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Impacts of Climate Change on Livestock-grassland Systems in Mongolian Plateau and Development of Information Tools for Early Adaptation

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Abstract

Climate change, including seasonal weather extremes, annual climate variations, and long-term global warming, is seriously affecting ecological environment and human society, particularly in semi-arid areas. Mongolian Plateau had repeatedly experienced massive livestock-loss in recent decades, which have been considered as climate impacts of drought, and freezing or snowstorm. Such losses are spatiotemporally heterogeneous even though the spatial distribution of weather conditions changes gradually. Previous studies clarified that this spatiotemporally heterogeneous severity of livestock loss in Inner Mongolia was caused by the difference of the severity of land degradation, which directly affects insufficiencies of forage for grazed livestock. However, the cause of the spatiotemporally heterogeneous severity of land degradation itself is still unclear. Meanwhile, serious livestock loss in Mongolia, which is called as dzud, had been also primarily considered climate-driven, due to severe winter condition after the summer drought in particular. However, the cause of the spatiotemporally heterogeneous severity of a dzud is also not clarified yet. The purpose of this study is to clarify the cause of spatiotemporal difference of the severity of livestock loss in Mongolian Plateau through the analysis of land degradation in Inner Mongolia and dzud in Mongolia.

Although substantial studies examined the factors contributing to livestock loss so that climate-extremes and overgrazing were noted as the common factors in both cases of Inner Mongolia and Mongolia. However, the limit of data quality and data availability made its investigation difficult. The spatial characteristics of the variables in these two regions are essential at multiple spatial scales. This study applied GLEWS (Global Livestock Early Warning System) data to correct forage and meteorological data in Mongolia, and Palmer Drought Severity Index (PDSI) index to show the severity of drought in Inner Mongolia. Landscape Ecological Zoning (LEZ) approach was applied at fine scale for the assessment of forage availability in Inner Mongolia, and Geographically Weighted Regression (GWR) modelling at the county scale in major dzud areas of Mongolia. The results of this study concluded that the severity of droughts had little contribution to the spatiotemporally heterogeneous severity of land degradation in Inner Mongolia, at the same time, severe weather conditions were not a main contribution factor to the spatiotemporally heterogeneous severity of dzuds in Mongolia. In particular, the degree of contribution on factors with regards to the severity of dzud was not spatially nor temporally uniform, and also that they could be categorized within some regions. This study concludes the spatiotemporal patterns of the severity of livestock loss in Mongolian Plateau were primarily caused by an overgrazing-driven social factors.

As a practical solution, this study developed information tools for mitigation of land degradation and adaptation to dzuds by demand-driven and science-informed approach. The Web-based GIS tool for NPO's rangeland management in Inner Mongolia and SMS communication tools, which had provided weather forecast and forage distribution and shared users' comments, were tested in the specific study areas. Visualized information from the developed system realized rangeland-management planning by corporation with local governments and companies' CSR activities in Inner Mongolia, in addition, SMS based information successfully supported the decision for traditional seasonal migration of local herders and their fodder preparation sites. In both cases, local partnerships such as NPO and national institute realized demand-driven and science-informed approach. Not only the system development, but also the analytical method on this study might be applicable not only for whole Mongolian Plateau but also other countries where overgrazing contributed severe livestock loss on grassland.

Keywords: Weather Extremes, Overgrazing, Massive Livestock Loss, Demand-driven and Science Informed Approach, Mongolian Plateau

主　論　文　要　旨　　No.1

報告番号	甲　乙　第　　　　　号	氏　名	大場　章弘

主 論 文 題 目 ：
モンゴル高原における気候変動による家畜生態システムへの影響と早期適応情報ツールの開発

（内容の要旨）

本研究はモンゴル高原（中国内モンゴル自治区とモンゴル国を含む）を対象に、複数の時空間スケールでの空間統計分析を行い、家畜の大量死の原因とその時空間的異質性を解明し、気候変動適応で提唱されているデマンドドリブン(demand-driven)/エビデンスベース（science-informed）のアプローチを具現化して情報ツールによる災害の早期適応支援システムを構築することを目的としたものである。

気候変動は季節的異常気象、年次的気候変化、長期的地球温暖化を伴い、生態環境と人間社会に深刻な影響を与えている。中国内モンゴルとモンゴルで構成されるモンゴル高原では、近年、干ばつや寒冷などの異常気象が頻発し、家畜が大量に死亡する災害が報告されている。これは異常気象、気候変化および人間活動の影響として研究されているが、時空間スケールの違いやデータの制約のため、その被害の実態とメカニズムは解明されていない。また科学研究の知見を現場に導入されることが少なく、災害リスク回避を支援する有効な方策はなかった。

本研究では、内モンゴルでは全球レベル干ばつ指数である Palmer Drought Severity Index (PDSI)による市レベルの分析と、村落レベルの景観生態区分によって土地劣化の原因の分析を行った。モンゴルにおいては国際的牧草・気象データベースである GLEWS (Global Livestock Early Warning System)を用いて郡レベルの地理的加重回帰モデルである GWR（Geographic Weighted Regression）を構築して家畜の大量死の原因を分析した。その結果、モンゴル高原における家畜の大量死は時空間的異質性が顕著であり、その原因として慢性的な過放牧が強く影響することを定量的に明らかにした。それに対応するためには牧草配布や植林費用の援助など一時的な施策ではなく、現場において習慣的に過放牧を防ぐ早期適応策が必要であることを確認した。

この科学知見を踏まえて、住民による早期適応を支援するために、本研究では情報支援ツールを開発し、現地組織との協力によって社会実装を行った。内モンゴルでは WebGIS ベースの植林管理ツールを開発し、NPO・行政が土地利用を計画し、植林経過や成果を住民および寄付者である企業へ報告できる仕組みを構築した。モンゴルでは国の研究機関と現地政府、通信業者による協力体制の下、気象予報・牧草分布の情報を SMS

ベースのツールを開発し、定期的に遊牧民の携帯電話に配信した。それにより、実際に遊牧ルート変更、牧草の越冬準備といった行動変化が多く報告され、本研究の有効性を実証した。

キーワード：異常気象、過放牧、家畜大量死、デマンドドリブン/エビデンスベースアプローチ、モンゴル高原

Contents

1. Introduction

Transformation of livestock-grassland systems in Mongolian Plateau has been dramatically changed in recent years, in particular, since 1990s. This dynamics are attributed by economic development, which has been dramatically growing in Mongolian Plateau. The growth of real per capita GDP in Inner Mongolia is the fastest in all the regions of China, which was 24 times from 1979 to 2009 (Lee, 2014). In Mongolia, the data provided by the National Statistical Office of Mongolia showed that it grew over 700 times from 1991 to 2014. Livestock production is one of the most important sectors on GDP in the areas of Mongolian Plateau; therefore the number of livestock animals has also been dramatically increasing by following economic development. Livestock population becomes over twice from 1991 to 2010 in Inner Mongolia (Briske et al., 2015) and from 1991 to 2014 in Mongolia. Although Mongolian Plateau had such high increase in the dynamics of livestock population, the level of the grassland-grows has not adapted. Grazing pressure on the grassland has been reported to be high in both Inner Mongolia and Mongolia. Its intensity in Inner Mongolia increased 62% from 1963 to 2000 (Pei et al., 2008), however current condition is still high in communal grazing land (Wu et al., 2013). At the same time, Mongolian grazing pressure was generally higher from 2000 to 2014, in particular, in the central and western aimags [Mongolian prefecture] (Gao et al., 2015). Those high grazing pressure have been reported that they have affected land degradation in Inner Mongolia and dzud in Mongolia. Common factors with intensive pressure on the pastureland in Mongolian Plateau also have the number of goat and sheep. **Fig.1-1** and **Fig.1-2** showed the dynamics of the each livestock population from 1991 to 2014 in Mongolia and 2000 to 2008 in Inner Mongolia, which said the high composition and increase of the small animals: goat and sheep. Goat and sheep are harmful to the environment because they disturb the pasture's regenerative capacities by feeding on roots and flowers; consequently, the shift to goat keeping is putting increasing pressure on the pasturelands in Mongolia, threatening to accelerate pasture degradation and processes of desertification (Wei & Ling, 2012; Dorj et al., 2013). Background of this biased composition of livestock has the ease of grows and by-productive values on markets (Meserve, 2001) such as foods and cashmere/wool for winter cold weather. High intensity of such small stocks was concerned more land degradation in Mongolian Plateau.

