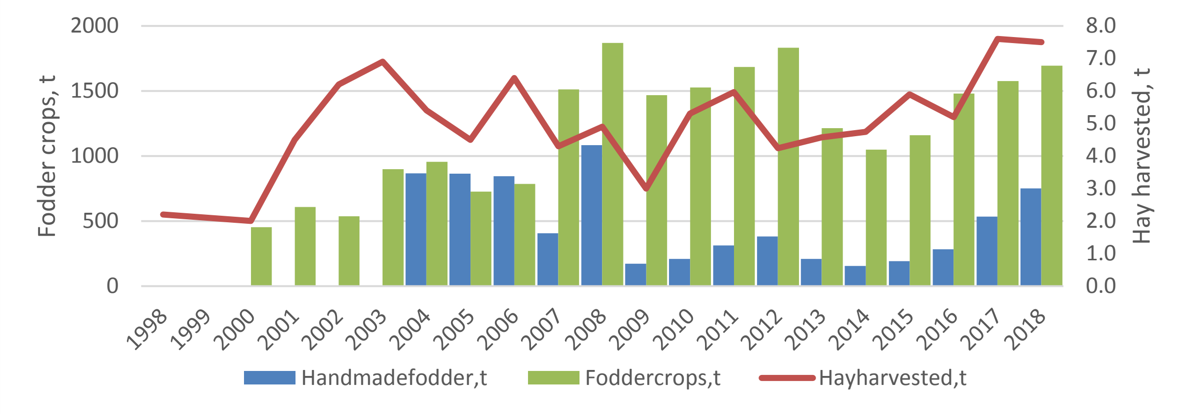


Figure 32. Prepared hay and fodder, Gobi-Altai province

As seen from the research, in most sums, fodder plants and hay fields are highly vulnerable to pasture degradation, and in the years following the dzud, they are ineffective.

Economy

One of the criteria for expressing the economic capability of herders in the short-term 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.

Also, 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 savings in Gobi-Altai province amounted to 6.9 billion MNT (Mongolian currency) in 2010 and 59 billion MNT in 2018. During the same period, the loan debt was 7.1 million, higher than the deposit amount and in 2018, the number of loans and deposits have become similar (Figure 33).

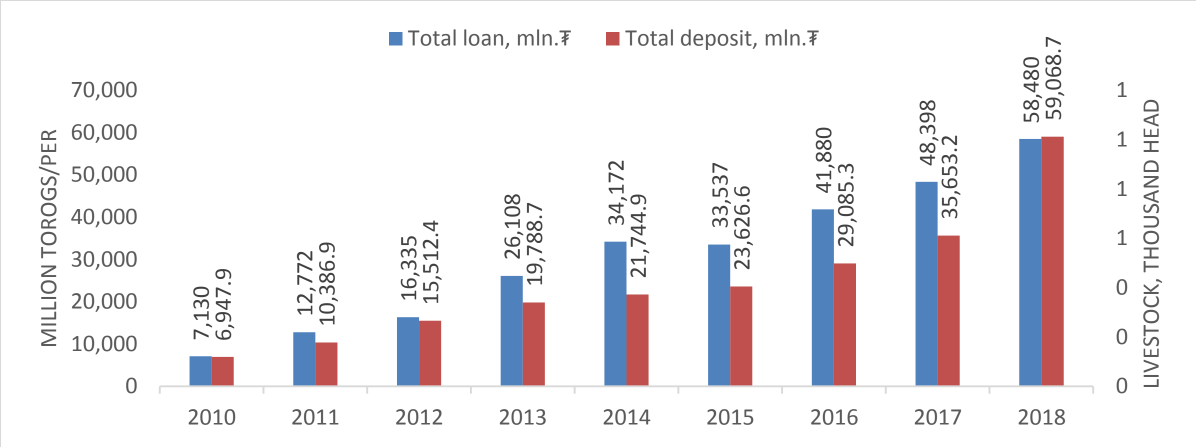


Figure 33. Total bank savings and loan, Gobi-Altai province

As seen from Figure 34a, the savings per person is more than 2.6 million MNT in Altai and Taishir soums, and less than 1.2 million MNT in Tonkhil, Darvi, Sharga, Khuhmorit, Khaliun, Chandmani, Tsogt and Erdene soums. The base colour shows savings per person and graph shows pastoral vulnerability by soums (Figure 34a) and the base colour is loan per person and graph show pastoral vulnerability (Figure 34b). The loan per person is over 2.1 million MNT in Altai and Ysunbulag soums and less than 1.35 million MNT in Darvi, Bayan-Uul, Bugat, Tugrug, Tseel, Khaliun and Biger soums.

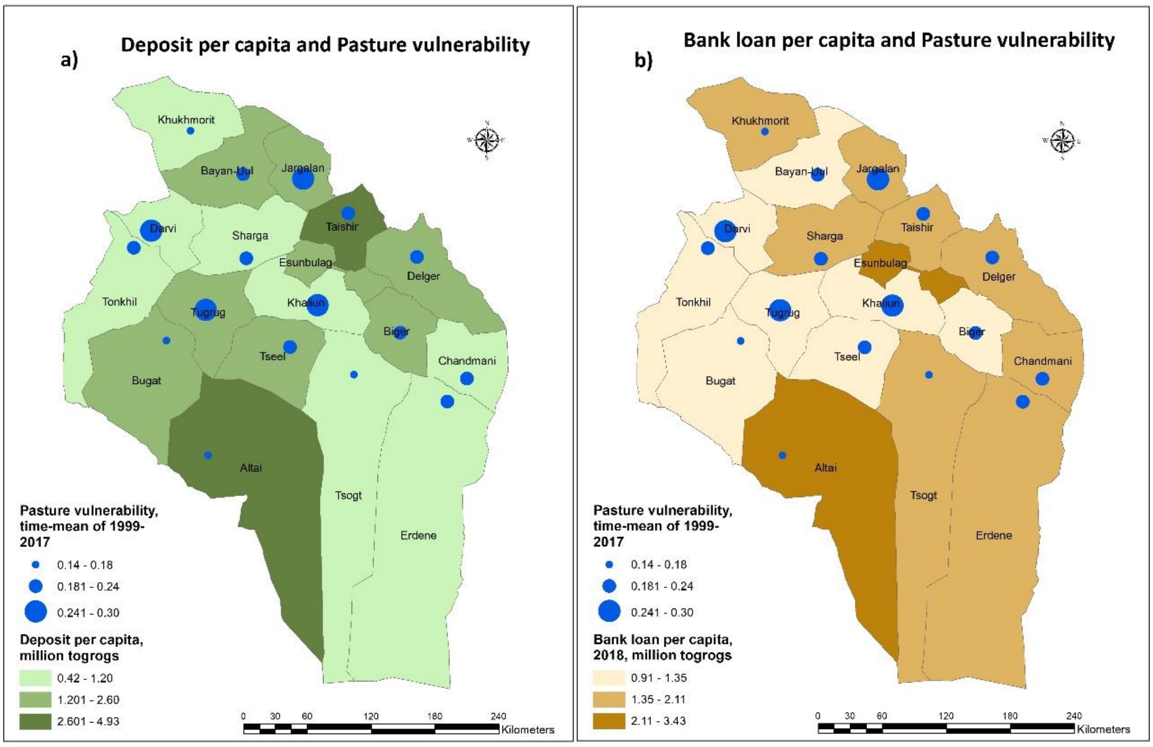


Figure 34. a) Saving and livestock number per person b) Loan and livestock number per person, Gobi-Altai province

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 were insured in Gobi-Altai province, and in 2018 the number increased to 1.9 thousand households (26% of total herder households) and 485 thousand livestock respectively. Herders now understand about the risk reduction mechanisms and increase mitigation. Figure 35 shows the number of insured livestock and herding households against the number of livestock loss.

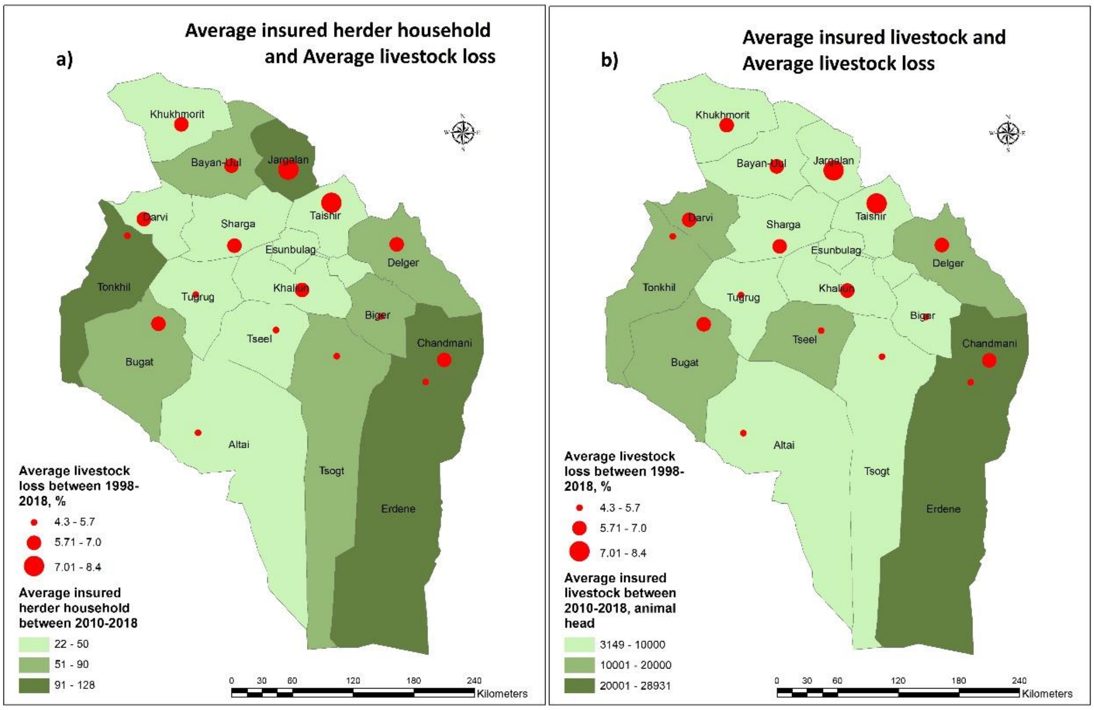


Figure 35. a) Number of insured herding households and b) Number of insured livestock vs average livestock loss, Gobi-Altai province

<u>Social demographics</u>

The population in a soum lives in two main 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 change and migration of population. The total population of Gobi-Altai province was 73 thousand in 1995; it declined to 53 thousand from 1998 to 2013 and increased to 58 thousand from 2014 to 2018 within 5 years (Figure 36).

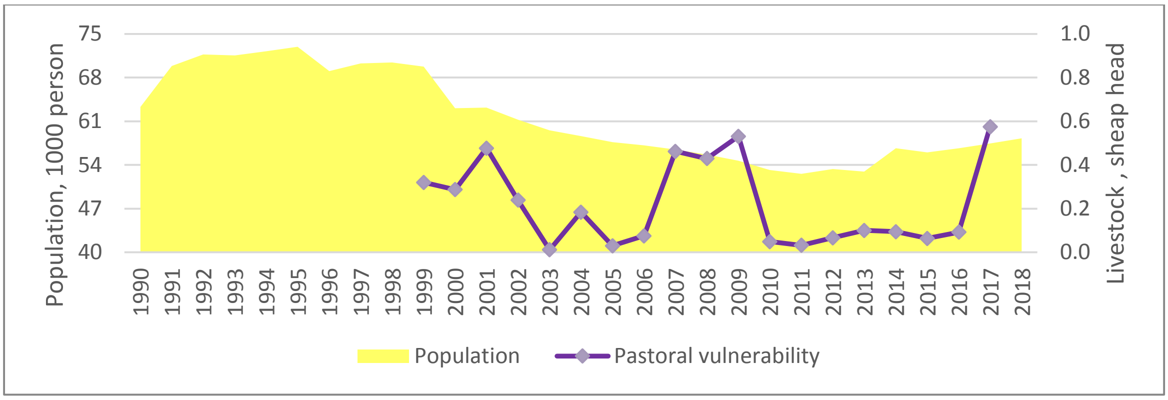
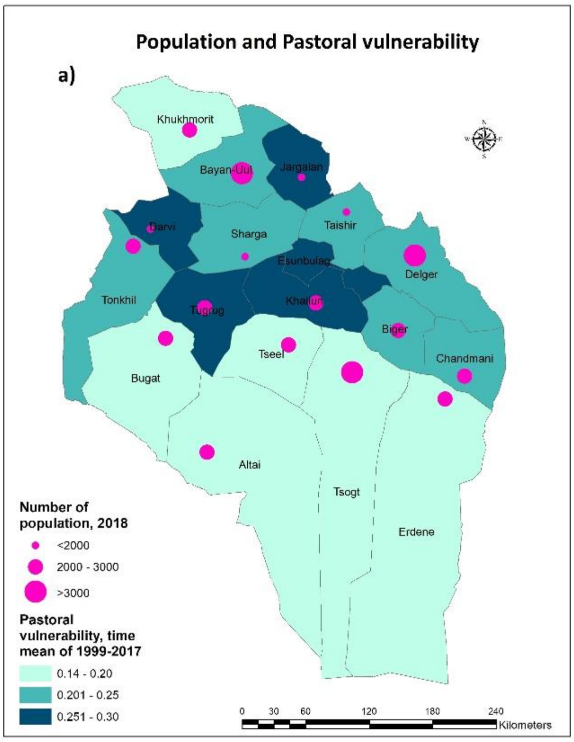


Figure 36. Population change vs. pastoral vulnerability, Gobi-Altai province

The total population in Tsogt, Delger, Bayan-Uul and Ysunbulag soums have more than 3,000 inhabitants, and Darvi, Jargalan, Sharga and Taishir soums are less than 2000 population (Figure 37a). Darvi and Jargalan soums with high pastoral vulnerability where have low population 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 up to 350 herder households. 8 soums have over 60%, 6 soums in 50-60 %, and 4 soums lower 50% of total populations are herder households (Figure 37b).



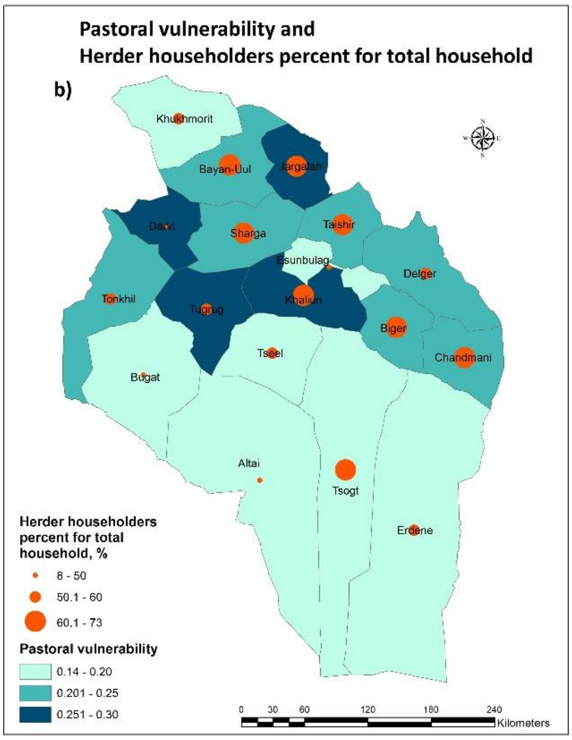


Figure 37. a) Soum population vs pastoral vulnerability, b) Pastoral vulnerability and herder householders percent for total household.

The net migration of the population has been negative from 1993 to 2016, with people migrating out of the province and soums (Figure 38). In particular, the out-migration increased in 2002, and between 2008-2010, the years with high pastoral vulnerability.

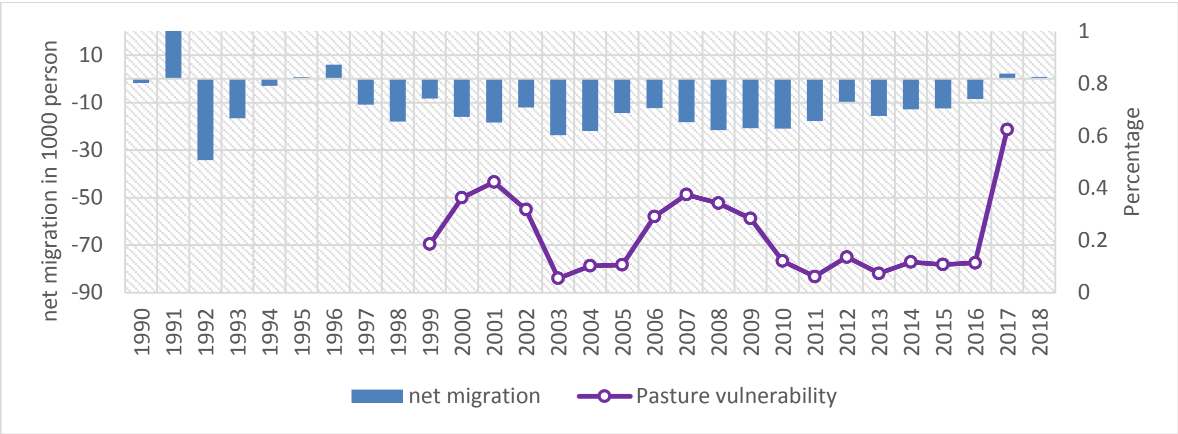


Figure 38. Net population migration vs Pastoral vulnerability, Gobi-Altai province

The province population change percentage vs pastoral vulnerability is shown in Figure 39. Spatial variability of population change and pastoral vulnerability is highly correlated; high pastoral vulnerability sees greater change in population growth. where vulnerability is high change of population is high.