Land degradation in Inner Mongolia has seriously affected ecosystems on grassland such as decreases of nutrients, plant species, and building desertification (Qian et al., 2014), which resulted severe livestock loss (Li & Huntsinger 2011; Liu & Wang, 2012; further reading in Derry, 2009) in **Fig.1-2**. Current land degradation in China was reported that it has been mainly caused by its intensive agriculture-stock production, in which overgrazing on the steppe is one of the most serious driving factors for grassland degradation (Zhang et al., 2007a, 2007b; Qian et al., 2014). Subjected to a considerable population pressure with overgrazing, grasslands are much

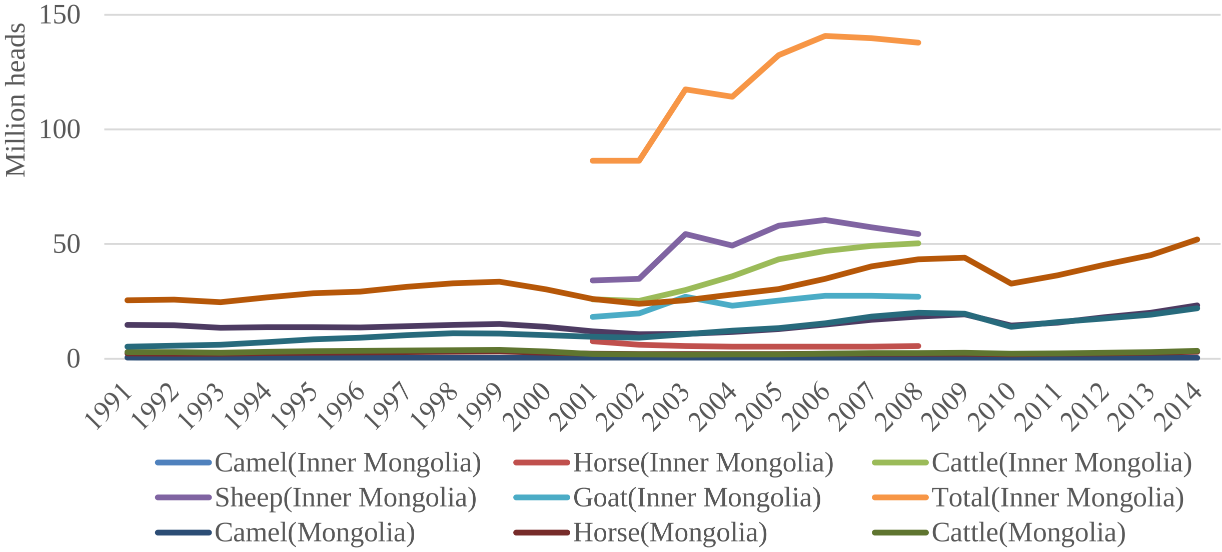


Fig.1-1 Livestock population from 1991 to 2014 in Mongolia and from 2001 to 2008 in Inner Mongolia. The livestock numbers are from the National Statistical Office (NSO) of Mongolia and the China Animal Industry yearbook.

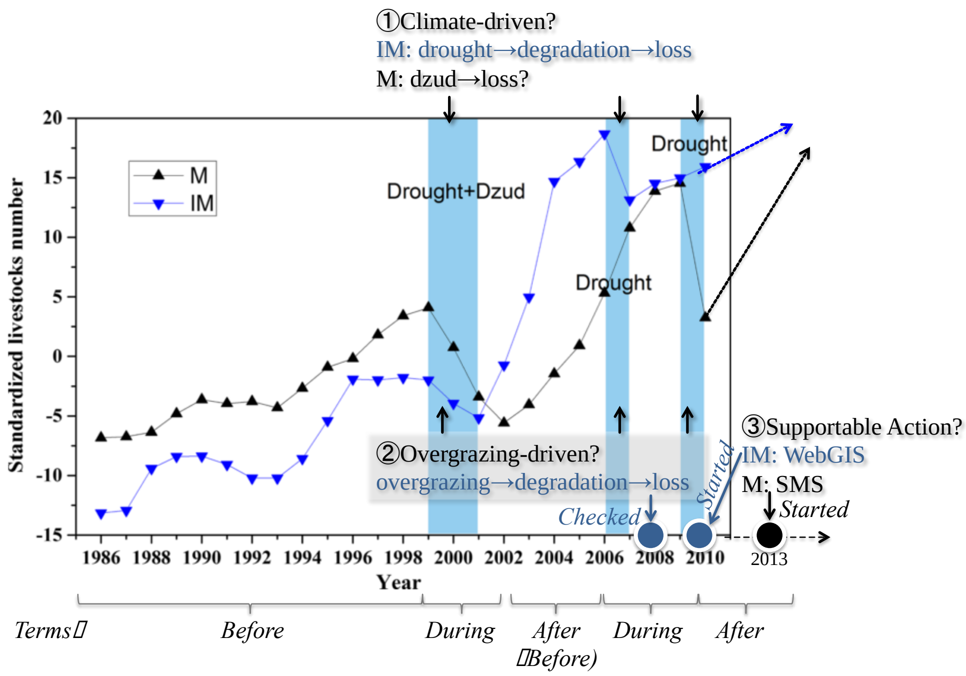


Fig.1-2 Standardized livestock numbers and extreme events (popular terms are colored blue), which mainly reported, in IM (Inner Mongolia) and M (Mongolia), with the focuses of this study. The livestock numbers are from the National Statistical Office (NSO) of Mongolia and the China Animal Industry yearbook. The category of animals constitutes substantial animals (camels, horses, and cattle), sheep, and goats that rely on grasslands for grazing. The graph and the notes were quoted from Miao et al. (2015).

susceptible to land degradation (Qian et al., 2014). At the same time, frequent drought was also pointed out as one of the important factors of land degradation (Briske et al., 2015). Monitoring of droughts in Inner Mongolia from 1960 to 2012 (Huang et al., 2015), notable frequent droughts after 2000 were reported. More stress on future drought from 2020 to 2040 was concerned in the projections (Zhang et al., 2013). Those frequent droughts, persistent winds and exposed land surfaces which favor the formation of deserts, irrational land use and over exploitation has been concerned as obvious causes of land degradation (Zhang et al., 2007). Inner Mongolia is located in the marginal zone of East Asian monsoon climate and continental climate by extraordinarily complex topography of a narrow strip of land sloping, which is the vulnerable location to the drought with dominating by slow drying tendencies in those years (Huang et al., 2015). Therefore, even though the temporal and spatial distribution of the severity of drought changes gradually, the severity of the land degradation is spatiotemporally heterogeneous. (Details are discussed with **Fig.4-2**, **Fig.4-3**).

At the same time, such frequent droughts after 2000 also affected Mongolian rangeland, and future droughts are also concerned as a prediction (Tachiiri & Shinoda, 2012). Mongolia, a nomadic country with expansive land area, even directly suffers from this serious loss known as dzuds. Some dzuds were reported with severe climate events such as the case of freezing or snowy winter after summer drought. Four types of dzuds are conventionally recognised according to weather and pastureland conditions: 'white dzud', unusually abundant snowfall and accumulation; 'ice dzud', impenetrable ice layers covering pastureland; 'black dzud', an extremely cold winter without sufficient fodder following a summer with a drought; and 'hoof dzud' resulting from the trampling of pastures (Siurua & Swift, 2002). Recent dzuds occurred in the country sequentially during the winters of 1999-2002 and 2009-2010. In the winters of 1999-2002, the air temperature was colder by 2-7°C, and the snow accumulation was greater than 15-20 cm following a drought in the previous summer (Altanbagana et al., 2010). Dzuds in 1999-2002 resulted in the loss of ten to twelve million livestock, approximately 30% of the national herd, and affected more than one hundred thousand families (Sternberg, 2010). The dzud in 2009-2010 was also reported to involve severe weather conditions, with temperatures below -40°C in nineteen of the twenty-one aimags and a heavy snow coverage of 20-200 cm, causing the deaths of 1.7 million livestock by February, 3 million by March and 6 million by April (Sternberg, 2010).

On the other hand, those climate severities such as the drought and severe winter conditions were pointed out that had not exactly affected the severity of land degradation and a dzud in Mongolian Plateau, in the reviews of previous studies and data (Miao et al., 2015). Climate extremes often occur over a very short and unexpected period; however, these extreme events can affect a relatively large area (Rao et al., 2015). Actually, citizens' decisions to contingent manage with a complex web of natural, economic, structural, and cognitive factors exposed their livestock system (Keshavarz & Karami, 2014; Miao et al., 2015). A previous study focused on such citizens' social differences in the soums at an aimag to explain the spatiotemporal differences of the severity of the dzud, whose result could point out some important social factors such as the difference of their practices: forage management or migration for instance

(Middleton et al., 2015). Therefore, whether the spatiotemporally heterogeneous severity of livestock losses in Mongolian Plateau was caused by climate-driven factors or not was quantitatively not clarified so far, which is challengeable topic. Lack of not only accurate and fine-scale but also multiple data sources of climate and social data are necessary for approaching to study this unclear topic (Miao et al., 2015). Therefore, adaption measures with only focusing on weather simulation and forecasts will not work effectively for households or local groups (Easterling et al. 2000; Miao et al., 2015). Thus, traditional adaption measures by the household or local groups need to be coordinated with a disaster relief campaign offered by the government or relevant organizations; advance preparations to increase adaptation capacity are extremely important (Miao et al., 2015).

Such adaptation issue, related information is also important to inform mitigation decision-making, with benefits for long-term planning as well as for the operational level (Lourenço et al., 2015). Providing climate information in a way that assists decision-making by individuals and organizations, whose services require appropriate engagement along with an effective access mechanism, must respond to user needs (Hewitt et al., 2012; WMO,2014; Lourenço et al., 2015). Although the previous information approaches on adaptation were based on so-called science-driven and science-informed or science-driven and user-informed method, information services need to shift to demand-driven and science-informed practices because adaptations are interlinked with longer-term factors on lifeworks and resilience to extreme events (Lourenço et al., 2015). Therefore, whole design from information providing to adaptation process is ongoing issue. It identifies a set of priority areas and sectors, but does not define which decision-making processes need what information, or why they need it. Rather the focus is on what information is available and the format in which it can be delivered (Lourenço et al., 2015). Currently, some information environments such as laptops or mobile phones with Internet are spreading to local areas of grasslands in Mongolian Plateau, which is available to provided information that previously couldn’t reach to people who lived there. Therefore, if the designs are constructed well by demand-driven science-informed approach, supporting adaptation becomes possible through information providing.

Consequently, the purpose of this study is to clarify the cause of the spatiotemporally heterogeneous severity of the livestock losses in Mongolian Plateau through focusing on land degradation and a dzud, and to develop advanced preparation tools for early adaptation.

2. Spatiotemporally heterogeneous severity of land degradation and a dzud in Mongolian Plateau

2.1 Land degradation in Inner Mongolia

In theoretically, Charney (1975) and Charney et al. (1975, 1977) suggested that the drought and dynamics of deserts, the result of land degradation mentioned above, be controlled by a biogeophysical feedback mechanism; deforestation and resulting hydrological changes of land surface affect regional and even global climates (Shukla and Mintz, 1982; Shukla et al., 1990; Nobre et al., 1991; Wright et al., 1992; Li et al., 2000). Desertification is the process of deterioration in ecosystems of arid and semi-arid areas resulting from interplays of climatic variations and human activities, which bring the spatiotemporally heterogeneous severity of desertification (Dregne, 1985; UNEP, 1992; Li et al., 2000). Both natural and anthropogenic factors caused them, however primary, anthropogenic factors exponentially expanded desertification in a short period (UNEP, 1992; Li et al., 2000).

Similarly in case of Inner Mongolia, previous studies also suggested that such anthropogenic factors might cause the spatiotemporally heterogeneous severity of land degradation. The Horqin Sandy Land, located in the eastern part of Inner Mongolia of China that had the worst land degradation and resulted enormous desertification (Zhao *et al*., 2005), had been formed the deserts and its expansion with significantly high-correlation of the crop and livestock farming at the village level, and in particular, the effect of livestock farming (Miyasaka & Yan, 2007). The villages of this Horqin Sandy Land have administrative districts, and grazing is limited to their grasslands. The farmers stock goats and cattle in these rangelands, but the incentive to increase household income by increasing the number of livestock allows little area for rotating grasslands and achieving appropriate grazing capacity. This vicious cycle is the most primary cause of continuous land degradation and desertification in Inner Mongolia. Thus, such overgrazing, a social factor, has been considered as the primary contributor to grassland degradation and desertification, similarly, the difference of overgrazing condition resulted the spatiotemporally heterogeneous severity of grassland degradation and desertification in Inner Mongolia (Wu et al., 2014).

At the same time, drought has been also focused as the important factor for the land degradation in Inner Mongolia. The continental climate of Inner Mongolia supports a short growing season of the plants that extends from June through September (120 frost-free days), the majority of annual rainfall occurs during the summer, however, summer droughts decrease the rainfall and the growth of plants (Briske et al., 2015). The summer drought and extreme winter temperatures (-40C) frequently contribute to livestock mortality (Kemp et al., 2011, 2013; Briske et al., 2015). Although Supplemental livestock feeding is a common and necessary practice in Inner Mongolia that enables animals to survive long, severe winters and reoccurring summer drought, excessive animal numbers that graze grasslands throughout the year have exacerbated this dependence on supplemental feeding to the extent that it has become a major contributor to the severity of grassland degradation (Briske et al., 2015). Thus, droughts in Inner Mongolia might contribute the degradation on whole grasslands, not only the rangeland grasses but also forages for feedings in the fences in villages.

2.2 Dzud in Mongolia

Comparing the term 'dzud' used in the academic community with the term used in Mongolian daily life, the definition of the term is obscure, and the cause and effect of the events are unknown. Dzud conventionally signifies harsh winter conditions and the resulting massive livestock loss (Tachiiri & Shinoda, 2012). However, this term is sometimes used as an indicator of the weather conditions (Tachiiri et al., 2008; Altanbagana et al., 2010; Hilker et al., 2014). Conventionally, dzud is a collective judgment on the past winter or a personal feeling of a herder regarding his/her livelihood. This feeling can be a combined reflection of the experience and knowledge of the herders and the results of social supports.