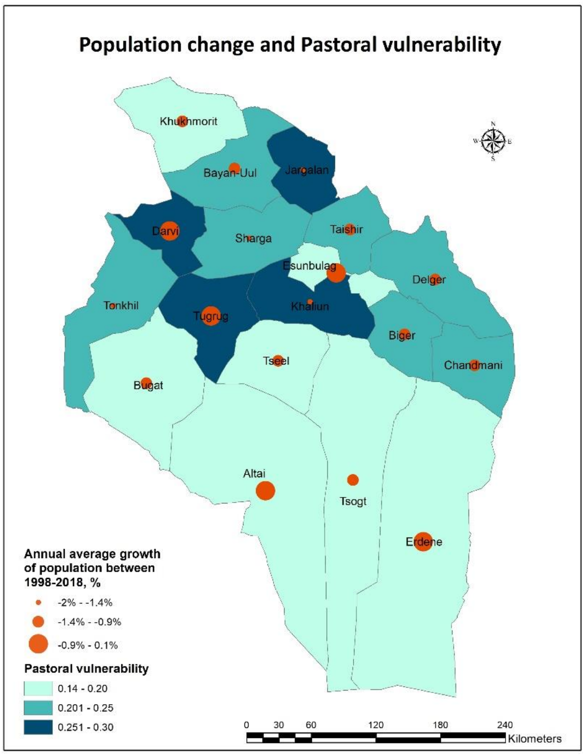


Figure 39. The population change vs. pastoral vulnerability, Gobi-Altai province

During the last 20 years, the life expectancy in Gobi-Altai province has reached the national level (Figure 40). 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 difficult 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 following 2 to 3 years such as in 2000-2003, 2007-2009 and 2012-2017, the life expectancy for men is constant or become lower. The numbers suggest that men are more sensitive to pastoral vulnerability. This result is considerable issue especially in Gobi-Altai province as well as at national level for pension system policy for men.

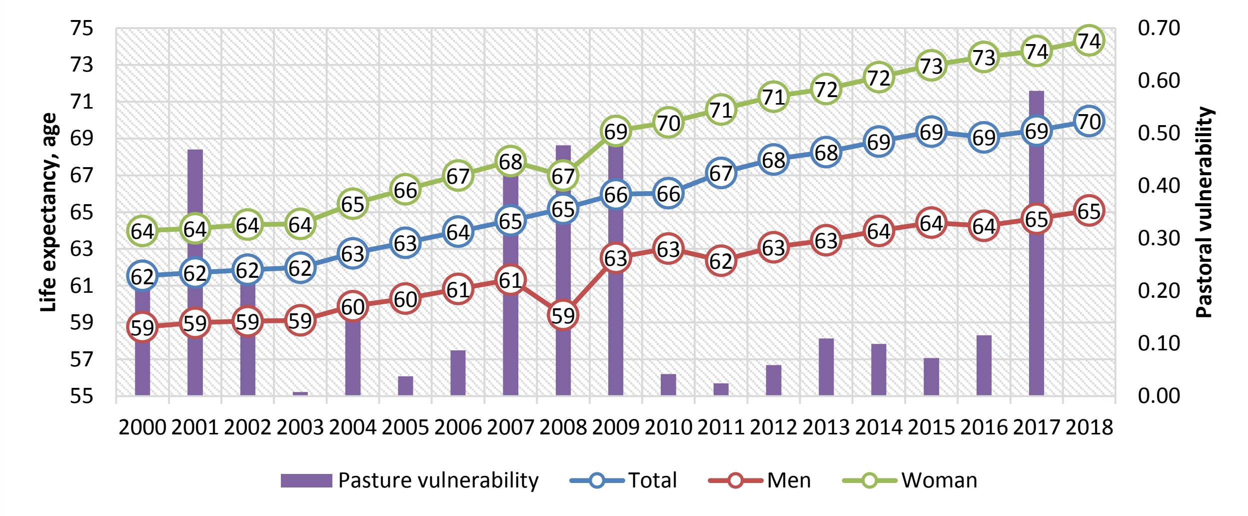


Figure 40. Life expectancy vs. pastoral vulnerability, Gobi-Altai province

3.2.2 Khovd province, Mongolia

Agriculture and animal husbandry 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. In Khovd province, three major growth and declines in the livestock numbers have occurred since 1990. Until 1995, the number of livestock, slaughtered livestock and the growth change of total livestock in Khovd province increased steadily. However, due to the pastoral vulnerability combined with dzud disasters (1996-1998, 2000-2002 and 2008-2010) the stability had been lost. Since 1996, the number of livestock had fallen down by 3-21% from the previous year due to the vulnerability of pasture multiplied by the dzud. The growth rate of the livestock number fluctuated from 16% to 25% in the post-high mortality years (Figure 41). The herders reduced the number of livestock for consumption per year down to 0.2-0.4 million sheep to increase their herds. After the disaster, herders’ income decreased due to the reduction in the productivity of live animals and the number of slaughtered livestock, ultimately resulting in an 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 to increase their income by increasing the number of slaughtered livestock for consumption.

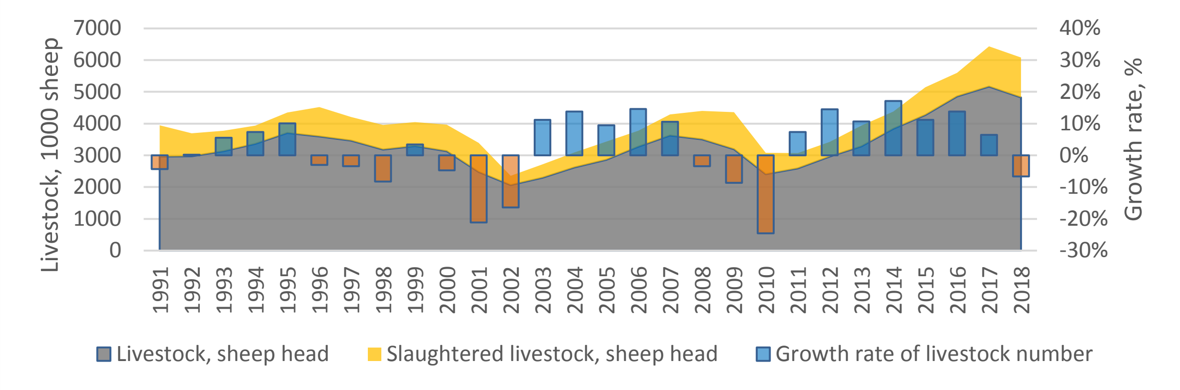


Figure 41. Comparison of dynamic changes in the total number of livestock, number of livestock consumption and growth rate of livestock number in Khovd province

As seen from Figure 42, Tsetseg, Buyant, Darvi, and Duut soums have more than 650 heads of sheep per herder household and Uench, Zereg, and Myangad soums have up to 550 heads of sheep per herder household. The base colour shows the total number of livestock, and graph shows the number of livestock per household (Figure 42a) and the number of livestock for consumption per household (Figure 42b) in the soums of Khovd province. Erdenburen, Duut, Darvi, and Chandmani soums used over 140 sheep for consumption per household and Bulgan, Uench, Altai and Durgun soums used less than 100 sheep per household for their livelihood and food.

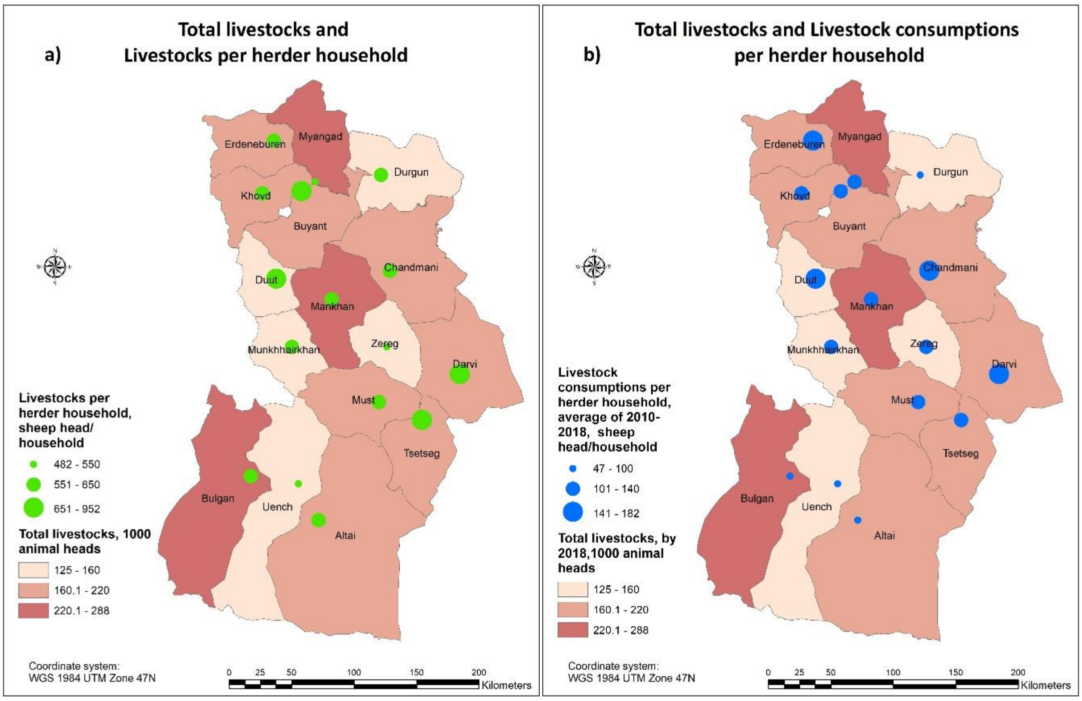


Figure 42. a) Livestock number per herder householder and b) Livestock number for consumption per herder household, Khovd province

Pastoral vulnerability is a key factor for increased livestock miscarriage and loss, which may negatively impact the herders' income. *Dzud* is one of the main causes of livestock loss (Natsagdorj, 2009), 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 to 3 consecutive years leads to insufficient fat intake in livestock during 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 (Figure 43).

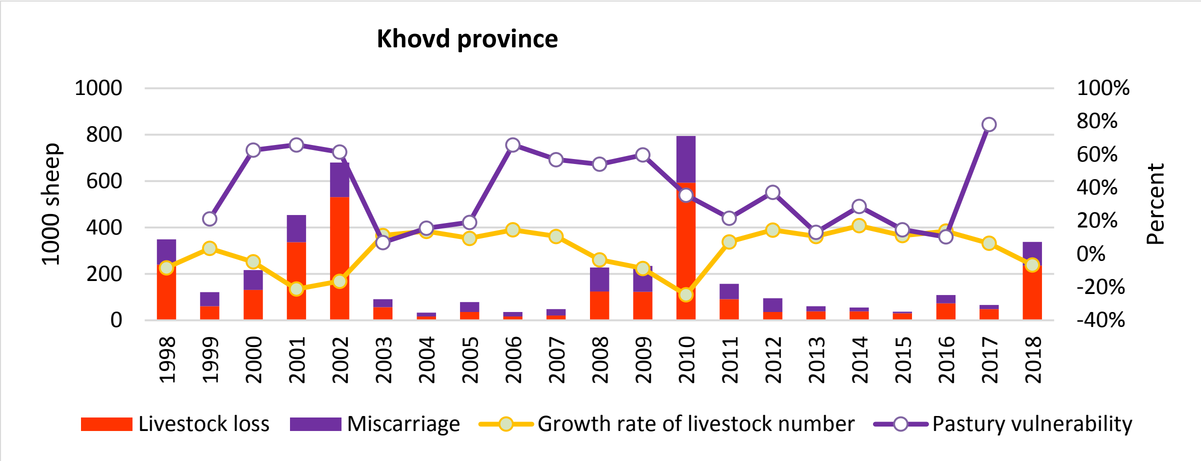


Figure 43. The effect of pastoral vulnerability on the livestock sector, Khovd province

Statistical correlations were calculated for pastoral vulnerability and the miscarriage rate among the breeding stock of four types of female animals (Table 14). High miscarriage rates devalue the herders' labour and reduce their income. In Khovd, 83% – 93% of the total livestock are small animals (i.e. sheep and goats), of which 37% – 66% of the total herd are goats. The miscarriage rates of small livestock animals were more susceptible to pastoral vulnerability, and pastoral vulnerability was strongly correlated with the miscarriage rate of female goats in this province. However, no strong correlations were found for other herd types.

Table 14. Correlation analysis of pastoral vulnerability and livestock miscarriage rates among different types of livestock, Khovd province

Khovd province soums	*Mares*	*Cows*	*Female sheep*	*Female goats*
Darvi	-0.05	0.10	-0.05	0.81
Altai	0.67	0.53	0.29	0.69
Zereg	0.37	-0.05	0.13	0.67
Chandmani	0.34	0.16	0.37	0.65
Munkhkhairkhan	0.20	0.41	0.64	0.61
Bulgan	0.34	0.28	0.29	0.61
Mankhan	0.23	0.22	0.40	0.56
Must	0.27	0.20	0.22	0.50
Tsetseg	0.69	0.52	0.17	0.46
Durgun	0.40	0.38	0.41	0.40
Khovd	0.22	0.07	0.13	0.37
Myangad	-0.12	0.23	0.41	0.33
Duut	-0.16	0.16	0.19	0.27
Buyan	0.03	0.14	0.21	0.26
Uench	0.04	0.35	0.11	0.26
Erdeneburen	-0.02	0.10	0.66	0.13

Crop farming is an important sector for animal husbandry. Khovd province is located in the desert, desert steppe and mountain areas with rivers, streams, and lakes for surface water resources. Buyant, Myangad, Bulgan and Khovd soums, in particular, have used crop cultivation among soums of Khovd province. Figure 44 shows the total harvest of wheat, potato and vegetables in Khovd province. With the deterioration since 2000, wheat is no longer cultivated in the province as of 2017, while the cultivation of potato and vegetables has increased since 1992. There is no observed link between crop harvesting and pastoral vulnerability.

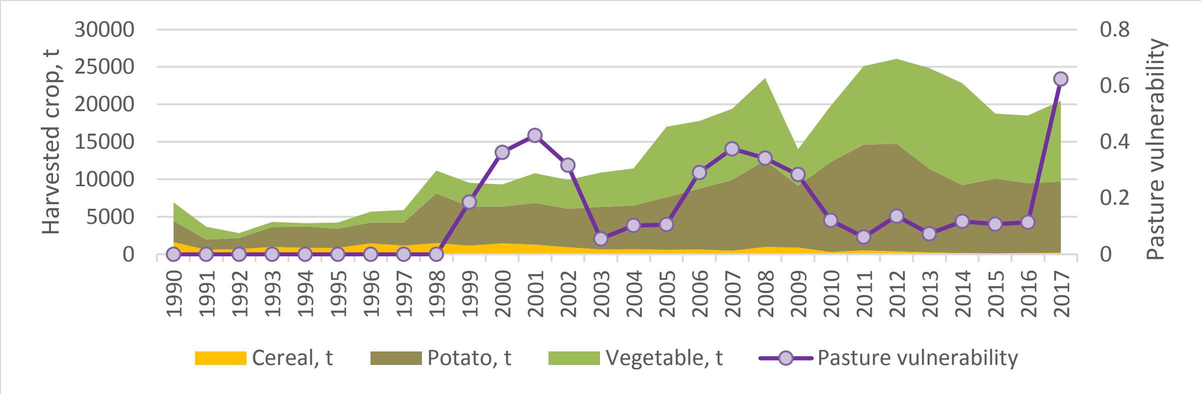


Figure 44. Total harvest of wheat, potato and vegetables vs. pastoral vulnerability, Khovd province

The total harvest of wheat, potato and vegetables compared with the population in each soum is shown in Figure 45. Myangad, Khovd, Buyant and Bulgan soums have increased their potato and vegetables harvest by over 200 tonnes annually, which is important to adapt with pastoral vulnerability. Altai, Must, Munkhkhairhan and Duut soums in the high mountain and desert regions have limited condition for cultivation (Figure 45a and b). Wheat farming has been increased in Darvi, Uench and Bulgan soums by traditional cultivation (Figure 45c).