As you can see above, a dzud is a complicated physical and social phenomenon (Miao et al., 2015). The process of a dzud begins with exhaustion and wasting among livestock and leads to death (Murphy, 2011). **Fig.2-1** illustrates the timeline of the severity of a dzud and the major drivers of a dzud. This figure shows that a dzud typically starts at the beginning of November and concludes at the end of March in the following year. This process may continue for weeks, months, and in some cases, years.

Sequential dzuds might produce more severe damage. Similar livestock mortality in a different dzud year may not result from identical causes. Already weakened animals are more susceptible to adverse conditions, and subsequent cold weather may cause more severe losses. Extreme weather may simply overwhelm an already fragile livestock population (Tachiiri et al., 2008). Statistically, the loss of livestock documented is a measure of the total loss of livestock at the end of a winter season. The aggregated data of deaths may not directly correspond to the daily weather observations.

Moreover, the severity of a dzud may differ geographically across the country from an aimag to a soum (county). One soum might experience white and hoofed dzuds, whereas another soum in the identical aimag might suffer from a black dzud (Fernandez-Gimenez ta al., 2012a). This variation may be indirectly induced by natural changes in the vegetation, soil moisture (Shinoda & Morinaga, 2008), or water resources (Batima et al., 2008) or changes in the social condition of the livelihood, pasturing practice and traditional knowledge of the herders (Fernandez-Gimenez ta al., 2011, 2012b, 2015).

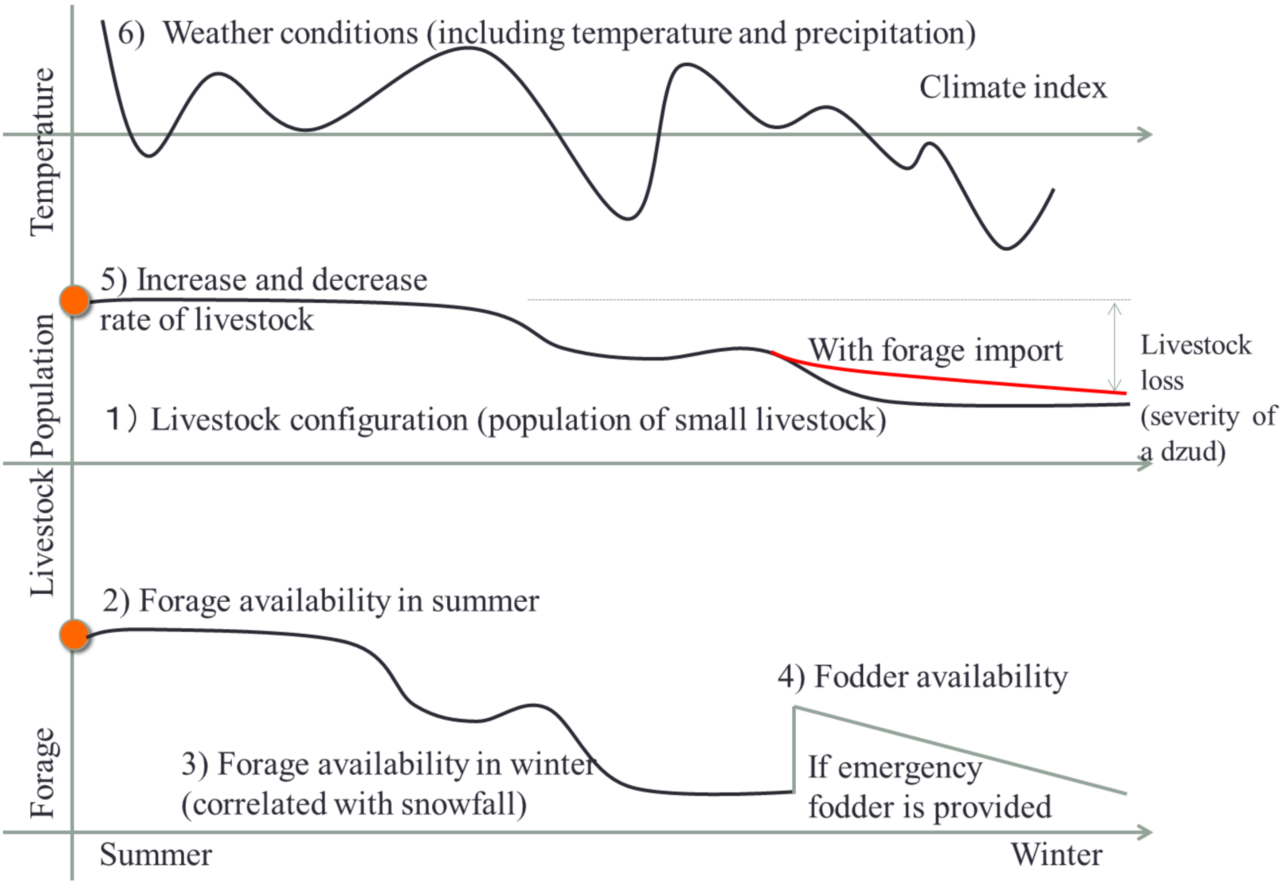


Fig.2-1 Dzud as a complex process. X-axis shows the timeline from summer to winter season. Y-axis respectively shows forage, livestock population, and temperature.

2.3 Previous approaches

1) Previous analysis and early adaptation on land degradation in Inner Mongolia

1-1) Analysis on land degradation in Inner Mongolia

In previous analysis on the relationship between the severity of drought and land degradation / desertification, there were basically two types of the approaches: focusing on broad scale with use of satellite and statistical data (e.g. Li et al., 2010; Do & Kang, 2014; Tian et al., 2015) or village scale with temporal plant / soil survey data (e.g. Li et al., 2001; "Pei et al., 2008; Wu et al., 2014). Satellite and statistical data is useful for focusing on climate condition, and surveying on the ground is also useful on considering social condition such as stocking rate in village scale.

In case of broad scale analysis, estimation of the severity of droughts in Inner Mongolia was presented by various data, statistical data (Li et al., 2010; Tian et al., 2015), drought stress / vulnerability index through MODIS satellite imagery data (Do & Kang, 2014). Statistical data in China is difficult to access, the drought stress / vulnerability index seems to be useful, however this index did not directly show the severity of drought. Emergency Events Database (EM-DAT; http://www.emdat.be/database) is also spreading of the use cases (Lesk et al., 2016) and has a possibility to solve this problem, however the database does not have the data of Inner Mongolia. At the same time, previous researches has also used Terra/MODIS satellite image for estimation of the severity of land degradation / desertification by calculation of vegetation degradation through the difference of estimated NDVI (Normalized Difference Vegetation Index) (e.g. Do & Kang, 2014; Tian et al., 2015). However, for analyzing the relationship between the severity of drought and overgrazing in Inner Mongolia, getting the dataset about livestock is still hard so far. In particular, fine-scale statistical data about livestock in Inner Mongolia is hard to correct. Currently, previous data is now gradually getting open on the Internet. Although it is still limited, city scale data of each livestock population from 2001-2008 becomes now available in All China Data Center (ACMR; http://chinadataonline.org/), which could be possible to access more data in the future.