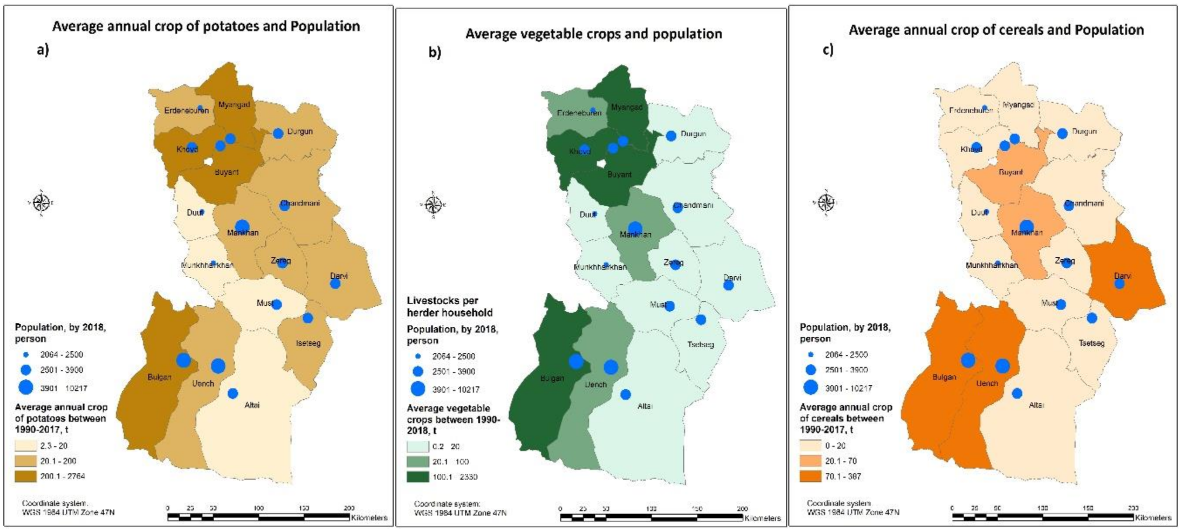


Figure 45. Comparison of the soum population with a) Potato harvest, b) Vegetables harvest, and c) Wheat harvest, Khovd province

Preparation of the hay and fodder is crucial to reduce the miscarriage rate of breeding animals and the loss of livestock. The hay harvest since 1990 has increased year by year, but it accounted for 6.4 % of the national level and 33% of the total hay harvesting in the western region (Figure 46). Khovd province produces 48 thousand tons of hay and 2.5 thousand tons of handmade fodder per year. The natural hay harvesting is possible to be prepared from the lake edges and shores of Khar us, Khar nuur and Durgun lakes, which is not accounted in the statistics.

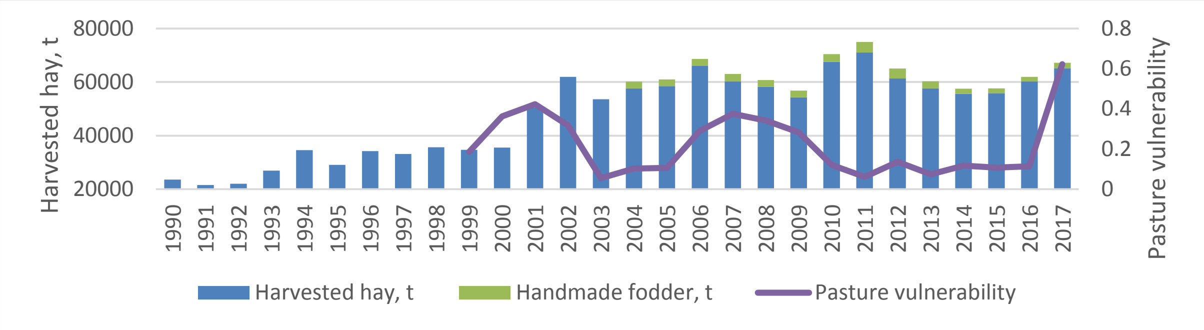


Figure 46. Prepared hay and fodder vs pastoral vulnerability, Khovd province

Economy

One of the criteria for expressing the economic capability of the herders is the short-term 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.

Also, 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. Therefore, herders use livestock, the primary source of their income, as collateral in order to get a bank loan. If somehow there is a risk for herder's source of income, repayment of loans will slow down or be delayed causing a debt burden on herders. As a result, 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.

The total loans in Khovd province amounted to 13 billion MNT in 2010, and 77 billion MNT in 2018. The total savings amounted to 8 billion MNT in 2010, and 47 billion MNT in 2018. During this period, the loan debt was always higher than the deposit amount (Figure 47).

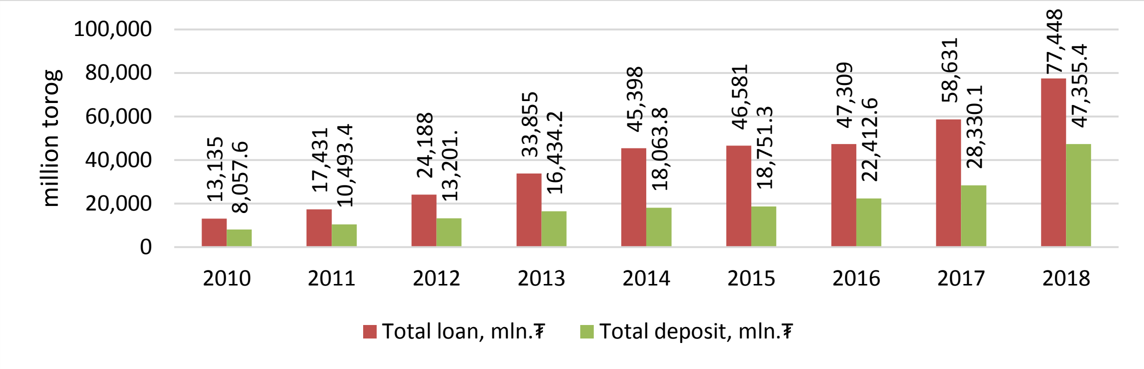


Figure 47. Total bank savings and loan, Khovd province

As seen from Figure 48, savings per person is 1- 2.4 million MNT in Altai, Darvi and Khovd soums, and 0.36-0.60 million MNT in Mankhan, Chandmani, Munkhkhairkhan, Durgun, Myangad and Erdeneburen soums. The base colour shows savings per person and graph shows pastoral vulnerability by soums (Figure 48a), and base colour is loan per person and graph shows pastoral vulnerability (Figure 48b).

The loan per person is between 1.4-2.2 million MNT in Bulgan, Uench and Duut soums, and 0.81-1.00 million MNT in Khovd, Myangad, Durgun and Buyant soums (Figure 48b).

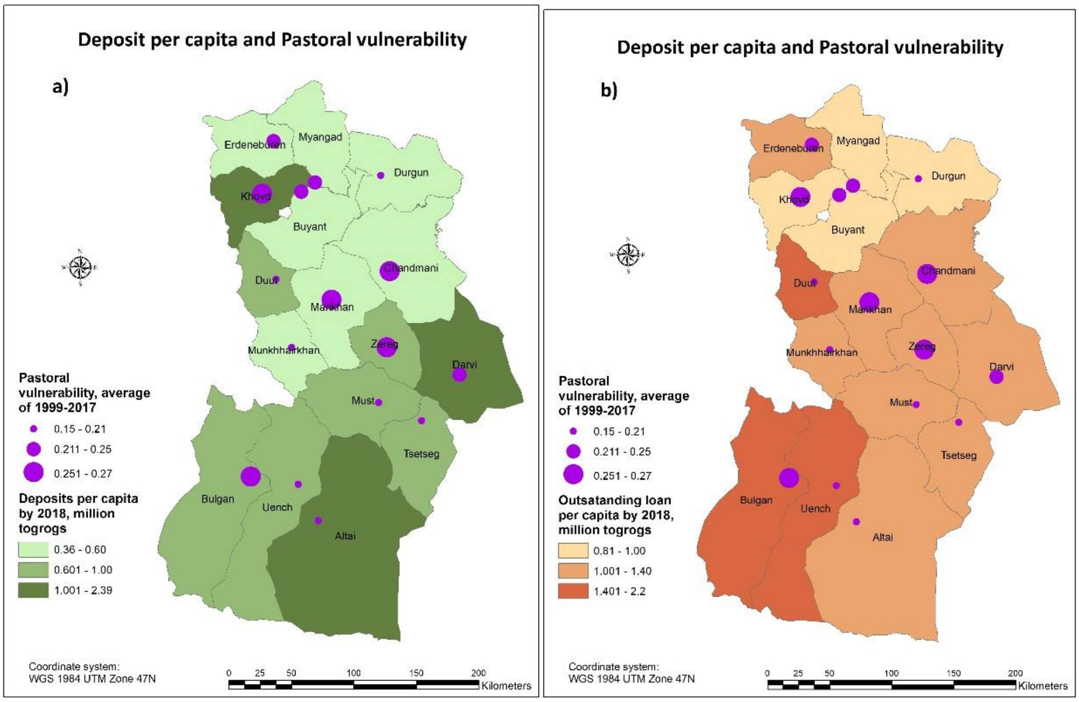


Figure 48 a) Savings and pasture vulnerability b) Loan and pasture vulnerability, Khovd province

Insurance is one of the adaptation options to reduce pastoral vulnerability. In 2011, 0.2 thousand households and 44 thousand livestock were insured in Khovd province, while in 2018, 1.6 thousand households (22% of total herder households) and 442 thousand livestock (14% of total livestock) were insured. The number of herders understanding the risk reduction mechanism of insurance has increased 10 times for the last 7 years. Figure 49 shows the number of insured livestock and herding households vs. pastoral vulnerability. Erdeneburen, Khovd, Duut and Uench soums have not been insured sufficiently for herder households (Figure 49a). Durgun, Chandmani, and Mankhan soums are well insured for both livestock and herder households (Figure 49b).

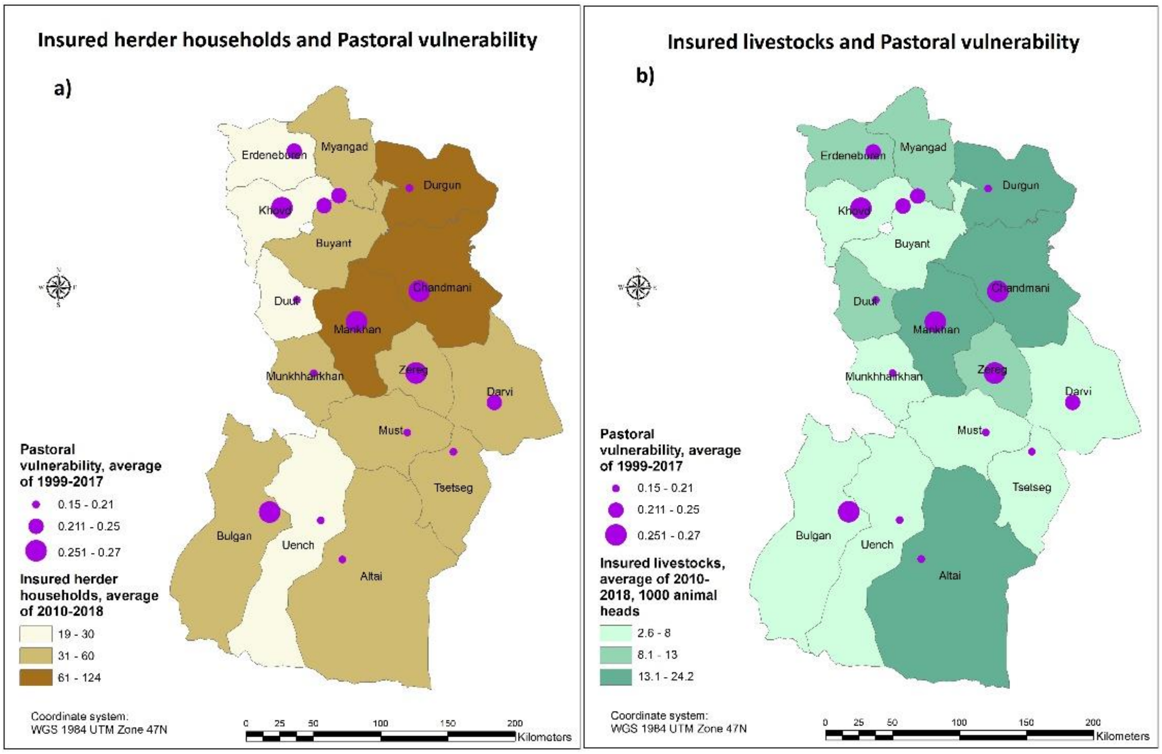


Figure 49. a) Number of insured herding households, and b) Number of insured livestock vs. pastoral vulnerability, Khov province

Social demographics

The population in a soum lives in 2 main areas, town center and rural herding places. Majority of the rural population are herders. Herders are hardly affected by pastoral vulnerability coupled with dzud disaster, which leads to poverty and population change and migration. The total population of the province was 91 thousand in 1999, but it declined to 76 thousand from 2000 to 2010 and increased to 88 thousand from 2011 to 2018 within 7 years (Figure 50).

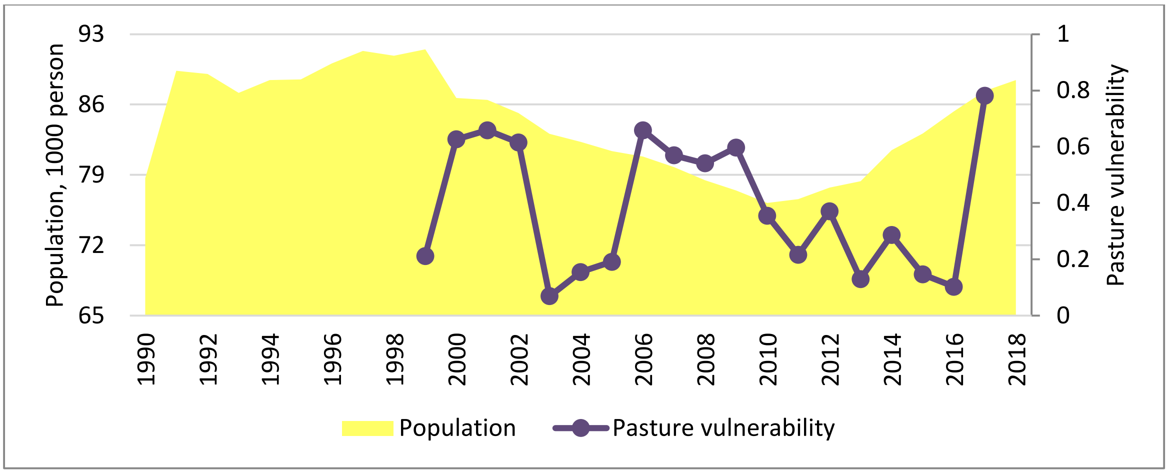


Figure 50. Population change vs. pastoral vulnerability, Khovd province

Bulgan, Uench, Mankhan and Jargalant soums have a population of more than 3,900 inhabitants, and Erdenburen, Duut, and Munkhkhairkhan soums have a population of less than 2500 (Figure 51a). Bulgan and Mankhan soums with high pastoral vulnerability where have a high population over 5000 and over 550 herder households. 6 soums have over 60%, 3 soums in 50-60 %, and 7 soums lower 50% of total householders are herder households (Figure 51b).

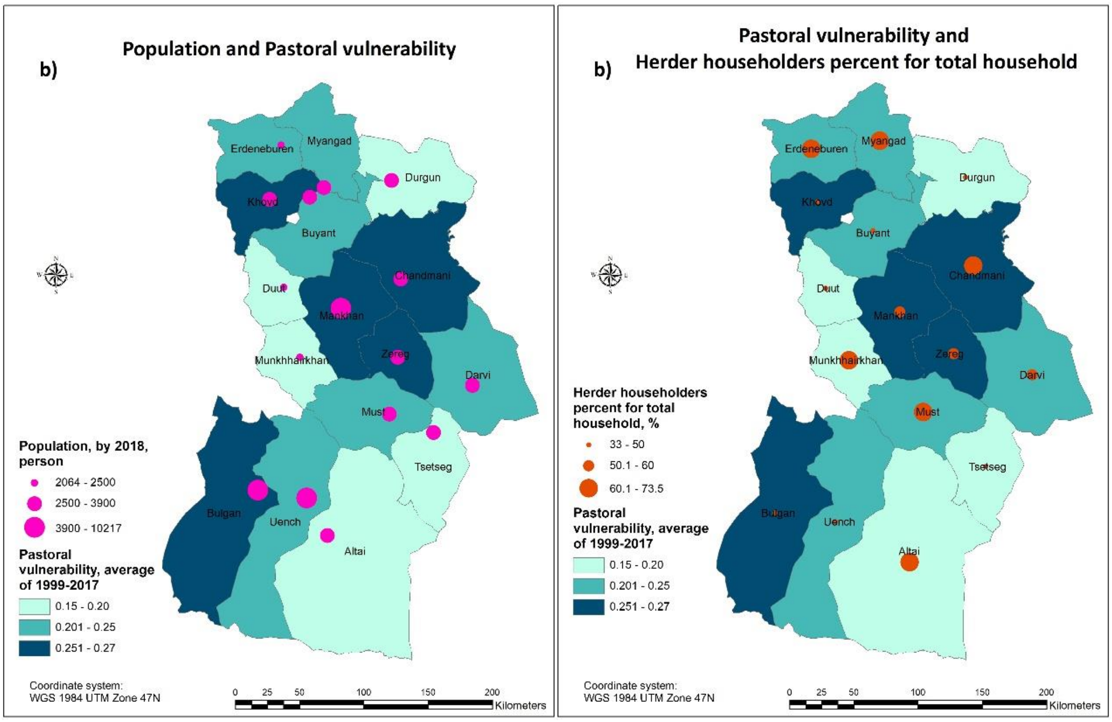


Figure 51. a) Population vs. pastoral vulnerability, b) Percentage of herder households in total soum households vs.pastoral vulnerability, Khovd province

The net migration of the population has been negative from 1992 to 2016, with people migrating out of the province and soums (Figure 52). In particular, the out-migration increased during 2000-2002 and 2007-2009, the years with high pastoral vulnerability. The population growth vs pastoral vulnerability in the province is shown in Figure 53. Spatial variability of population change is relatively depending on pastoral vulnerability.

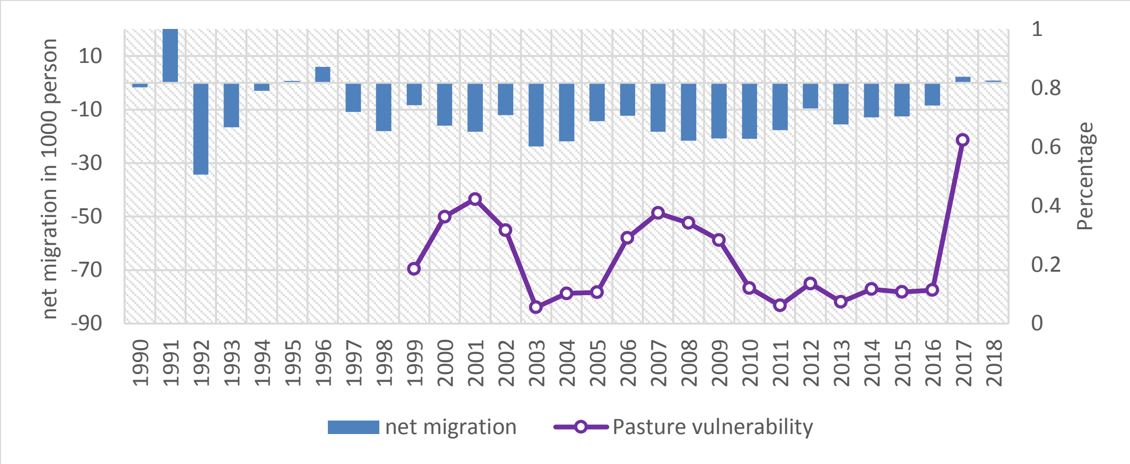


Figure 52. Net population migration vs. pastoral vulnerability, Khovd province

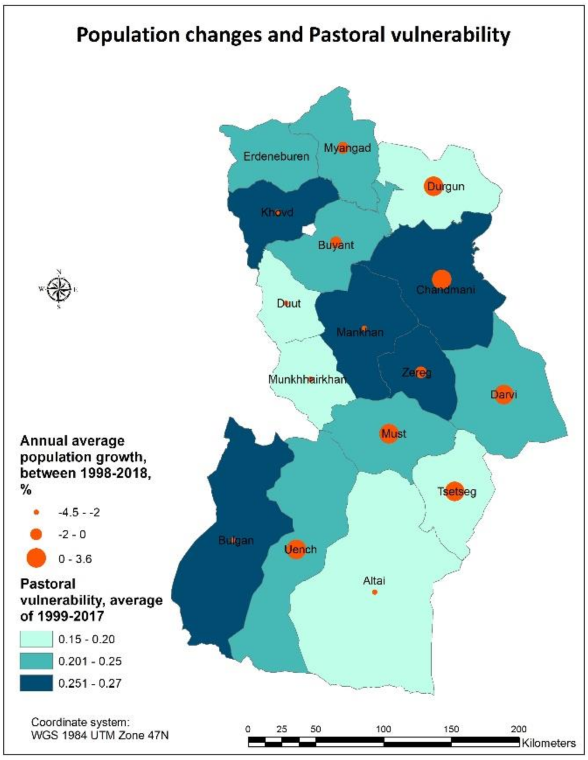


Figure 53. The average population growth vs pastoral vulnerability, Khovd province

Over the past 18 years (2000 - 2018), the life expectancy of the population in Khovd province surpassed the national average increasing by 8 years (Figure 54). As of 2000, women had lived 6 years longer, on average, than men in Khovd province. In 2018, the difference was 6 years same as 2000 level. In 2008, the average life expectancy of men decreased from 64 to 61 compared to the previous year, while it dropped from 71 to 70 for women. During the period from 2006 to 2009, the pastoral vulnerability was high in this province. When the pastoral vulnerability was high in 2000-2002, 2006-2009, and 2017 the average life expectancy for men was stable or decreased. These numbers suggest that men are more sensitive to pastoral vulnerability. This result is an important issue for pension system policies related to men.

Herders, especially men, are more affected by pastoral activities due to their working conditions in a harsh climate and the limited services provided by social systems in the region.

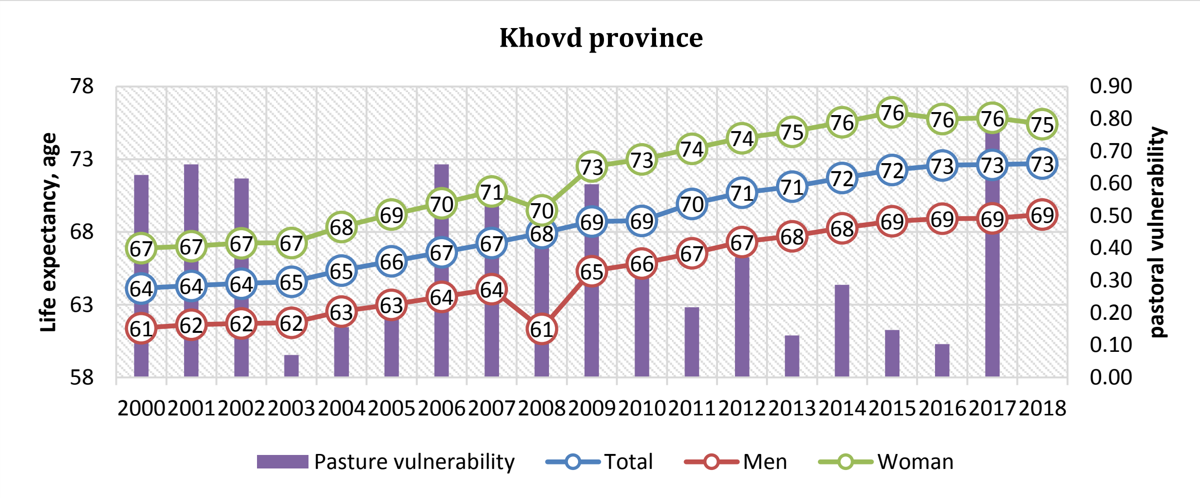


Figure 54. Life expectancy in Khovd province

3.3 Evaluation of policy documents

This part has assessed the extent to which policies in development and environment sectors align with climate change response (adaptation, mitigation) and sustainable development goals and identified varying levels of coherence amongst these policies in Gobi-Altai and Khovd provinces. Using the scoring (Table 6), scores were determined for each policy based on the strategies, activities, and approaches relevant to climate change adaptation and mitigation and their alignment with SDGs.

3.3.1 Policy evaluation, Gobi-Altai province

Table 15 summarizes how the policies of Gobi-Altai province integrate climate change adaptation and mitigation measures along with sustainable development goals. These scores give an overall impression of policy area attention of Gobi-Altai province to climate change and sustainable development. Analysis of the development and environment policies shows that they align differently with each of adaptation, mitigation and transforming capacity.

Table 15. Scores of policy documents in relation to the SDG-based building blocks, Gobi-Altai province

Policies	**Building blocks for climate resilient development based on SDGs**				
	Adaptation (Social resilience) *(SDG1, SDG3, SDG6, SDG8)*	Adaptation (Natural resilience) *(SDG15)*	Mitigation *(SDG7)*	Transforming capacity *(SDG4, SDG9, SDG11, SDG13)*	Overall alignment
Comprehensive development policy	2	2	1	1	(1.75) limited alignment
Governor's Action Program	2	2	0	1	(1.25) limited alignment
Environmental Master Plan	1	3	0	2	(1.50) limited alignment
Pasture management program	0	2	0	2	(1.33) limited alignment
Sub-program to combat desertification	0	2	1	1	(1.33) limited alignment
Overall alignment	(1.00) limited alignment	(2.20) partial alignment	(0.40) no alignment	(1.40) limited alignment	

Comprehensive development policy (CDP)

Adaptation- Social resilience: CDP provides specific strategies for poverty reduction and livelihood improvement including creating new jobs. It includes measures to improve the quality and accessibility of public health services, build the capacity of soum and family health centers to provide quality basic health services. It mentions about measures to prevent water resources pollution and depletion, ensure sustainable use, and provide people with water that meets hygienic requirements. Also, there are measures to prioritise tourism development as one of the leading economic sectors in the province by developing eco-tourism and community-based tourism.

Adaptation-Natural resilience: CDP mentions measures to improve herd composition and breed, to improve pastureland use through seasonal pasture rotation and provision of water supply in remote and water-scarce pastures. There are measures to protect and rehabilitate ecological sustainability of forest reserves, to combat desertification including planting suitable trees to stop the sand movement, establishing green belt in the back of Mongol sand, and encourage the involvement of volunteers in reversing desertification. Further measures mentioned are to use traditional methods for environmental protection, and intensify works aimed at youth to care for nature.

Mitigation: The policy seeks to deliver mitigation by reducing carbon emissions with wide use of renewable energy. It also mentions to supply rural herder households with completely renewable energy sources and establish small-scale plants to produce smoke-free fuel from coal.

Transforming capacity: CDP proposes to provide accessible education, good quality and meets needs. The policy acknowledges climate change and seeks to develop climate change adaptation and mitigation measures. However, it is short of details on how these can be achieved. The policy proposes to build capacity to adapt to climate change, reduce desertification and mitigate negative impacts by establishing and maintaining climate change, environmental status, and natural disaster information center.

Governor's Action Program (GAP)

Adaptation- Social resilience: It includes measures to improve the quality and accessibility of public health services, build the capacity of soum and family hospitals to provide quality basic health services. It proposes to create no less than 400 new jobs, but without details on how these can be achieved. Includes measures to establish water ponds and protect springs. Proposes to create green jobs by planting trees and creating green structures.

Adaptation-Natural resilience: It proposes measures to prevent pasture degradation, biodiversity conservation and enhanced protected area management.

Mitigation: No specific mitigation measure is proposed.

Transforming capacity: It proposes to protect livestock from risks, increase forest reserve, improve conservation management of Gobi's Magnificent 6 animals and to expand the network of national and local protected areas.

Environmental Master Plan (EMP)

Adaptation- Social resilience: EMP only proposes environmentally friendly eco-tourism development, increase local community participation, and support realistic actions and investment. No specific adaptation measure is proposed on social resilience.

Adaptation- natural resilience: EMP reduces desertification effects, measures to decelerate climate change impacts, and adapt to changes and variability, and take preventative and risk mitigation measures for potential natural disasters. EMP also emphasizes objectives for sustainable land and pasture use and protection in compliance with pasture carrying capacity, improving pasture water supply, and sustainable water management.

Mitigation: No specific mitigation measure is proposed.

Transforming capacity: EMP acknowledges climate change mitigation and adaptation measures, take preventative and risk reduction measures, proposes to improve information system to disseminate environmental policies and decisions to the public, establishing common understanding on environmental issues, ecological education, regular consultation, training and seminars, and organize public awareness campaigns aimed at promoting the right attitude towards the environment

Pasture management program (PMP)

Adaptation- Social resilience: No specific measure is proposed.

Adaptation- Natural resilience: PMP proposes pasture information system, which is open for public use and capacity building of herder communities, to introduce pasture management plan for rational utilization, improvement and protection of pastures, restoration of degraded pastures and increases hay production and irrigation of remote pastures.

Mitigation: No specific mitigation measure is proposed.

Transforming capacity: PMP proposes to define and safeguard livestock breeding, protect the land from natural disasters. It also suggests reducing the number of livestock exceeding pastureland carrying capacity through the creation of a proper local network of livestock raw materials and preparations and markets. It further proposes to take *otor* (long-distance movement of Mongolian herders, typically in autumn, to fatten livestock for winter) zones of inter-soum and soum as a protected reserve area to be used in harsh times to prevent livestock from risks

Sub-program to combat desertification (SCD)

Adaptation- Social resilience: No specific actions are mentioned.

Adaptation- Natural resilience: SCD proposes to improve pasture use efficiency with the assistance of herders group, promote forestation, sustainable use and conservation of water resources and increase investment for combating desertification.

Mitigation: Proposes to support renewable energy, but not enough actions.

Transforming capacity: There are measures on awareness-raising and educating people and youth about desertification and its consequences. But no actions mentioned related to climate change impacts. It also proposes to intensify works on educating children and youth about consequences and factors causing desertification and degradation of nature and ecology and disseminate traditional knowledge and advanced technology to combat desertification.

In Gobi-Altai province, the policies reviews showed 'limited alignment' with the SDG based building blocks. The development policies, the CDP and GAP, are partially aligned with climate change adaptation and have inadequate adaptation measures in strengthening social resilience. Furthermore, these policies have limited to no alignment with mitigation and transformative capacity. The environmental policies, the EMP, PMP and SCD, have good alignment with adaptation measures to enhance natural resilience but have limited to no alignment with adaptation measures in terms of social resilience in the face of climate change. It implies that people are not well prepared for future changes, and the capacity remains low for dealing with adverse climate and environmental impacts. In terms of transforming the capacity, the policies usually emphasise capacity building and public awareness on climate and environmental change and taking adaptive measures for livestock sector to climate change including pasture management, livestock management with changes in herd composition, reduction of livestock numbers and breeding strategies.

The analysis of the policy documents reveals that development and environment policies of Gobi-Altai province acknowledge climate change as a threat to development, and therefore, all propose measures to tackle climate change impacts in particular in the livestock sector and reduce the resultant environmental degradation. Approved in 2012, Gobi-Altai province has not updated its midterm development policy, or comprehensive development policy (CDP), to align with global SDGs and the new national policies, Sustainable development vision 2030 and Green development policy. This finding has implications for the province, as it needs to formulate new policies to integrate climate change adaptation and sustainable development. The analysis further indicates there is a need for well-aligned adaptation policies to integrate climate change and sustainable development to enhance the resilience of people's livelihoods to climate change because climate change is seen as a development issue, and adaptation activities can potentially reduce vulnerability to climate and other variability and can advance economic development at local level.

3.3.2 Policy evaluation, Khovd province

Table 16 summarizes how the policies of Khovd province integrate climate change adaptation and mitigation measures along with sustainable development goals. These scores give an overall impression of policy area attention of Khovd province to climate change and sustainable development. Analysis of the development and environment policies shows that they align differently with each of adaptation, mitigation and transforming capacity.

Table 16. Scores of policy documents in relation to the SDG-based building blocks, Khovd province

Policies	Building blocks for climate resilient development based on SDGs				
	Adaptation (Social resilience) *(SDG1, SDG3, SDG6, SDG8)*	Adaptation (Natural resilience) *(SDG15)*	Mitigation *(SDG7)*	Transforming capacity *(SDG4, SDG9, SDG11, SDG13)*	Overall alignment
Development strategy	1	2	3	2	(2.00) partial alignment
Green development policy	1	3	3	3	(2.5) partial alignment
Governor's Action Program	1	1	2	1	(1.25) limited alignment
Pasture use improvement program	2	2	1	1	(1.5) limited alignment
Overall alignment	(1.25) limited alignment	(2.00) partial alignment	(2.25) partial alignment	(1.75) limited alignment	

Development strategy (DS)

Adaptation- Social resilience: DS proposes measures to build the capacity of hospitals and medical staffs improve water supply and sanitation in soum centers. It acknowledges reducing unemployment, but there is a lack of details on how to achieve this. However, there are no specific objectives directed at diversifying income and reducing poverty, in particular, among pastoral societies.

Adaptation- Natural resilience: DS proposes to restore the traditional method of pastureland seasonal rotation, develop a mid-term program at soum and bagh (administration unit) level and develop a highly productive livestock breeding adapted to climate change and complied with pasture carrying capacity. It proposes to provide forest land and reservoirs with state protection and contract with environmental protection partners. It further proposes to stop the use of bushes along the shoreline and rivers by replacing herders' fuel needs with wood replacement products, encourage herder families to use smoke-free, fuel-efficient gas and condensing stoves, and plant trees and shrubs adapted to drought-tolerant climate conditions on 20 hectares of land per year. It further recognises the expanding state and local protected areas as a way for biodiversity conservation.

Mitigation: The policy recognizes renewable energy as the main energy source in a rural setting, to fully supply soums and settlements through introducing solar and wind renewable energy and other advanced technologies, and provide herder households with electricity source within "100 thousand solar lights" project.

Transforming capacity: DS recognises inclusive preschool and basic education for all children and youth. However, no specific objectives aimed at pastoral societies for vocational training and skills. It acknowledges the importance of infrastructure in reducing the urban-rural development difference and proposes to connect soum to the province center and nearby roads with paved and improved gravel roads. It further proposes to introduce new information and communications technology services such as distance training and high-speed telemedicine services at province and soum centers, and to move all soums and herders into mobile networks. DS highlights climate change risks and vulnerabilities in the region. Specific details of capacity building in reducing risks and vulnerabilities are provided.

<u>Green development policy (GDP)</u>

Adaptation- Social resilience: GDP proposes measures to reduce poverty by supporting green employment and developing environmentally-friendly tourism. Nevertheless, there is no specific measure of health and wellbeing, and safe water and sanitation.

Adaptation- Natural resilience: GDP proposes measures to reduce land and pasture degradation, combat desertification, foster sustainable forest management and biological conservation.

Mitigation*:* GDP promotes a sustainable consumption and production pattern with the efficient use of natural resources and low greenhouse gas emissions. It aims to increase the share of renewable energy in the total energy sector up to 100 percent of the province's electricity demand from hydro, solar and wind generators by 2026.

Transforming capacity: GDP acknowledges climate change risks and vulnerabilities in the region. Specific details of capacity building in reducing risks and vulnerabilities are provided. GDP has objectives to develop trends and behaviours for economic and sustainable resource utilization through formal and non-formal education at all levels. It proposes to develop roads, transportation and logistics networks that are economically viable and environmentally friendly and also aiming to preserve and develop traditional cultural values and livelihoods that are in harmony with nature and engrain citizens of green lifestyle with right attitude and mentality.