Therefore, overgrazing has been analyzing in small scale in Inner Mongolia. The assessment of the village-scale land-productivity with the survey of land resources is essential (Yan, 2008) in such analysis. Land productivity of grasslands can be assumed as the productivity of pasture that livestock prefers. In grasslands, plants are unevenly distributed depending on topography and moisture condition. Further, the spatial distribution of pastures affects human land use. For this reason, most research on pasture productivity assessment in arid or semi-arid lands including Inner Mongolia has used satellite imagery to examine actual conditions and influential factors on the spatial distribution of pasture. For examples, Akiyama *et al.* (1985) used Landsat/MSS and a multivariate regression model to estimate pasture productivity, and Ikeda *et al.* (2001) employed IKONOS multispectral imaging and a simple linear regression model by using NDVI. These studies used satellite imagery resolution, namely image cell as an evaluation unit, but could not assess administrative conditions such as land use improvement in mind.

Evaluation of pasture productivity in a region in consideration with the spatial heterogeneity of grasslands means examination of the relationship between species composition of pasture and natural factors (Japanese Society of Grassland Science, 2004). For this reason, such natural factors of topography and soil, and anthropogenic factors corresponding to the organism distribution data should be captured in patches. This is the approach named Landscape Ecological Zoning (LEZ) (Forman & Godron, 1986; Zonneveld, 1995; Turner et al., 2001), which is widely used for arid and semi-arid land studies. LEZ approach uses surface data from satellite imagery to create patches, in other words, evaluation zones, which is important to carefully consider three factors: selection of the study area, evaluation zones that are practical operation units, and resolution of the data (a minimum cell size).

As an example of pasture productivity assessment using such zones based on LEZ approach, Shiomi *et al.* (1991) showed an actual case for assessing forage biomass by zoning forage biomass. Xiangming *et al*. (1996) evaluated annual maximum pasture productivity from 1981 to 1990 by dominant plant communities, and analyzed their relationships by zoning the precipitation, temperature and soil conditions in Tumugi, Xingan League, in Inner Mongolia. Bin *et al*. (2004) calculated grassland productivity in 1 km mesh units for the whole Inner Mongolia, China, using NOAA-AVHRR satellite sensing data; grassland productivity was assessed by zoning of the grassland type, climate condition, and grazing zones categorized into 5 degrees of the severity of overgrazing. Above 3 studies were conducted in the large scale where the evaluation zones or the minimum cells ranging from 1 km mesh units to plant communities, in which consideration for the application to the land use improvement is unlikely. It is essential to draw LEZ that reflect the actual state of overgrazing in the range of village, which is a landowner, and evaluate pasture productivity adapted for characteristics of each zone for implementation of appropriate use of grazed pasture. Although this concept basically applies to the focusing areas for each study, no examples conducted in Inner Mongolia.

1-2) Early adaptation to land degradation in Inner Mongolia

As the early adaptation, afforestation is a countermeasure against the desertification where plants are difficult to grow due to land degradation. This approach is conducted by planting trees and building fences around the afforestation area to prevent intrusion of livestock and human, in order to keep the environment where plants can grow. Afforestation of a desertification area has been carried out in variety scales from local government policy to regional activities by NPO (non-profit organization). In afforestation, activities such as implementation of plans for planting and the management of afforested areas are important, but its process and the condition should be transparency in fund management. Especially, since NPOs enable to implement their activities by donations from companies and individuals, they have an obligation to report donators on the use of funds and afforestation progress. For the report, geographical information such as places where planting is operated, plant growth conditions and circumstances of local residents. In addition, such afforestation activities often involve NPO from developed countries, and that information is thus exchanged across borders.

However, NPOs often leave lack of efficient approach and poor management of information due to limited technical expertise and finances. Although measures of afforestation have been taken at the initiative of the northern part of China (Zhao *et al*., 2010) mentioned above, its management is still required for controlling land degradation / desertification (Liu *et al.*, 2013).

2) Previous analysis and adaptation on dzud in Mongolia

2-1) Analysis on dzud in Mongolia

Although dzuds have been widely studied by quantitative analyses (Tachiiri et al., 2008; Altanbagana et al., 2010) and qualitative research (Sternberg, 2010; UNDP & NEMA, 2015; Fernandez-Giemez et al., 2011, 2012a 2012b, 2015; Murphy, 2011; Shinoda & Morinaga, 2005; Batima et al., 2008), no clear evidence supports a strong correlation between the loss of livestock and the weather conditions.

Regarding the quantitative analyses, a tree regression analysis at the aimag level was conducted using satellite imagery data on the dzuds of 1999-2002 (Tachiiri et al., 2008). The authors concluded that serious livestock mortality was associated with poor vegetation in August of the previous year and the substantial snow accumulation in December of the previous year. The authors confirmed a positive relationship between the number of livestock and the deaths of livestock (a R^2 of 0.46). In qualitative research, the inter-related natural and human processes and the implications for pastoralism were examined through the analysis of the dzud in 2009-2010 (Sternberg, 2010). This type of study was normally conducted for a specific site, and the identified findings noted that the changing climate, herding practices and weak governance (Sternberg, 2010) are significant locally. However, these conclusions may not be general at a regional scale. Those previous researches were summarized in a review article (Miao et al., 2015), which concluded that dzud is a social-natural phenomena in previous studies, and has the problem in lack of data not only its category but also its accuracies for future study on dzud mechanism.

2-2) Early adaptation to dzud in Mongolia

Universities, scientific institutions, broadcasting medias, governments, nomadic herders have considered preparation to reduce the damage on dzud. Scientific institutions and broadcasting medias are providing weather forecast on the radio/TV and newspaper. Governments have provided emergency fodders with corporations of international organizations such as Asia Development Bank (ADB) or the Red Cross (Fernandez-Gimenez et al, 2011, 2015). After the serious dzud in 1999-2002, governments set up National Emergency Management Agency (NEMA) under the Cabinet Office of Mongolia, which has established a policy to organize an evacuation guidance system in case of some types of disasters（Sternberg, 2010）. For the case of dzud, NEMA is building an information system to announce current conditions of emergency fodders on TV/radio. So far, they have never provided this information to nomadic herders.

Therefore nomadic herders have taken preparations such as “winter preparedness” which is consisted of stores of pastures before winter, moves to winter camp area (Otor), or culling unprofuctive animals in fall, and “management innovation” which is consisted of purchasing breeding livestock, intentionally change species composition of herd, fencing/planting fodder or grass, using irrigation, digging a new well, taking action to reduce soil erosion, increasing capacity building through environmental monitoring (Fernandez-Gimenez et al, 2015). Two multiple regressions models were calculated by each of the number of answers to take actions on winter preparation and management innovation as an explained variable with explanation variable such as social capital, leadership, pro-activeness, knowledge exchange, and information diversity. As the result of regression analysis, both “winter preparation” and “management innovation” were significantly contributed by information diversity and knowledge exchange (the former: R2=0.375, the latter: R2=0.308). However, other factors such as social capital, leadership, pro-activeness were not contributed. Knowledge exchange was contributed to management innovation, but not to winter preparation. Thus, information diversity makes help to support their winter preparation as a strategy on adaptation to dzud.