<u>Governor's Action Program (GAP)</u>

Adaptation- Social resilience: GAP provides specific actions aimed at increasing livestock and farming sector and improving herders' income and livelihoods. It proposes measures aimed at improving the quality and accessibility of health services. However, it does not provide specific actions directed at herder community. GAP further acknowledges the development of tourism based on ethnic culture, traditions and history, and natural environment and nomadic lifestyle.

Adaptation- Natural resilience: GAP proposes to develop and implement policy directed at biological diversity conservation and sustainable use. There are also actions aimed at reducing land degradation, forest management, and protection of water resource with limited details.

Mitigation: GAP proposes to provide affordable and reliable energy source by increasing the share of renewable energy production.

Transforming capacity: GAP provides measures to improve the quality and accessibility of educational services that meet the needs. It highlights developing trends and behaviours for environmental conservation and sustainable use of resources through formal and non-formal education at all levels. It also acknowledges cloud seeding as a measure to reduce climate change impacts in the region.

Pasture use improvement program (PUIP)

Adaptation- Social resilience: It aims to increase herders' income through diversified income opportunities and initiative to create savings and credit cooperatives.

Adaptation- Natural resilience: PUIP proposes to improve pasture use efficiency with the assistance of herders group, encourage responsible pasture use by introducing a levy on additional livestock number, and increase investment for combating desertification.

Mitigation: The policy mentions to support renewable energy, but not enough actions.

Transforming capacity: There are measures on awareness-raising and educating people and youth about desertification and its consequences. But no actions mentioned related to climate change impacts.

In Khovd province, the reviewed policy documents have 'partial' and 'limited alignment' as these contain climate change responses with good adaptation measures directed at enhancing natural resilience. The development policies, the DS and GDP, are partially aligned with climate change adaptation, whereas GAP has only limited alignment with climate change response. The DS and GDP, long term development policy documents acknowledge climate change as a threat to development, and vision mitigation measures suited at local scale and further propose measures for transforming capacities such as capacity building in reducing risks and vulnerabilities, and encouraging environmentally-friendly trend and behaviour change in people while preserving traditional cultural values and livelihoods that are in harmony with nature. However, these policies have inadequate adaptation measures adopted to strengthen social resilience, in particular, directed at pastoral and herding societies, who are most exposed to the impacts of climate change. As a 4-year local government policy document, GAP has contained actions of long term policies of the province. However, the policy has limited alignment with mitigation and transforming capacity with no detailed objectives and measures. The only environmental policy reviewed, PUIP, has a partial alignment with adaptation measures to enhance social and natural resilience, but have limited to no alignment with mitigation and transforming capacity measures.

Khovd province has developed and approved its long and midterm policies, DS and GDP, aligning with the new national policies, Mongolia's Sustainable development vision 2030 and national Green development policy. The analysis of the policy documents, however, reveals that these policies have not sufficiently integrated climate change and sustainable development in terms of enhancing social resilience of people, especially herding communities, who are most affected by the impacts of climate change. Ultimately, it implies that these people are not well prepared for future changes, and the capacity remains low for dealing with adverse climate and environmental impacts. The analysis further indicates there is a need for well-aligned adaptation policies to enhance the resilience of people's livelihoods to climate change because climate change is seen as a development issue, and adaptation activities can potentially reduce vulnerability to climate and other variability and can advance economic development at the local level.

3.4 Policy recommendations and adaptation options

Rapid responses of info service to the herders, including climate service, epidemic prevention stations for health service to the men and women, as well as quarantine for the livestock. Increase the opportunity of being accessible to the market for the herders to reduce livestock number and increase income, as a result, reduce pastoral pressure. A final workshop was organised on 23 – 24 August 2019 at the Mongolian Academy of Sciences in Ulaanbaatar to conclude the research outputs and identify potential adaptation options to reduce pastoral vulnerability in the selected areas. The participants included academic research members from all collaborating countries, herders, soum and provincial government officers, and civil societies from the two case areas and other experts from national advisory groups. During the workshop, the results of academic studies of pastoral vulnerability, socio-economic impacts, and the policy document review, as well as land degradation processes and the adaptation experiences of Chinese and Japanese team members, were presented before conducting a group discussion. Based on the research outputs and experiences of local participants, ways to resolve issues were discussed, and suitable adaptation options were identified and mapped for each soum in the Gobi-Altai province (Figure 55.a) and Khovd province (Figure 55.b). The following general adaptation options are expected to be useful to reduce pastoral vulnerability in the case areas:

- Establish a pasture degradation inventory and monitoring system for future prevention and measurable database
- Identify areas experiencing drinking water contamination for human and groundwater depletion for livestock and biodiversity in current and future condition
- Protect pasture degradation from steppe mouse, grasshopper and other rodents
- Improve health services for herding communities taking into consideration men`s living and working condition for their life expectancy
- Establish herders capacity development system through adaptive technologies and latest information
- Men in the Gobi-Altai province were more sensitive to pastoral vulnerability, which should be taken into account when considering future implications.
- Adaptation policies that integrate sustainable development and climate change mitigation are needed.

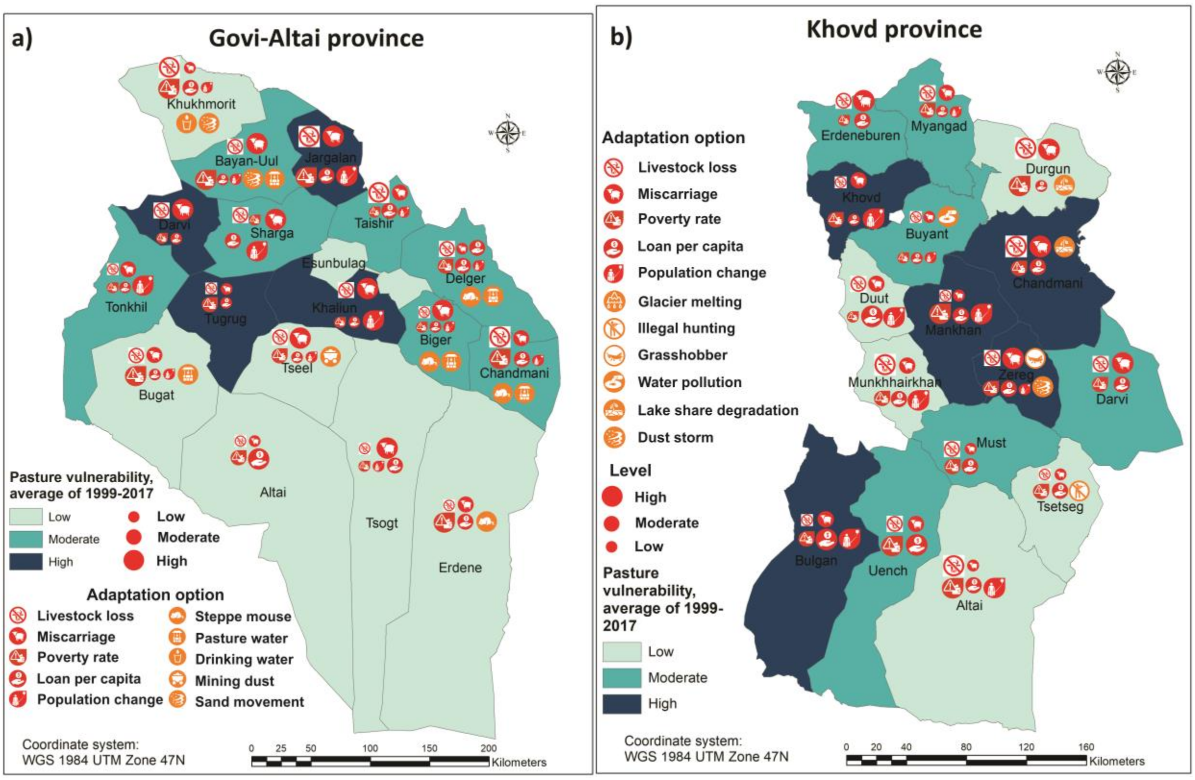


Figure 55. Adaptation options in Gobi-Altai and Khovd provinces, Mongolia

3.5 Grassland and pastoral system in China

China's grasslands play crucial roles in livestock production, household livelihoods and global ecosystems (Kang et al., 2007). Northern China contains over 50% of China's grasslands, which are called the traditional pastoral areas (Ho & Azadi, 2010), and which were home to the world's largest population of sheep and goats and the fourth-largest concentration of cattle in the 1990s (Zhang & Yang, 1990; National Research Council, 1992; Ho & Azadi, 2010). They are considered to be the major areas for livestock production in China, with a long history of producing meat, milk, wool and fur. Moreover, local animal husbandry provides livelihoods to millions of people, with a majority existing as traditional self-sufficient enterprises and a few commercial grazing businesses (Li et al., 2014).

The socio-economic and environmental functions of grasslands have involved the increasing attention of central and local governments to adopt policy interventions for sustaining the productivity of the grassland ecosystem. China's livestock systems can be classified as traditional grazing, industrial production or mixed systems (Cao et al., 2013b). Traditional grazing systems are characterised by the direct consumption of permanent pastures (Waldron et al., 2007). The majority of production in traditional grazing systems provides subsistence to local residents, and therefore their livestock production usually includes several species of multipurpose animals—producing meat, milk, hides, fibre, transport, and manure for fuel (Suttie et al., 2005). These regions are called pastoral areas, which are geographically vast but sparse in population. They are mainly located in the west, north and northwest of China, including the Mongolian and Tibetan plateaus and Xinjiang Uighur Autonomous Region (Cao et al., 2013b).

Industrial production systems aim to produce commodities for market sales, such as milk and meat. Their livestock production usually concentrates on one or two species of animals and relies also on crop products and sown pastures. Industrial production systems are mainly located in the southeast (Guangdong Province and Guangxi Zhuang Autonomous Region), north (Shanxi Province, Hebei Province and Beijing and 8 Tianjin Municipalities) and northeast (Liaoning Province, Jilin Province and Heilongjiang Province) (Cao et al., 2013b).

Mixed systems are the interface between traditional grazing and industrial production. China is a major player in the international livestock sector and has experienced impressive increases in livestock production but it has been observed that the increases in livestock production are predominantly associated with industrialised, rather than traditional, grazing systems in China (Cao et al., 2013b). The intensification of livestock production in China started in the late 1980s and has advanced progressively ever since, which resulted in significant changes in livestock production structures as well as the geographical distribution and composition of the livestock commodities of China (FAO, 2016).

In the 1990s, the central government called for moving cattle and sheep production from the traditional grazing region to the grain-producing provinces, because overgrazing of pastoral areas was stated as the main reason for grassland degradation. This policy strategy was strengthened after a series of environmental disasters had occurred in the 2000s. In short, the market share of livestock products in China has experienced a geographic shift from pastoral areas to crop-farming areas under changes in production technology and national policy strategies in recent years (Li et al., 2008).

Overgrazing and unsuitable grassland reclamation for cultivation have been accepted as the principal reasons (Ho, 2001). The total number of livestock in China increased by 594 million from 1981 to 2006 (Cao et al., 2013b), and an estimated 67 million hectares of high-quality grasslands have been converted to the cultivation of grains since 1949 (Ho & Azadi, 2010).

Climate-related factors are an ongoing concern as a significant driver of grassland degradation in arid and semi-arid areas. For example, the distribution of precipitation is discussed as a principal factor of the changes in grassland condition (Harris, 2010; Cao et al., 2013b), while the temperature is concluded to be a driver for changes in the biomass production of grasslands (Piao et al., 2006).

3.5.1 Vegetation Coverage and Net Primary Productivity (NPP) Distribution of Tongliao, Inner Mongolia, China

From Figure 56, the vegetation coverage is low in the middle part of Kailu, the middle part of Naiman in Horqin sandy land. And northern Zalute is the ecological hinterland of Tongliao city with high vegetation coverage.

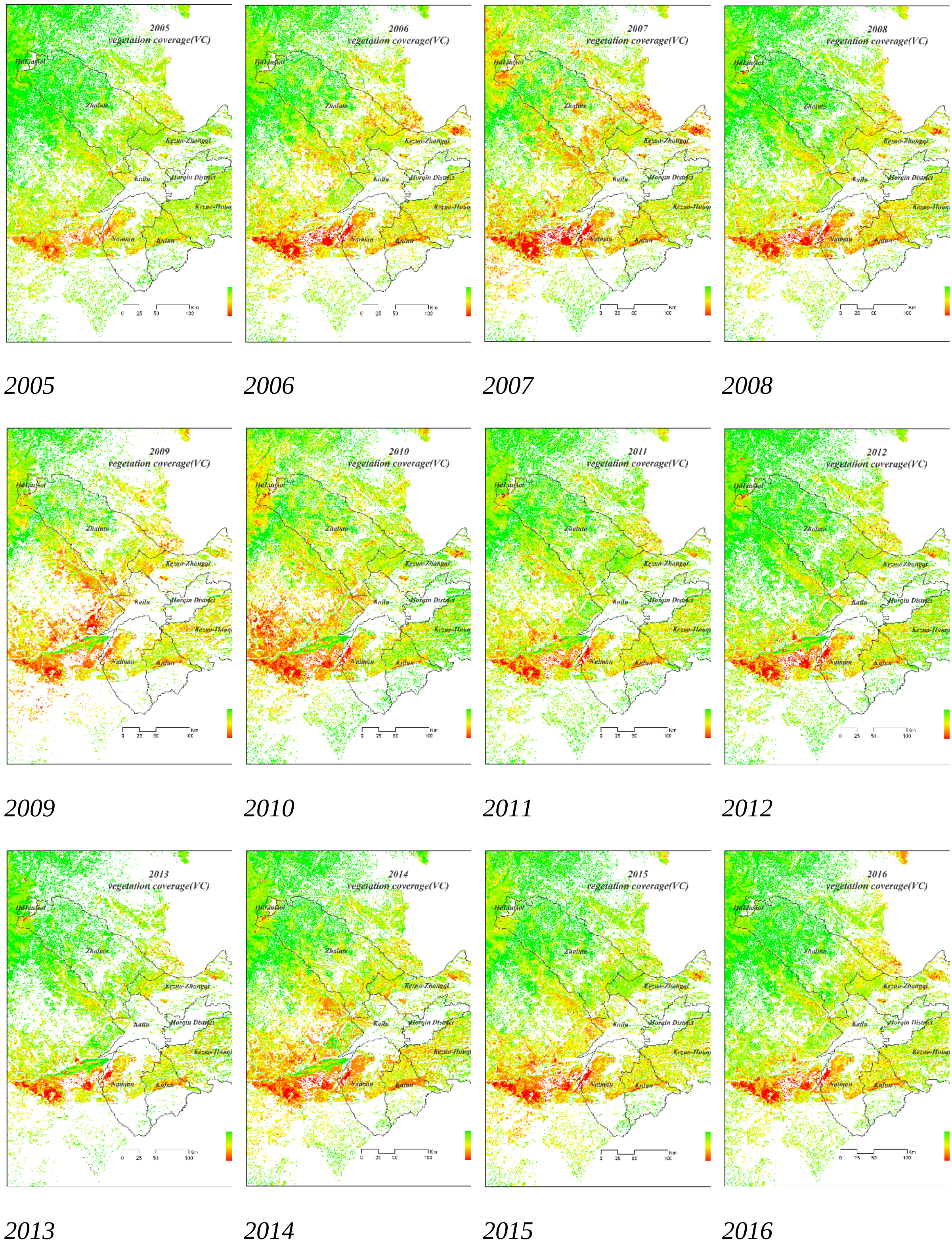


Figure 56. Distribution of vegetation coverage in Tongliao from 2005 to 2016

From Figure 57, the annual variation curve of vegetation coverage conforms to the law of average annual rainfall. Within 10 years, the vegetation coverage was relatively low in 2009 and the highest in 2013.

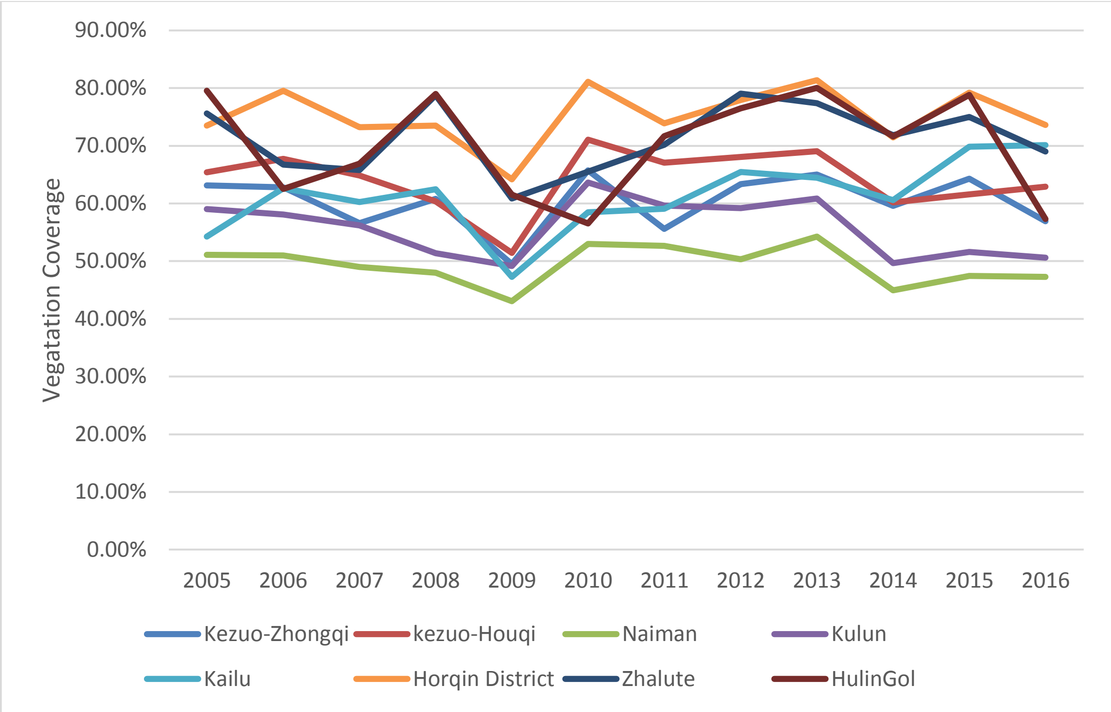


Figure 57. The variation trend of vegetation coverage of each county in Tongliao from 2005 to 2016

NPP is calculated by CASA model, and the distribution of Tongliao is shown in Figure 58. On the whole, the vegetation production of Tongliao was the highest in the north meadow steppe and the lowest in the middle. The pattern of appearance is similar to vegetation coverage.