According to the result of previous study, information diversity is possible to build adaptive capacity, the ability to experiment, innovate, and learn, and to act on new information in response to change and disturbance (Armitage, 2005; Smit & Wandel, 2006; Engle, 2011; Fernanedez-Giemenez et al.,2015) such as dzud. That is, herders may adapt to dzud by early (habitual) preparation through information providing system of NEMA. At the same time, Fernanedez-Giemenez et al. (2015) noted 5 constraints in this strategy on adaptation to dzud: limited human capital （lack of labor, an aging herder population limited their ability, young herders without knowledge of how to pass a dzud）, limited social capital (lack of social networks, which comprised primarily of bonding ties with family and neighbors, with few linking ties to technical experts, government officials, or donor project staff), economic constraints (lack of opportunities for income diversification in rural areas), institutional constraints (poor communication and coordination among different types of organizations and agencies (e.g., donors, NGOs, government) within and across different levels of administration, and environmental constraints (inherent natural endowments of each study soum and changes in the condition or availability of resources). Although specific devices for those constraints are essential part of actual strategies on adaptation, approaches to overcome those constraints are ongoing topics, which should be studied step by step in mind.

Vernooy et al.(2013) tested providing weather forecast to nomadic herders. In their report, weather information providing system has a possibility to get rid of two constraints: human capital and environmental constrains. On the other hand, they descripted problems, lacks of information diversity for overcomes of constraints. Unfortunately, their tests were already finished. As a hypothesis, if we add information not only weather information but also other information, which nomadic herders sought for preparation, it has a possibility to overcome such constraints. However, actual types of information to overcome constraints are not clarified, and whole system from information providing on pilot project to preparation process has not been not designed well. As mentioned above, providing climate information in a way that assists decision-making by individuals and organizations, whose services require appropriate engagement along with an effective access mechanism, must respond to user needs (Hewitt et al., 2012; WMO,2014; Lourenço et al., 2015). Moreover but should be noted again, it identifies a set of priority areas and sectors, but does not define which decision- making processes need what information, or why they need it. Rather the focus is on what information is available and the format in which it can be delivered (Lourenço et al., 2015).

2.4 Approaches of this study

Possible contribution factors to cause spatiotemporally heterogeneous difference of the severity of land degradation in Inner Mongolia and a dzud in Mongolia and the approaches of this study were summarized in **Fig.2-2,** whose details are mentioned below. In summarize of previous studies, although land degradation resulted the spatiotemporally heterogeneous severity of livestock loss in Inner Mongolia, whether climate-driven or overgrazing-driven factors significantly contributed them has not been shown yet. Dzud in Mongolia seems more complex, severe climate has a possibility to directly contribute to livestock loss. Those mechanisms of severe livestock loss in Mongolian Plateau might be divided into such Inner Mongolian and Mongolian cases, therefore, the contribution factors consisted of naturogenic and anthropogenic factors, which can be possible to build quantitative variables by using current available datasets. The hypothesis is those variables in this study would show the relationship between the spatiotemporally heterogeneous severity of livestock loss and anthropogenic factor, in particular, the severity of overgrazing..

To show above hypothesis in case of Inner Mongolia, we approached two analyses: broad scale analysis and village scale analysis, which are followed by previous approaches. First, broad scale analysis would focus on the relationship between drought / overgrazing and land degradation. Previous studies used statistical data and estimated drought stress / vulnerability index, however, the statistical data is difficult to obtain, and both indexes did not directly drought. Currently, Palmer Drought Severity Index (PDSI) (Dai et al., 2004; Dai, 2011a, 2011b, 2013) is now available in the website on University Corporation for Atmospheric Research (UCAR; http://www.cgd.ucar.edu/cas/catalog/climind/pdsi.html), which directly shows the drought estimated by using MODIS satellite in each month; therefore, this study used this data for the drought. In addition, livestock data in each city at Inner Mongolia from 2001 to 2008 is now available at the website of All China Data Center (ACMR; http://chinadataonline.org/), therefore this study used cattle, horse, sheep and goat data as the main livestock in Inner Mongolia (Miao et al., 2015) from downloaded data. Finally, the land degradation is estimated by popular method of NDVI difference by following previous studies mentioned above. Relationship itself was evaluated by the popular statistical method, a correlation analysis whose detail method on this study would be described later.

Second, in village scale analysis, landscape ecological zoning approach is considered as the appropriate method, which mentioned above. The feasibility of this concept is often dependent on the accuracy of the usable spatial data. Some of the previous research had been constrained by the resolution of satellite imagery at that time. Although high-resolution systems such as IKONOS were available, it was not widely applied because of the high expense. The PRISM sensor carried on the ALOS satellite (Daichi), which has operated since 2006, has high resolution of 2.5 m, generates exceptional topography data and also, is available at low cost, so that it may be the solution to the issues mentioned above. For realizing this potential, applying the landscape ecological method to a village scale, the smallest administrative district in China, was considered the most effective. Thus, in this study, we created landscape ecological zones in village boundaries using ALOS/PRISM images, and together with the fieldwork data, assessed pasture productivity so as to present a land use improvement method adapted for characteristics for each zone.

As the early adaptation to land degradation / desertification, afforestation has been conducted in Inner Mongolia for years, as mentioned above. However, the scale of its management is complex. Desert afforestation plants trees in a vast space with high spatial dependence, which enforces NPO its management of many villages at the same time. Further, one village has many fences consisted of different donators and owners managed by farmers and staffs of NPO. Thus, development of a spatial database to organize these complex spatial relations is required. In this study, operated contents on the desert afforestation were first analyzed, the spatial scale of data, data contents, and spatial inclusion relations were clarified to design a hierarchical spatial database. Based on this design plan, we developed a WebGIS application that can be autonomously operated by NPOs. The developed system was tested in the field and the results and future possibilities were evaluated.

For analysis of dzud in Mongolia, livestock loss in dzud has been told that it had occurred during winter season and its damage confirmed in a statistics in the next October (Tachiiri et al., 2008). Factors of the dzud has also been researched in previous researches, which mainly summarized as livestock configuration such as increase of small livestock such as goat and sheep (Sternberg, 2010; Fernandez-Gimenez et al., 2012a), forage availability the summer (Tachiiri et al., 2008), forage availability in the winter (Murphy, 2011; Campbell & Knowles, 2011), fodder availability (Suttie, 2005; Sternberg, 2010) increase and decrease rates of main-livestock (goat, sheep, horse, cattle, camel) population (Mellor & Stafford 2004; Tachiiri et al. 2008), and weather condition such as summer drought and winter snow (Sternberg et al., 2009). In addition, those conditions might differ from geographical locations (Sternberg, 2010; Miao et al., 2015). Although the assessment of those effects in dzuds is a systemic issue, showing the whole mechanism is still challengeable.. This study aims to analyse the causes of the spatiotemporally heterogeneous severity of dzuds in 1999-2002 and 2009-2010 through modelling of the severity of each dzud. The effect of geographical variability is considered by modelling variables of the factors in a geographically weighted regression (GWR) to improve the accuracy of a simple ordinary least squares (OLS) analysis. The model output is expected to be useful for governments when improving the policies covering the conservation of pastureland and sustainable development.

As the early adaptation to dzud, preparation of fodders, seasonal migration including otor (migration in case of emergency for herders), and meat storage are listed in the previous study, at the same time, information providing to local herders could supports those adaptation strategies (Fernandez-Gimenez et al., 2015). Vernooy et al.(2013) tried to provide weather information to local herders through SMS of mobile phone, which could technically confirm that the information reached to the herders. To connect to the actual support of their early adaptation, data demands for each adaptation action and its effects should be evaluated though interview researches to local herders. Including the concepts of demand-driven and science-informed approach mentioned above many times, this study conducted demand researches of the information, and development and its test of the SMS system, and check its effects to herders' actions through the interview. This process is the same in both cases in Inner Mongolia mentioned above and Mongolia.