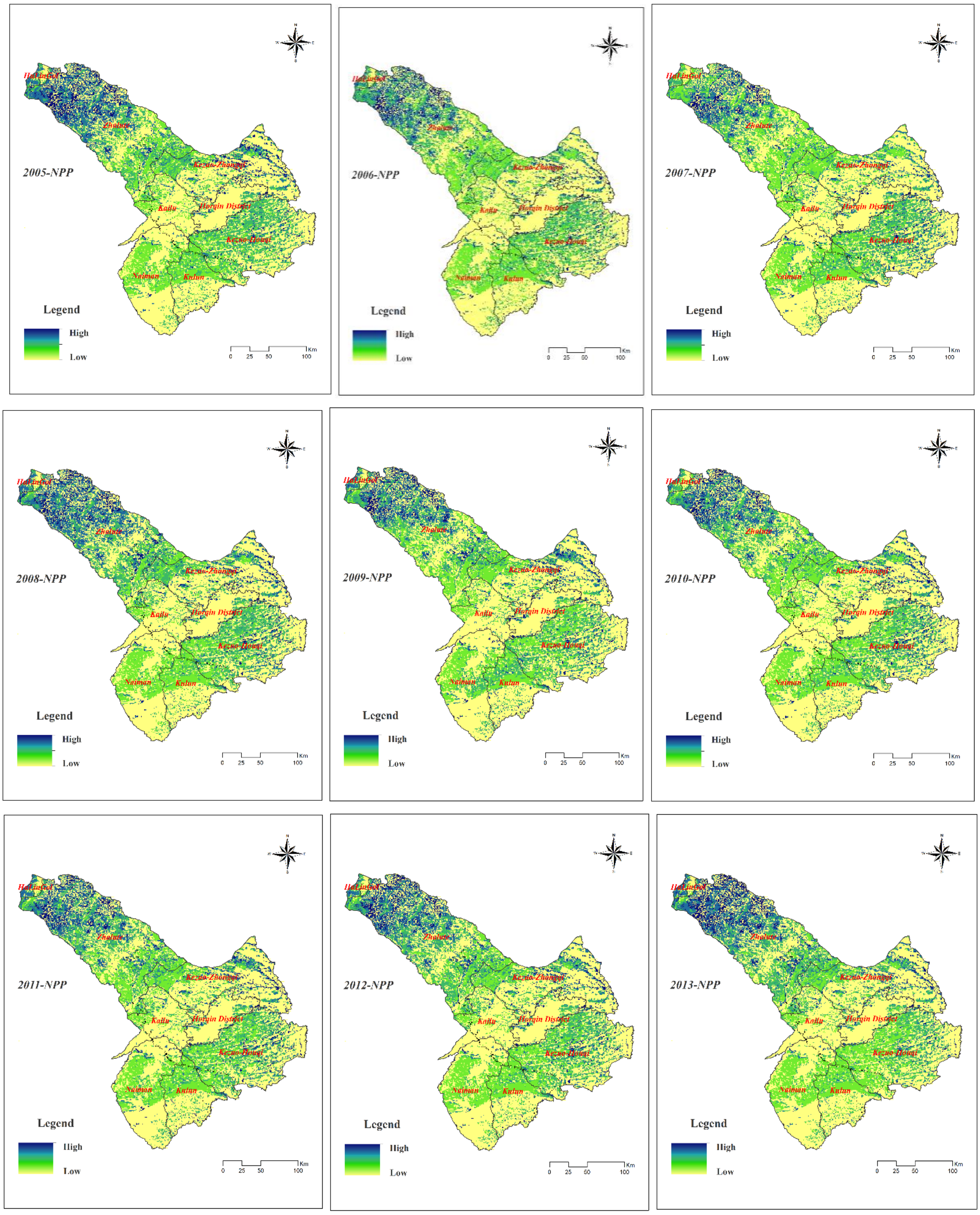


Figure 58. Distribution of NPP of each county in Tongliao from 2005 to 2016

As shown in Figure 59, Zalute has the highest vegetation productivity and the lowest in Kailu. Among the changes in the annual productivity of the whole Tongliao, productivity was the lowest in 2008 and the highest in 2013, and this regulation accords with the supply effect of vegetation hydrothermal condition.

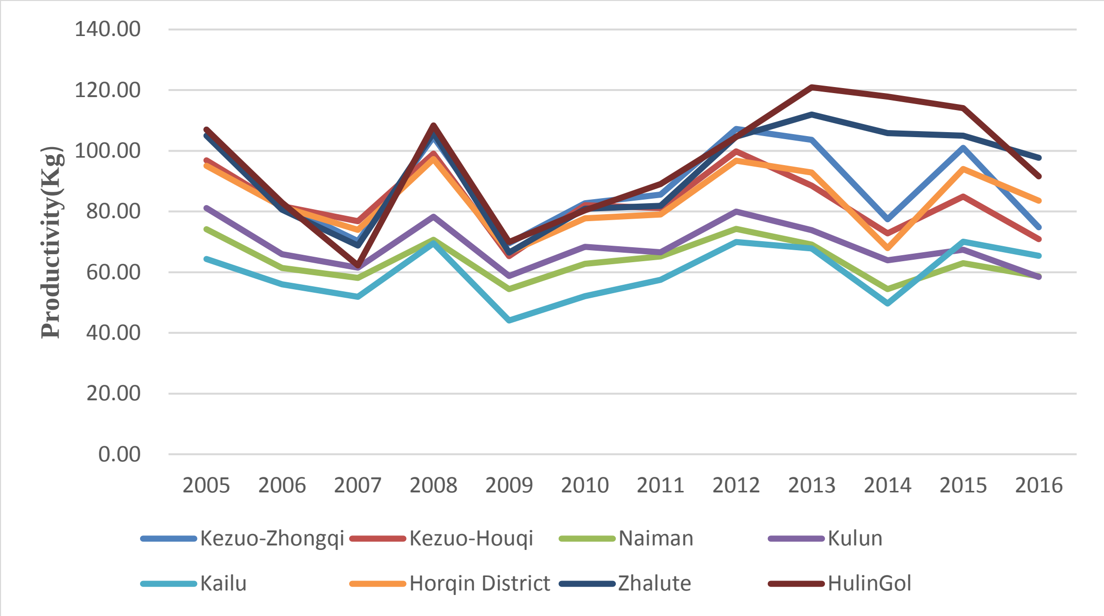


Figure 59. NPP of each county in Tongliao from 2005 to 2016

3.5.2 Isolation of efficient cellulose decomposer in sandy cropland and its application in straw turnover in agro-pasture ecotone of northern China

The ecological function of China's grasslands is being emphasized increasingly, such as biodiversity conservation, carbon sequestration, soil retention, soil fertility maintenance, and catchment protection (Suttie et al., 2005). It was shown that the grasslands of northern China significantly impact both regional climates and the global carbon cycle (Ni, 2002).

Isolation

Table 17 showed the numbers of decomposing cellulose fungi that are isolated from the cropland soils. 85 decomposing cellulose fungi were detected in the CMC medium plates, 11 of which were purified from the isolation due to different colour and shape of the colony. Five strains grew much faster after prescreening in the litter medium plates. These five screened strains were numbered as NMCel-crop1、NMCel-crop2、NMCel-crop3、NMCel-crop4 and NMCel-crop5. Advanced screening showed that NMCel-crop1 grew much faster and the diameter of hydrolytic ring was significantly larger than the other four strains in the Congo Red CMC medium plates (**Table 18**). Therefore, NMCel-crop1 was selected as the highly efficient cellulose decomposing fungi.

Table 17. Number of cellulose decomposing fungi

Procedures	Isolation	Purification	Pre-screening	Advanced screening
Number of strain	85	11	5	1

Table 18. Diameter of hydrolytic ring of the selected 5 strains

Strains	Diameter（cm）
NMCel-crop1	2.1±0.3 a
NMCel-crop2	1.5±0.2 b
NMCel-crop3	1.5±0.1 b
NMCel-crop4	1.2±0.2 c
NMCel-crop5	1.1±0.1 c

Note: Values (mean ± SE) with different letters within a column are significantly different at $p < 0.05$

Identification

From the microscopic images (Figure 60), we could see that there is no separation in the hypha, and single sporangiophore emerges at the end of each hypha. Spherical sporangium, with a significant number of spore appears at the top of sporangiophore. The morphological characteristics illustrated that NMCel-crop1 could be assigned in Mucoraceae family. DNA sequencing analysis showed that the length of the extracted DNA is 1048 bp, with 38.26% of G+C base. Blast alignment of the DNA sequence in NCBI Genbank database indicated that the strain is mostly associated with the known fungal (HQ285715.1: *Rhizomucor variabilis*) sequence (genetic similarity > 99%) (Figure 61). The NMCel-crop1 fungi were identified as the species of *Rhizomucor variabilis* in the genus of Rhizomucor and family of Mucoraceae.

Figure 60. Microscopic morpha of NMCel-crop1 magnified at 10 (1-1), 40 (1-2) and 100 (1-3) times

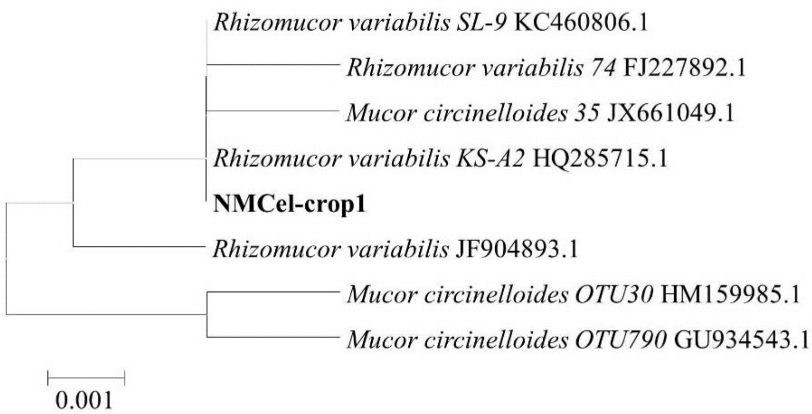


Figure 61. Phylogenetic tree of NMCel-crop1 and its related strains

CMC enzyme activity

CMC enzyme activity from the supernate was determined at different temperature gradient (20, 25, 30……, 70 °C). The CMC enzyme activity increased gradually from 20 °C to 40 °C, then increased smoothly, and get to its peak at 50 °C. It decreased shapely from 55 °C (Figure 62). Therefore, the optimized temperature for the NMCel-crop1 fungi to fulfil its decomposing ability is 50 °C. The CMC enzyme activity produced by the NMCel-crop1 fungi (0.43±0.03 mg/ml·min) was significantly higher than that from the sandy cropland soil (0.05±0.01mg/ml·min) ($p<0.001$).

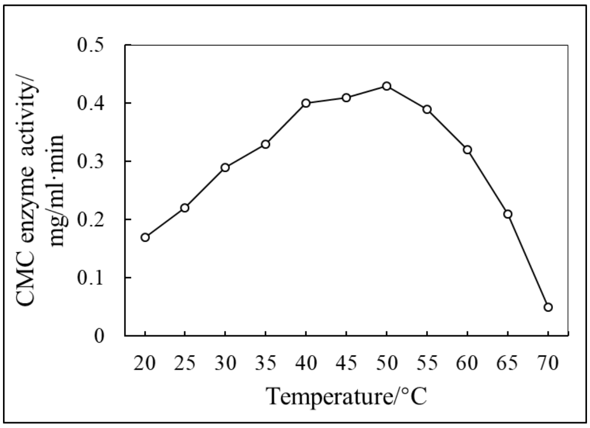


Figure 62. CMC enzyme activity at a different temperature gradient

Decomposition ability

The changes of filter paper mass loss, decomposed by the NMCel-crop1 fungi, showed that it decomposed very slowly in the first 3 days (D<20%). From the 3rd to the 6th day, the filter paperweight lost very fast from 20% to 80%, almost lost its weight for 20% per day. Then after the 7th day (D=82.03±2.46 %), the mass did not change significantly.

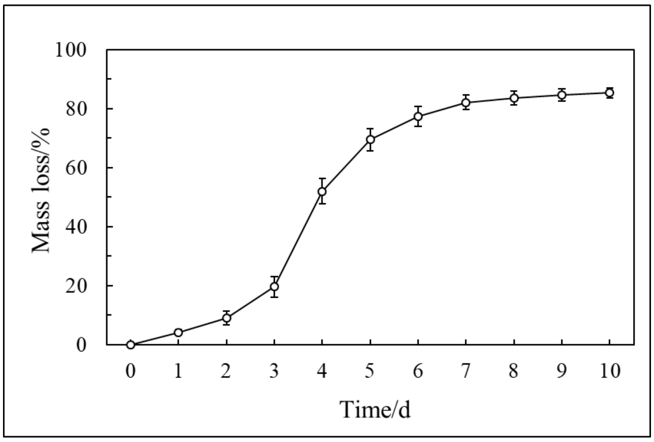
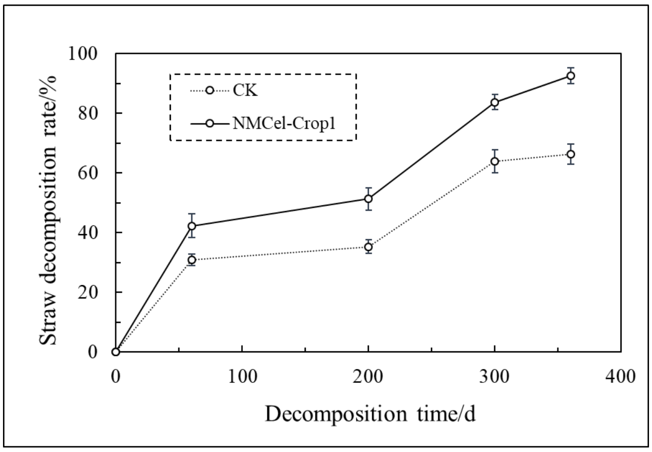


Figure 63. Mass loss of the filter paper decomposed by the NMCel-crop1 fungi

Straw decomposition in field experiment

The result from the field experiment (Figure 64) showed that straw decomposed very fast at the first decomposing stage (harvest to frozen season, 0-60 d) by 42.27±3.91 % infected by

NMCel-crop1 fungi, which was 11.47% higher than CK. The straw decomposed much slower in the frozen season from early December to early May (60-200 d), 9.03% infected by the NMCel-crop1 fungi, and 4.47% in CK. When the weather became warmer, the straw decomposition rate became faster again. The decomposition rate reached at 83.69±2.50 % infected by the NMCel-crop1 fungi, 20% higher than CK at the end of the growing season in middle August. The daily decomposition rate did not show statistical difference between NMCel-crop1 fungi (0.28%/d) and CK (0.26%/d) at the 3rd decomposing stage (seeding season to growing season, 200-300 d). The straw decomposition rate slowed down after the growing season in CK. However, the straw decomposition rate still flourished infected by the NMCel-crop1 fungi. The decomposition rate reached at 92.49% infected by the NMCel-crop1 fungi, 26% higher than that in CK after one year buried in the sandy cropland soil. The residual of the straw remained less than 10% infected by the NMCel-crop1 fungi, which significantly accelerate straw turnover in the semi-arid sandy cropland.



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Discussion

We have isolated and selected abundant high-efficient cellulose decomposers in the former work in Horqin sandy grassland, some of which degrade the litter by 50% in 30 days (Wang et al., 2015). However, the cellulose decomposers detected in the sandy cropland was much less (Wang et al., 2016), and could not isolate high-efficient cellulose decomposers for a long time. We optimized the isolation, purification and screening procedures to obtain a high-efficient cellulose decomposing fungi (*Rhizomucor variabilis*) in Horqin sandy cropland. Our work could greatly benefit straw turnover and nutrient cycling in semi-arid sandy cropland maintenance.

Many species in Rhizomucor genus are key fungi for formation in the food industry and some of them are pathogenic fungi for skin disease. They play a very important role in alcoholic fermentation, sugar production, lipid enzymolysis. Research showed that *Rhizomucor pusillus* could catalyze different carbon source substrates into small particles, such as glycerinum, lactic acid and xylitol, which are very important products in the food industry (Millati et al., 2005). Chadha et al. (2004) isolated a fungus (*Rhizomucor pusillus*) with high phosphatase activity from the compost, and it could be used to optimize the composition of livestock fodder. Several species of Rhizomucor was isolated from soils in semi-arid area of southern Africa. These fungal species had high tolerance in nitrite and could survive under extreme drought stress (Seabi et al. 1999). Another species of Rhizomucor (*Rhizomucor miehei*) could produce lipase, which could be used in dairy products (Soltani et al., 2019), and also in biofuel industry (Adnan et al., 2018; Rodrigues & Fernandez-Lafuente, 2010). Some of the *Rhizomucor miehei* could also produce mannose enzyme in strong acid and high-temperature environment (Li et al., 2017).

Reports about *Rhizomucor variabilis* were mostly focused on medical science. They are pathogenic fungi for many skin diseases (Lu et al., 2009; Patil et al., 2013; Tomita et al., 2011). Recently, a few reports on food production indicated that *Rhizomucor variabilis* showed highly alkali resistance to produce lipase (Bancerz et al., 2015; Bancerz et al., 2018). Researchers isolated *Rhizomucor variabilis* from mushroom (Ke et al., 2016) and corncob (Xu et al., 2017). These fungi were sensitive to nitrogen variations and beneficial for protecting crop from rot disease. However, researches seldom focus on the cellulose decomposition ability about *Rhizomucor variabilis*. Our research recruited new fungal species into soil functional microbe bank in semi-arid sandy cropland.

There are many microorganisms living in cropland soils. These microorganisms regulate soil's health and maintain sustainable production in agricultural cropland (Acostamartínez et al., 2010; Chapin III et al., 2002; Jaiswal et al., 2017). Cellulose decomposers are mainly responsible for crop straw decomposition and accelerate its turnover in agricultural ecosystem. Crop straw turnover could promote soil microbial activity and increase soil fertility so that less chemical fertilizer would be applied and high quality of agricultural products could be produced in green agricultural development. Therefore, straw turnover became an effective practice in sustainable agricultural management (Roper & Gupta, 1995; Wei et al., 2017). However, in the cold and semi-arid agro-pasture ecotone, such as Horqin Sandy Land, both precipitation and the temperature is very low, especially in winter and spring. Hence, straw decomposed very slowly after its turnover and the organic material could not return to the soil on time, leading to a waste of organic resource and even pests disease in the coming year. In the natural field condition of Horqin Sandy cropland, maize straw decomposition rate is only 35% from its harvest to the next seeding season, and it reaches to 66% in a whole year, with 1/3 remaining of the maize straw that could not be decomposed.

The straw residual is mostly lignin and/or polycellulose which is difficult to decomposed. We isolated and selected a high-efficient cellulose decomposing fungi (*Rhizomucor variabilis*) in situ soils from the Horqin Sandy cropland. The selected decomposing fungi were magnified and made as decomposing microbial agents to accelerate straw turnover. The application of the decomposing microbial agents significantly increased the straw decomposition rate by 50% from its harvest to the next seeding season and reached >90% in one year. The maize straw could mainly return into soil as organic matter in a recycle year. The demonstration of maize straw turnover in sandy cropland accelerate the soil nutrient input, and it is a potential application to reduce the chemical fertilizer and produce healthy crop products in sustainable agricultural management in the arid and semi-arid agro-pasture area.

Five decomposing cellulose fungi were isolated and one of them was selected as high efficient cellulose decomposer in sandy cropland of agro-pasture ecotone of northern China. These selected cellulose decomposing fungi were identified as *Rhizomucor variabilis*. The optimized temperature for expressing its CMC enzyme activity is 50 °C. The CMC enzyme activity produced by this fungi was 0.43 mg/ml·min, which was significantly higher than that from the sandy cropland soil. It has high ability to decompose cellulose material, not only in laboratory test but also in field experiment. The isolation and demonstration of this high efficient cellulose decomposing fungi could enrich soil functional microbe bank, as well as accelerate straw turnover and nutrient return in sustainable agriculture management in the arid semi-arid sandy cropland.

4 Conclusions

The stakeholders in this project consist of 11 different academic institutions and more than 6 local government organizations, 2 NGOs and farmers, and several herding communities. The participation of all stakeholders was beyond our expectation with deep interest and active roles to better understand Climate-Pasture-Livelihoods nexus and how this nexus might impact local communities now and into the future. The training and workshops successfully achieved their objectives of bringing stakeholders together to have a common discussion on science-based good management to climate adaptation, management of human activities and reducing vulnerability risks and ensuing loss and damage.

The project activities have educated young scientists and local communities of herders, practitioners and governors through climate change impact, its risks, pasture vulnerabilities, and the local development scenarios tied to regional and national issues, and application of spatial planning tools.

The flexibility of the local pastoral adaptation strategy process has allowed the application of geovisualisations in place-based problem solving and decision-making process in the specific socio-political context of municipal and regional governments.

The most significant variable was climate change-related drought, followed by intensive pasture use in the case areas. The study's 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 affect the income of herders directly.

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 the livestock sector and provide the sustainability of nomadic pastoralism.

This demonstrates the need for adaptation measures to ensure the sustainability of the 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 are needed to address the working conditions of herders impacted by climate change and their potential social service needs.

5 Future Directions

The study applied geospatial tools to assess pastoral vulnerability, conducted correlation analyses of variables related to the socio-economics of pastoral societies by evaluating key factors developed by the 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 which can be significant potential for their capability.

The future studies could be more concentrated on detailed research about social and economic issues such as average life expectancy for herder men, chain and accessibility of livestock marketing, and pricing for raw materials related with pastoral communities, responses of info service to the herders including climate service, epidemic prevention stations of health service to the herders.

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7 Appendix

7.1 Glossary of Terms

APN	Asia-Pacific Network for Global Change Research
APAR	Absorbed Photosynthetically Active Radiation
CASA	Carnegie-Ames-Stanford Approach
CDP	Comprehensive development policy
DS	Development strategy
DDP	Dryland Development Paradigm
EMP	Environmental Master Plan
GAP	Governor’s Action Program
GDP	Green development policy
GIS	Geographic Information System
GDP	Gross Domestic Product

IGEB	Institute of General and Experimental Biology
IMAR	Inner Mongolia Autonomous Region
MAS	Mongolian Academy of Sciences
NAMEM	National Agency of Meteorology and Environmental Monitoring
NGO	Non-Governmental Organization
NDVI	Normalized Difference Vegetation Index
NSOM	National statistics office of Mongolia
NAM	National Atlas of Mongolia
NPP	Net primary productivity
PMP	Pasture management program
PUIP	Pasture use improvement program
QDA	Qualitative Document Analysis
SCD	Sub-program to combat desertification
SDG`s	Sustainable Development Goals
SDV	Sustainable Development Vision of Mongolia
SDiWoM	Sustainable Development Institute for western Region of Mongolia

7.2 *Funding sources outside the APN*

- The sustainable development institute for the western region of Mongolia provided working good condition, and communication networks between collaborators and also shared local development planning fund (2016-2018) from World Wildlife Fund (WWF) for some events and researchers salary 3400$.
- The head office of Mongolian academy of sciences provided very good facilities to organize group meetings, internal and international workshops and training.
- Local government offices of Biger soum from Gobi-Altai province and Chandmani soum from Khovd province especially supported the compatible working conditions and provided local datasets for the field workers (approximate amount 220$ and 180$).
- Keio University of Japan provided very compatible working conditions for the researcher's and advanced experts knowledge on capacity development and adaptation, strategies/ technologies utilization (approximately 8000$).
- The Institute of Geography and Geoecology and Institute of General and Experimental Biology, Mongolian Academy of Sciences provided well supports for the young researcher's involvements with their good working condition as well as salary.

7.3 *List of Young Scientists*

- Bolor Kherlenbayar, The Institute of Geography and Geoecology, Mongolian Academy of Sciences; Mongolia. bkherlenbayar@gmail.com
- Wu Nitu, Inner Mongolian Grassland institute, China; Unteecass@outlook.com
- Shaokun Wang,Northwest Institute of Eco-environment and Resource, CAS; wangsk@lzb.ac.cn
- Damiran Manidari, Institute of General and Experimental Biology, Mongolian Academy of Sciences, 976-95110194, dmanidari@gmail.com
- Suhbaatar Otgonsukh, Institute of General and Experimental Biology, Mongolian Academy of Sciences, 976-97169607, s.otgoo1234@gmail.com
- Gunjargal Balt, Sustainable development institute for western region of Mongolia, gungee09@yahoo.com
- Batjargal Erdenebileg, Sustainable development institute for western region of Mongolia, erka@yahoo.com

7.4 *Conferences/Symposia/Workshops*

7.4.1 The science supporters and proposal development training workshop

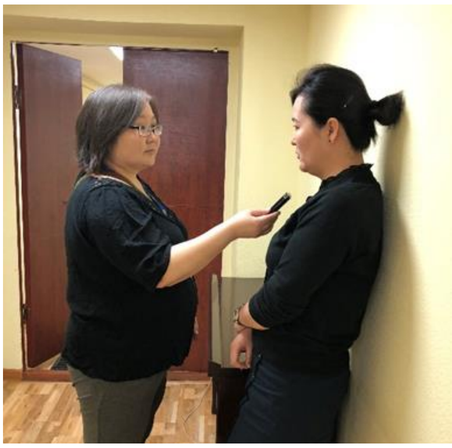
In developing countries, the contribution of scientific outputs to the decision-making and the financial support for scientific researches are not well linked and developed. In Mongolia, government funding and budget for science and technology development is very limited, which could only support basic theoretical studies for few sectors. In this case, policy research and application studies are not supported, and young researchers do not have opportunity to fund their research and contribute outputs to the application level.

Under the support of APN we implemented this scientific research project so that some of the project outcomes will have impacts on local community capacity development. While collaborating with some institutes of Mongolian Academy of Sciences (MAS) on this project, many young researchers requested the project team to conduct training on finding financial supports from international research funds, project proposal development and ways to contribute their research outcomes to the application level. Then, we decided to organize the local level training workshop, which was not planned in the project proposal. However, MAS hosted the training workshop and supported some part of its budget.

The training workshop called "**The science supporters and proposal development training workshop**" was held at the training center of the MAS on 27-28 February 2018 in Ulaanbaatar, Mongolia. About 27 young scientists from 11 research institutes participated and 4 experts from APN supported project presented and shared their experiences at the workshop.

The morning session of the first day of the workshop focused on introducing the project funding organizations, challenges of project proposal development, experiences of the experts to contribute their research outputs to the application levels and make good collaboration. The afternoon session introduced about APN, its calls of project proposals and guidelines. The second day of the workshop focused more on the proposal development to the APN. In this part we followed a guideline and teaching method of Proposal Development Training Workshop (PDTW) by APN.

During the training, participants were divided into 5 groups and developed 5 initial proposals. Team members consisted of different institutes and different research backgrounds to apply their diversity into proposals. During the training, 1 mentor and 2 researchers were interviewed by 2 television channels and 1 radio station about the training workshop, the APN and the APN-supported project "Ecological vulnerability assessment for adaptation strategy formulation at different spatial scales in western Mongolia and China". More details of the training workshop program and participants can be seen from Appendix 3.

During "**The science supporters and proposal development"** training workshop**,** on 27-28 February 2018 at the training center of MAS, Ulaanbaatar, Mongolia.

"The science supporters and proposal development training workshop" agenda

Time	Training	Moderator/Speaker
February 27, 2018		
09:00-09:10	Opening speech	Prof. R.Bandii, Head of Foreign relations and cooperation department, MAS
09:10-09:20	Introduction of participants	
09:20-09:50	Lessons learned from developing international joint projects	Prof. T.Chuluun, Director of Sustainable development institute, National University of Mongolia
09:50-10:30	Introduction about project funding organizations	Prof. Walter, Advisor, Institute of Geography and Geoecology, MAS
10:30-10:45	Coffee break	
10:45-11:20	International organizations for funding Asian research projects and some Japanese and Korean projects	Dr. B.Suvdantsetseg, Sustainable Development Institute for western region of Mongolia, Senior specialist of Foreign relations and cooperation department, MAS
11:20-12:00	Asia Pacific Network for Global Change Research (APN) projects, types, criteria and strategy	Dr. B.Suvdantsetseg, Sustainable Development Institute for western region of Mongolia, Senior specialist of Foreign relations and cooperation department, MAS
12:00-12:30	Team work on inter-sectoral research project development (Divide participants into working groups based on professional background and skills, inter-sectoral coordination, impact and teamwork skills)	By Moderator
12:30-13:30	**Lunch break**	
13:30-15:30	Team work activities Determining the roles and responsibilities of project team leader and members in divided teams, and define project topics, needs, rationale and goals.	Dr. B.Suvdantsetseg, Sustainable Development Institute for western region of Mongolia, Senior specialist of Foreign relations and cooperation department, MAS
15:30-15:45	**Coffee break**	
15:45-17:30	Team work activities	Dr. B.Suvdantsetseg, Sustainable Development Institute for western

	Selecting the project team's international and local partners to meet the requirements of the project financier, and define their involvement, and inter-sectoral coordination	region of Mongolia, Senior specialist of Foreign relations and cooperation department, MAS
17:30-17:35	Closing (home work)	
February 28, 2018		
09:00-10:30	Determine the project approach, assumptions, research areas, technical activities and its calendar plans	Dr. B.Suvdantsetseg, Sustainable Development Institute for western region of Mongolia, Senior specialist of Foreign relations and cooperation department, MAS
10:30-10:45	**Coffee break**	
10:45-12:30	Define the project research theory and methodology, softwares to be used and developed, application and development of project research and formulation	Dr. B.Suvdantsetseg, Sustainable Development Institute for western region of Mongolia, Senior specialist of Foreign relations and cooperation department, MAS
12:30-13:30	**Lunch break**	
13:30-15:00	Project budgeting and its realistic estimates, calculation of the amount of co-financing and spending	Dr. B.Suvdantsetseg, Sustainable Development Institute for western region of Mongolia, Senior specialist of Foreign relations and cooperation department, MAS
15:00-15:15	**Coffee break**	
15:15-16:30	Project outcome assumptions, and projections of benefits for socio-economy and science and technology in Mongolia, and for financing organizations	Dr. B.Suvdantsetseg, Sustainable Development Institute for western region of Mongolia, Senior specialist of Foreign relations and cooperation department, MAS
16:30-17:20	Presentations of teams 5 teams, 10 minutes each	Heads of all departments, Deans of research of institutes
17:20-17:30	**Closing remarks**	B.Avid, Dean of Research, MAS

List of participants

No	Name	Institute & affiliation	Email	Phone	Team	Feb 27, 2018	Feb 28, 2018
1.	Dr. N.Jargalan	Researcher, Department of Materials science, Institute of Physics and Technology	njagaa@gmail.com	86018195	1	+	+
2.	Dr. N.Ganbat	Senior researcher, Department of Xiongnu Archaeology, Institute of History and Archaeology	Jijgee01@yahoo.com	99881895	1	+	+
3.	Dr. N.Erdene-Ochir	Senior researcher, Department of Bronze and early iron age, Institute of History and Archaeology	erdeneochir.mgl@gmail.com	91069595	1	+	+
4.	Dr. D.Usukhjargal	Researcher, Laboratory of Plant biotechnology, Institute of General and Experimental Biology (IGEB)	osokhoo0412@gmail.com	99248943	1	+	+
5.	Dr. A.Saruulzaya	Researcher, Department of permafrost, Institute of Geography and geoecology (IGG)	saruulzaya@gmail.com	99290816	1	+	+
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8.	Dr. S.Enkhtuul	Institute of Chemistry and Chemical Technology	enkhtuulls@yahoo.com	99193345	2	+	+

9.	Dr., Associate.Prof. D.Gantulga	Head, Laboratory of Molecular Biology, IGEB	gtulga37@gmail.com	99105464	2	+	-
10.	E.Saruul	Researcher, Laboratory of Molecular Biology, IGEB	Saruul_erdenebileg@yahoo.com	91611123	2	+	+
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12.	Dr. B.Zoljargal	Department of Applied linguistics, Institute of Language and Literature (ILL)	zol_chee@yahoo.com zolushzol@icloud.com	86082099	3	+	+
13.	Dr. Z.Badamkhatan	Institute of palenteology and geology	badmaa@gmail.com	99115537	3	+	-
14.	Dr. A.Munkhsaikhan	Researcher, Institute of astronomy and geophysics (IAG)	moogii@iag.ac.mn a.munkhsaihan@gmail.com	11458527	3	+	+
15.	Dr. Ts.Batsaikhan	Researcher, IAG	batsaihan523@yahoo.com	88116146	3	+	+
16.	MSc, J.Byambasuren	Researcher, Department of Philosophy, Institute of Philosophy	jbyambaa1020@gmail.com	96022250	3	+	+
17.	Dr. D.Uuganbaatar	Head, Department of Informatics, Institute of Physics and Technology	uugaa3000@gmail.com	99069054	4	+	+
18.	Dr. O.Shinebayar	Head, Department of Applied linguistics, ILL	och.shinee@yahoo.com	99794324	4	+	+
19.	Yo. Undral	Researcher, Department of Sociology and social psychology, Institute of Philosophy	undralyondon@gmail.com	99078265	4	+	+
20.	Dr. M.Urtnasan	Researcher, Department of Geographical information system and mapping, IGG	m.urtnasan@gmail.com	91060506	4	+	+
21.	Dr. N.Tungalag	Institute of palenteology and geology	naidantungalag@gmail.com	99879996	5	+	-
22.	Dr. M.Nyamaa	Researcher, Department of desertification study, IGG	mendsaikhannyamaa@gmail.com	99768012	5	+	+ -
23.	Dr. A.Nyamdoljin	Dean of research, Institute of international affairs (IIA)	nyamdoljin@yahoo.com	80092345	5	+	+
24.	Dr. Navchtsetseg	Presidium's office, MAS			5	+	
25.	D.Zolboo	Project leader, IIA	ulziinaran@yahoo.com	99292529	5	+	-
26.	Dr. S.Chinzorig	Researcher, Department of water resource and use, IGG	chk_chnz@yahoo.com	90410022		+	-
27.	Dr. Ts.Munkhzul	Researcher, Laboratory of mammalian ecology, IGEB	tsmunkhzul@yahoo.com	88061276		+	-

7.4.2 1st Discussion Workshop in Tongliao prefecture, Inner Mongolia, China

Under the support of APN, we organized ***1st discussion workshop on Ecological vulnerability assessment*** on 5-8 July 2018 in Tongliao prefecture, Inner Mongolia, China to exchange knowledge, research output, and practical experiences between scientists, herders, farmers, representing leadership, policymakers and replanting practitioners that collaborated on this project. This workshop was hosted by the Green Network NGO branch office of China in collaboration with the Northwest Institute of Eco-environment and Resource, CAS, Sustainable development institute for western region of Mongolia, and Mongolian Academy of Sciences.