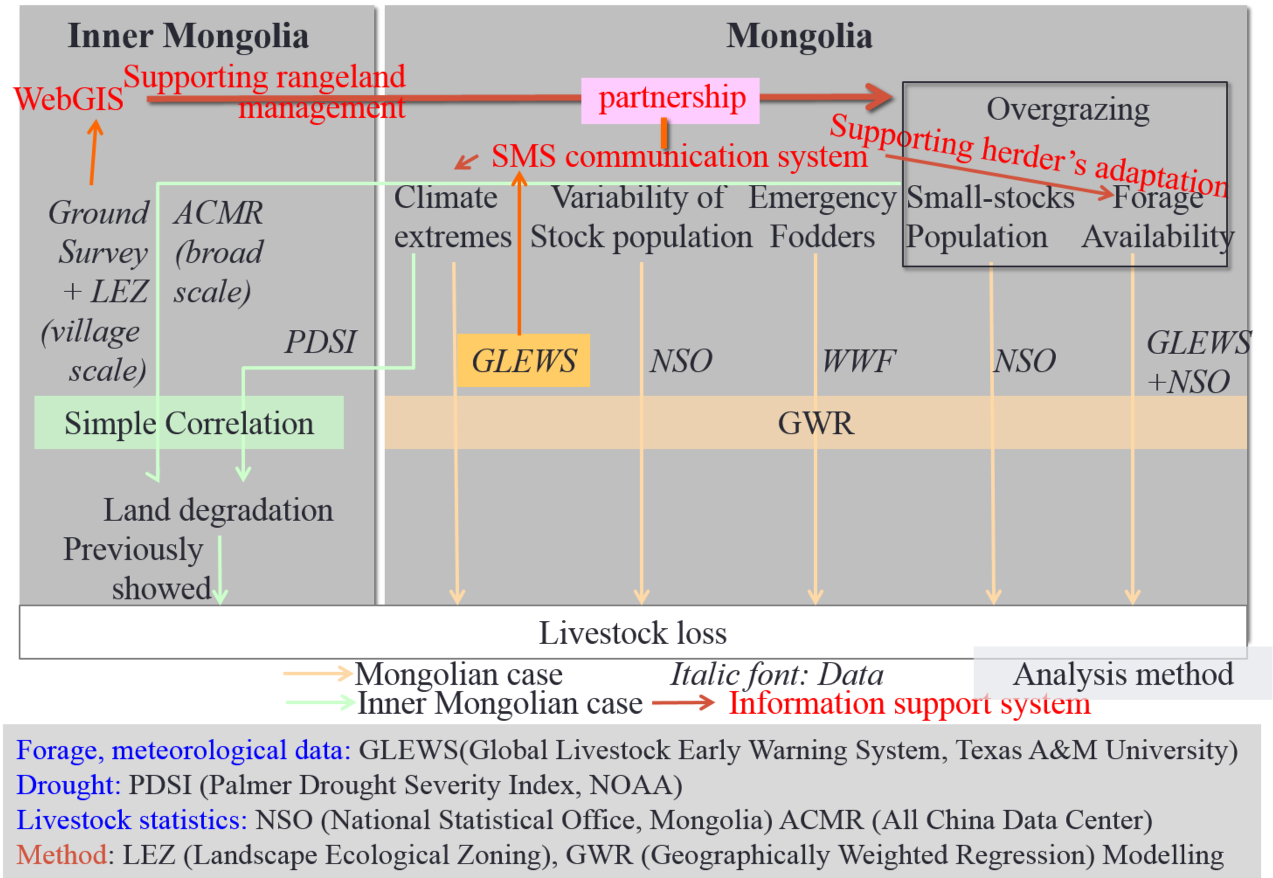


Fig.2-2 Approach of this study. See legend of this figure such as each color of the font or line in the middle part of the figure.

3 Method

3.1 Method for analysis of the relationship between severe climate events and impacts on livestock

3.1.1 Relationship between land degradation and drought / overgrazing

1) Broad scale analysis

In the broad scale analysis, this study conducted the analysis between land degradation and drought / overgrazing through correlation analysis. Explained variable is land degradation shown by annual difference of NDVI, which was calculated by using MODIS image and available in the website of NASA Earth Observations (http://neo.sci.gsfc.nasa.gov/view.php?datasetId=MOD13A2_M_NDVI). Each difference of NDVI was calculated in annual August, a typical summer of Northern Hemisphere, since this month is the highest season of the forage amount in Inner Mongolia. Drought, a explanatory variable, was shown by Palmer Drought Severity Index (PDSI) (Dai et al., 2004; Dai, 2011a, 2011b, 2013), which is available in the website of University Corporation for Atmospheric Research (UCAR; http://www.cgd.ucar.edu/cas/catalog/climind/pdsi.html). Both dataset is cell based data, so this study selected plant land covers from IGBP (International Geosphere Biosphere Programme (IGBP) MODIS Land Cover (http://glcf.umd.edu/data/lc/), which is calculated by University of Maryland, Department of Geography and NASA with MODIS imagery (Channan et al., 2014). Overgrazing, another explanatory variable, was shown by annual difference of livestock population of main stock: cattle, horse, goat, and sheep. Finally, correlation analysis with drought and overgrazing was respectively conducted. Unit of the correlation analysis was conducted in each city from 2001 to 2008 to fit available statistical data of Inner Mongolia. For fitting the data of land degradation and drought to city unit, each cell data was averaged within each city in Inner Mongolia.

2) Village scale analysis

a) Pasture productivity and grazing capacity assessment

Potential Stocking rate can be defined as an index of carrying capacity that allows to keep adequate reproduction in grazed pasture, and can be determined from forage per unit area, namely pasture productivity, and demand for livestock. The amount of pasture consumed per unit area (g/m^2) by livestock is expressed by the following equation (3-1), according to the Japanese Society of Grassland Science (2004).

$$\text{The amount of pasture consumed per unit area } (g/m^2) = \frac{\text{Feed Intake}(g/head/day) \times \text{Grazed Population}(head) \times \text{Grazed Periods}(day)}{\text{Grassland Areas}(m^2)} \tag{3-1}$$

Feed intake is the dry matter weight of plants consumed per livestock per day, grazed population is the number of animals stocked in an area, grassland area is the area covered with pasture, and grazed period is the number of days from when the stocking started in the area to the ended of its date.

The relationship between stocking rate and forage is represented as in **Fig. 3-1** *F*(*t*) is forage per unit area and *t* is calendar month. (A) and (B) represent the case for hayfield and rangeland, respectively, and the difference α is stocking rate. As plants grow, forage thrives to obtain the peak of the weight curve in the summer in the Northern Hemisphere as in **Fig. 3-1**. In rangelands, as plants are grazed while growing, curve (B) can be drawn. In contrast, when livestock do not consume growing plants, as is the case for hayfields, curve (A) can be drawn. For example, if the same area is used under the same conditions for (A) or (B), theoretically, α becomes the stocking rate. Based on this theory, given that α is (b), not considering subsequent regenerating ability, forage (b) will be entirely grazed over the rest of grazing period of the year.