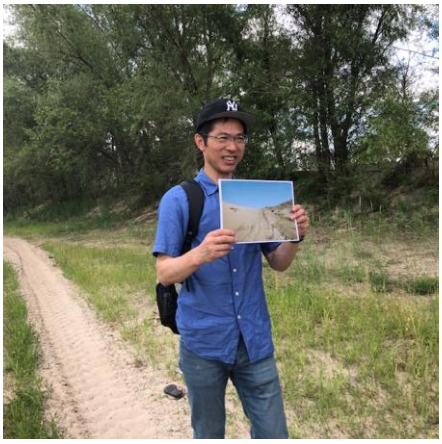
In the workshop, totally 25 people (9 experts, 5 young researchers, 6 local staffs, 3 herders/ farmers and 2 local governors) participated from 3 countries and 9 institutions.

The workshop aimed to discuss the progress and situation of the project, preliminary outcomes of the assessment in each selected research area, the next steps of the project, and to exchange experiences between all research collaborators.

On the first day of the workshop, we visited different management groups (individuals, local government and community groups) of replanting areas managed by Green Network NGO, Japan. We found out that the involvement of stakeholders plays an important part in replanting the large area of sandy desert. The participants learned a lot and gained rich knowledge about management, local communities collaboration, their livelihood support, protection of environment and contribution to local sustainability, and reduction of both ecological and socio-economic vulnerabilities.

The field visit of local herders and farmers was a special event for Mongolian herders from Gobi desert area. They had the opportunity to learn about the replanting process, method, management, and livelihood support for local communities.

a. Forest support for local communities livelihood and farmers daily life support
b. Hay planting and preparation for animals forage
c. Vegetables for farmers and herders daily food supply



The workshop was held on the second day but due to the security problem in China, we were not able to officially make presentations. The workshop went on but only with the presence of foreign participants; all Chinese participants were not able to join. However, we distributed all presentation materials to the participants. The workshop presentations focused on the methodology development, assessment results at the case areas and future algorithm development of ecological vulnerability assessment including pasture degradation, agriculture, water resources shortage and climate change-related extreme impacts in Mongolia and China. Booklet of the workshop is in attachment 1.

The detailed program

5 July 2018 (Thursday)		
8:30-23:00	**Arrival**	**At Horqin** all delegates arrival **Bo Wang Hotel**
6 July 2018 (Friday)		
08:50	**Registration**	At lobby of hotel
09:00-12:00	**Field visit Tour**	Visit to Replanting area of Green Network
12:00-14:00	**On site**	Lunch with local farmers at local restaurant
14:00-18:00	**Field visit Tour**	Visit to different management (individuals, local government and community groups) of Replanting area
18:00-20:00	**Dinner**	Welcoming dinner at Hotel restaurant
7 July 2018 (Saturday)		
08:30-08:55	**Registration**	➢ All participants
09:00-09:05	**Opening Remarks**	➢ Altanbagana.M PhD, Head of social economic division, IGG, MAS ➢ Prof. Wanglin YAN, Director of Research center for Climate Change Adaptation, Keio University, Japan
09:05-09:15	**Introduction**	Dr. B.Suvdantsetseg **Project introduction:** “Ecological Vulnerability Assessment for Adaptation Strategy Formulation at Different Spatial Scales in Western Mongolia and China”
09:15-9:40	**Invited lecture**	Prof. Wanglin YAN, Director of Research center for Climate Change Adaptation, Keio University, Japan

		Using Machine Learning to Assess and Predict the Risk of Livestock Disaster
09:40-10:00	**Invited lecture**	Prof. Xueyong Zhao Northwest Institute of Eco-environment and Resource, CAS **Growing vulnerability of desertification reversion in Horsing Sandy Land of China**
10:00-10:20	**Discussion**	
10:20-10:35	Group photo and Coffee break	
Session chair: T. Miyasaka (PhD)		
10:35-11:05	**Speaker**	Prof. Li Yuqiang, Northwest Institute of Eco-environment and Resource, CAS **“Carbon sequestration in the plant-soil system following grazing exclusion and afforestation in dessertified area of Horsing Sandy Land”**
11:05-11:35	**Speaker**	McS. Kherlenbayar.B, Sustainable development Institute for western region of Mongolia **“Ecological vulnerability assessment of Khovd and Gobi-Altai provinces, Mongolia”**
11:35-12:05	**Speaker**	McS. Wu Nitu, Grassland survey and planning institute of Inner Mongolia, China **“Grassland degradation and monitoring system in Case study of Tongliao province, China”**
12:05-12:30	**Discussion**	
12:30-13:30	**Lunch**	
Session chair: M. Altanbagana (PhD)		
13:30-13:50	**Speaker**	Dr.Takafumi Miyasaki, Nagoya university **“Social-ecological impacts of a payment for ecosystem services scheme in the Horqin Sandy Land”**
13:50-14:10	**Speaker**	Prof. Kenji Kai, department of Education, Ibaraki university **“Horqin Sandy Land as one of the sources of the Asian dust storm”**
14:10-14:30	**Speaker**	Dr. Shaokun Wang, Northwest Institute of Eco-environment and Resources, CAS **“Changes of soil microbial community along vegetation restoration in semi-arid sandy land of northern China”**
14:30-14:50	**Speaker**	Mr. Kitaura Yoshio, executive director of Green Network **Greening activity for restoration and adaptation management in Horqin case.**
14:50-15:10	**Discussion**	
15:10-15:20	**Closing Remarks**	Dr.B.Suvdantsetseg, Director, Sustainable development institute for western region of Mongolia
15:20-15:40	**Tea Break**	
15:50	**Departure to Naiman desertification station**	
19:30	**Dinner**	
8 July 2018 (Sunday)		
08:30-12:30	Visit to Naiman desertification research station	
12:30-13:30	Lunch	
13:30-17:00	Back to Tongliao and Shinyang airport	

List of Participants

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15.	Zhang ai wei	Green Network, NPO, China	
16.	Tana	Green Network, NPO, China	
17.	Baatare	Forest agency, local government, Horsing	
18.	Buqio	Forest agency, local government, Horsing	

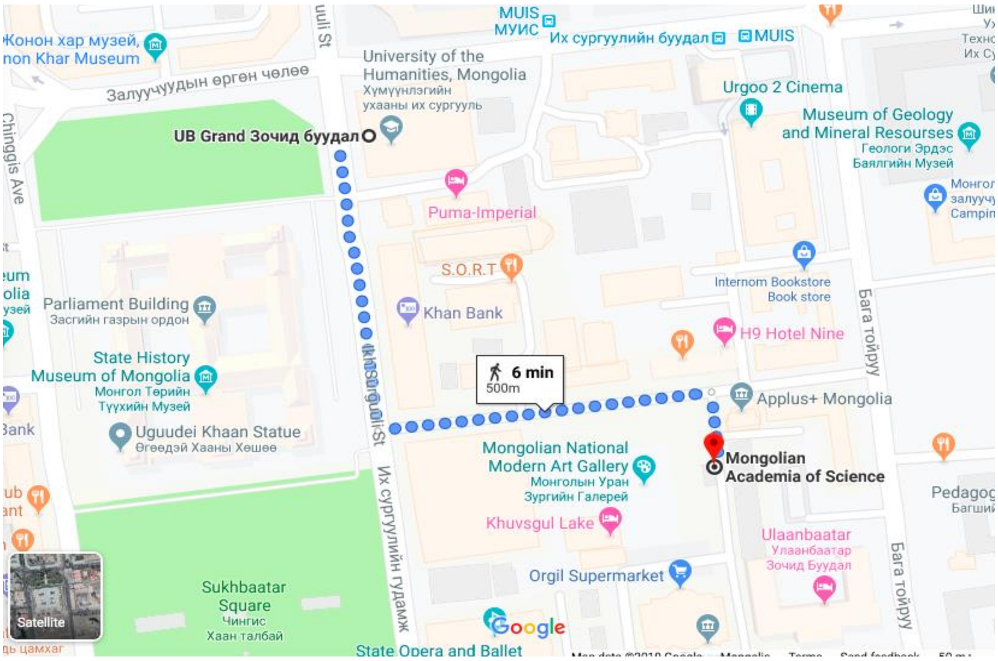
7.4.3 The 2nd workshop on social-ecological systems governance for sustainability

AIM OF THE WORKSHOP

The 2nd Workshop on Social-Ecological systems Governance for Sustainability (SESGOS2019) – as a part of science-policy interaction project activity organized by Sustainable Development Institute for Western Region of Mongolia (SDIWOM) along with many partners. The aim of the workshop is to bring together leading academic scientists, researchers, research scholars, decision-makers, practitioners, policy formulators and local communities to exchange and share their experiences and research results on the all aspects of Social-Ecological Systems and its Governance in central Asia as well as in Asian-Pacific region. It provided invaluable information where the representatives of different countries will share their knowledge and experiences in environmental and social science at multi-scale levels.

DATE & VENUE

The workshop was held at Conference hall (3rd floor, Soyliin tuv orgoo building) of Mongolian Academy of Sciences, head office, Ulaanbaatar, Mongolia on 23 August 2019. It takes about 6 minutes on foot from the UB Grand hotel.



An excursion to Hustai National Park on 24 August 2019 (82 km from Ulaanbaatar)

Under the support of APN, we successfully organized the ***2nd* workshop on social-ecological systems governance for sustainability** on 23-24 August 2019 in Ulaanbaatar, Mongolia bringing leading academic scientists, researchers, research scholars, decision-makers, practitioners, policy formulators and local communities who collaborated on this project to exchange and share their experiences and research results on the all aspects of Social-Ecological Systems and its Governance in studied areas as well as in the Asian-Pacific region. This workshop was hosted by the Sustainable development institute for the western region of Mongolia, with Mongolian Academy of Sciences. In the workshop, a total of 32 people (11 experts, 7 young researchers, 8 local government officers, 3 herders and 3 local staffs) participated from 3 countries and 9 institutions.

The aim of the workshop was to discuss the results of the research and outcomes of the project activities and identify the policy recommendations with adaptation options in the selected research areas.

Results of academic studies of pastoral vulnerability, socio-economic impacts, and the policy document review, as well as land degradation processes and the adaptation experiences of Chinese and Japanese team members, were presented in the morning and half of afternoon sessions on the first day of the workshop. Based on the research outputs and experiences of local participants, ways to resolve issues were discussed, and suitable adaptation options were identified during the group discussion sessions from local participants. This session was fruitful as academicians and local communities get to discuss the results and exchange opinions. Proceedings of the workshop can be found in Attachment 2.


THE 2nd WORKSHOP ON SOCIAL-ECOLOGICAL
SYSTEMS GOVERNANCE FOR SUSTAINABILITY
23-24 August 2019,


ЭРДЭМ

On the second day of the workshop, participants were brought to Hustai national park (HNP) for a site visit. HNP is one of the national protected areas with best conservation and ecosystem management practices which includes local communities. Participants were exposed to knowledge about management, local communities collaboration, local livelihood support, protection of environment and contribution to local sustainability, as well as reducing both ecological and socio-economic vulnerabilities.

DETAILED PROGRAM

22 August 2019 (Thursday)		
8:30-23:00	**Arrival**	**At UB grand hotel** all delegates arrival **Ulaanbaatar, Mongolia**
23 August 2019 (Friday)		
08:30-09:00	**Registration**	All participants
09:10-09:20	**Opening Remarks**	Acad. B. Avid, Secretary general of Mongolian Academy of Sciences Dr. Altanbagana Myagmarsuren, head of socio-economic geography division, Institute of Geography and Geoecology, MAS
SESSION 1: INTRODUCTION and KEYNOTE SPEECH **MODERATOR** – **Dr. Altanbagana Myagmarsuren , Institute of of Geography and Geoecology, MAS**		
09:20-10:30	**Project introduction**	Dr. B.Suvdantsetseg, sustainable development institute for western region of Mongolia. **“Ecological Vulnerability Assessment for Adaptation Strategy Formulation at Different Spatial Scales in Western Mongolia and China”**
	Keynote speaker	Prof. Okuro Toshiya, Graduate School of Agricultural and Life Sciences, University of Tokyo **“Restoration and reconstruction of sustainable land management systems under highly variable environments”**
	Invited speaker	Prof. Xueyong Zhao, Northwest Institute of Eco-environment and Resources, CAS **“Toward sustainable desertification reversion and development in Horqin Sandy Land, Inner-Mongolia, China”**
10:30-10:45	Group photo and Coffee break	
SESSION 2: SOCIO-ECOLOGICAL SYSTEMS SESSION *This session will share the pasture socio-ecological systems vulnerability assessment related research progress, and key findings for project partners.* **CHAIR:** – Prof. Xueyong Zhao, Northwest Institute of Eco-environment and Resources, CAS		

– **McS Khurel Nominbolor, Institute of Strategic studies**	
Speakers	
10:45-12:30	– Dr. Shaokun Wang, Northwest Institute of Eco-environment and Resources, CAS **“Changes of soil microbial community along vegetation restoration in semi-arid sandy land of northern China”** – McS. Kherlenbayar. B, Sustainable development Institute for western region of Mongolia **“The impact of Pastoral Ecological vulnerability on local socio-economic development at Khovd and Gobi-Altai provinces, Mongolia”** – Mr. Kitaura Yoshio, Green Network, Japan **“Greening experiences”** – Dr. Z.Burmaa, Khovd state University **“Study on rivers and lakes ecosystems in great lakes depression in western Mongolia”** – Dr. Tuvshintogtokh, McS. Manidari, McS. Otgonsukh, Institute of general and Experimental biology, MAS **“Pasture degradation assessment using botanical field survey and map comparison at biger and chandmani soums”**
12:30-13:30	**Lunch**
SESSION 3: SOCIO-ECOLOGICAL GOVERNANCE *This cluster will share the socio-ecological management and governance related research progress, key findings, and concrete activities for collaborative project partners.* **CHAIR:** – Prof. Okuro Toshiya, Graduate School of Agricultural and Life Sciences, University of Tokyo – Dr. Shaokun Wang, Northwest Institute of Eco-environment and Resources, CAS	
Speakers	
13:30-15:10	– Dr. Suvdantsetseg Balt, Sustainable development Institute for western region of Mongolia **“Participatory approach for conceptual development of local sustainable development plan: A case of Khuhmorit soum of Gobi-Altai provinces, Mongolia”** – McS. Nominbolor.Kh, Institute of Strategic studies **“Policy document assessments through SDG criteria in Khovd and Gobi-Altai provinces”** – Dr. Takafumi Miyasaki, Nagoya university **“Collaborative national park management and its effects on neighboring herders’ livelihoods in Mongolia”** – McS. Daginnas Batsukh, Mongolian University of Life Sciences, Mongolia **“Stakeholder engagement strategy for protected areas–a case study of Khustai national park in Mongolia”**
15:10-15:30	**Tea Break**
SESSION 4: LOCAL PARTICIPANTS SESSION *This session will share the pasture degradation, herding management, farming and policy related key findings, local activities and opportunities for collaboration among researchers, local participants and partners.* *Note: Networking development and experiences sharing at pasture adaptation managements will be discussed at this session.* **CHAIR:** – Dr. Balt Suvdantsetseg, Sustainable development Institute for western region of Mongolia – Dr. Takafumi Miyasaka, Nagoya university	
Panelist	
15:30-16:45	– Government officer of food and agriculture department, Gobi-Altai province

	– Local officer and herder of Biger soum, Gobi-Altai province – Local officer of Khuhmorit soum, Gobi-Altai province – Local officer of Chandmani soum, Gobi-Altai province – Local officer of Chandmani soum, Khovd province – Local officer and herder of Zereg soum, Khovd province – Local officer of Darvi soum, Khovd province – Local officer of Durgun soum, Khovd province	
16:45-17:00	**Tea Break**	
17:00-17:45	**Discussion**	Chairs to summarize 4 thematic sessions
17:45-18:00	**Closing Remarks**	Prof. Okuro Toshiya, Graduate School of Agricultural and Life Sciences, University of Tokyo Prof. Xueyong Zhao, Northwest Institute of Eco-environment and Resources, CAS Dr. Balt Suvdantsetseg, Organizing Committee chair, Sustainable development institute for western region of Mongolia
18:30	**Welcome Dinner**	
24 August 2019	**(Saturday)**	
08:30-12:30	Field Visit	
12:30-13:30	Lunch	
13:30-17:00	Field Visit	

LIST OF PARTICIPANTS

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