Further, equation (3-1) presumes that grass is highly abundant and cannot be exhaustively grazed. However, this presumption often does not apply to desertification regions and in some area, grass could be exhaustively grazed and the potential stocking rate is most likely to fall to zero. Based on this, the stocking rate, specifically potential stocking rate of the year, can be regarded as the existing forage in the equation (3-1). Similarly, the grazed population can be replaced by the grazing capacity per unit area, that is, the potential stocking rate. Therefore, the equation (3-1) can be modified to the following equation (3-2). Grazed period, however, is the number of grazed days left in the year.

$$\text{Potentical Stocking Rate}(\text{head/m}^2) = \frac{\text{Existing Forage}(\text{g/m}^2)}{\text{Feed Intake}(\text{g/head/day}) \times \text{Grazed Days}(\text{day})} \quad (3\text{-}2)$$

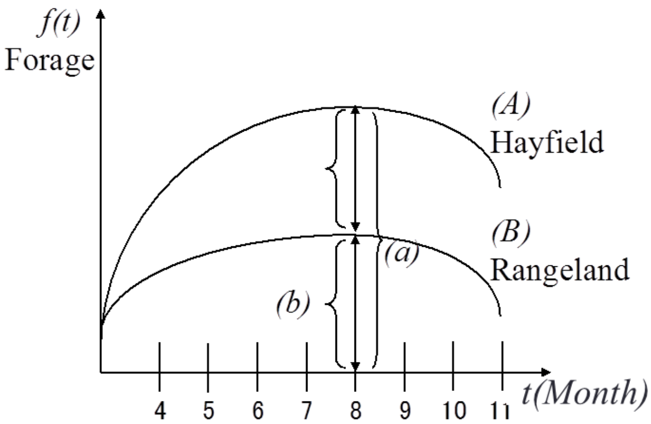


Fig. 3-1 Comparison of the forage between hayfield and rangeland. X-axis shows monthly timeline from April to November. Y-axis shows the amount of forage.

b) Status of the problem

Existing research focusing on the pasture productivity assessment can use the equation (3-2) for evaluation. In the case of land use planning practices, however, potential stocking rate on the left side of the equation (3-2) should be integrated by evaluation zones before evaluation. For these evaluation zones, the following points should be considered.

First, representation of habitat and time of the survey point should be contemplated. The existing forage, variable in the equation (3-2), can be obtained from vegetation data collected from field surveys; however, when deciding the survey point, the extent of the survey space that the existing forage represents needs to be considered. Surveys should be conducted in a space that existing forage is homogeneous. Prior to the surveys, determining such habitat as an evaluation zone and conducting survey at the survey point that represents each zone is proposed.

Secondly, independent of evaluation zones, timing of the survey needs to be determined. In **Fig.3-1**, (a) and (b) are the existing forage at month *t*, that is, the maximum pasture productivity during the year. If this is applied to the equation (3-2), grazing capacity per unit area can be calculated. Therefore, the survey requires specific timing when the maximum pasture productivity can be obtained during the year

Finally, the grazed period needs to be considered. Annual grazed period varies depending on lands. Some lands are close to communities and are grazed throughout the year, while others are distant from communities, or fenced, and grazed only half a year. For the determination of the grazed period, variable in the equation (3-2), the stocking form needs to be partitioned.

c) Landscape ecology based approach

The problems of the evaluation zones mentioned above can be addressed by the following landscape ecological zone approach. The flow is shown in **Fig.3-2**. The construction method of the landscape ecological zones described by Forman & Godron (1986) and Zonneveld (1995) is to overlay maps of various land conditions. Turner *et al*. (2001) classified land conditions which constitute the zones by taking into account abiotic factors such as climate condition and topography, biotic interactions such as natural vegetation, and human land use. Thus the LEZ can be drawn by overlaying various maps necessary to characterize a study area.

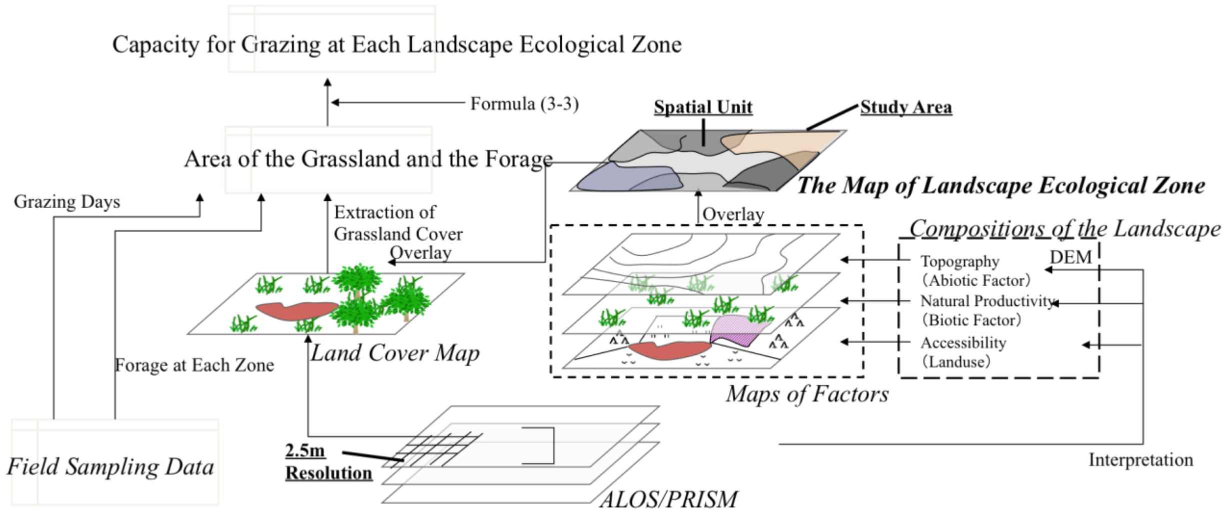


Fig.3-2 Relationships of Landscape Ecological Zones and Composition Factors.

At the time of drawing LEZ, the necessary data differs depending on the target range. For the scale of a village subjected in this study, high-resolution satellite images are required for mapping various factors including abiotic factors, biotic interactions and human land use. PRISM sensor on the ALOS satellite can create detailed topography data by simultaneously taking three directional images from forward, nadir and backward views in the travel direction. It also provides 2.5 m high resolution images. If imaging time and survey timing matches, it is possible to decipher and extract required landscape composition factors.

Total pasture productivities in each evaluation zone drawn by the above method become grazing capacity of the entire study area. For grazing capacity assessment at each LEZ, grazing capacity needs to be calculated by vegetation land covers other than forest or afforestation land covers (hereafter described as grassland cover) of each zone using the equation (3-2) and adding together. Thus, the following equation (3-3) is obtained.

$$\text{Grazing Capacity for Each Landscape Ecological Zone}(head) = \frac{\sum Exiting\ Forage(g/m^2) \times Grassland\ Cover(m^2)}{Feed\ Intake(g/head/day) \times Grazed\ Days(day)} \quad (3\text{-}3)$$

From this, grassland cover area can be compiled from land cover zones derived from 2.5 m resolution ALOS/PRISM images.

3.1.2 Analysis of the severity of a dzud in Mongolia

1) Modelling the severity of a Dzud

The dzud impact can be classified as direct and indirect. Direct impacts include the loss of livestock followed by a decrease in the sales of wool or cashmere, hides and skin, milk and meat products, winter clothing and heating fuel in the form of dried dung. Indirect impacts include problems of nutrition, health, poverty, education, crime, gender equality and environmental stability (Campbell & Knowles, 2011).

Usually, dzud impact is the severity of a dzud, therefore, this study also considers the direct *Dzud Impact* as the severity of dzud shown as the number of livestock loss (Reading et al., 2006; Sternberg et al., 2009; Lkhagvadorj et al., 2013) in terms of livestock mortality (Begzsuren et al., 2004; Tachiiri et al., 2008; Fernandez-Gimenez et al, 2012). As mentioned above, the severity of a dzud is the consequence of the weather conditions and social responses (Sternberg, 2010). This severity can be expressed by equation (3-4):

$$The\ severity\ of\ a\ dzud(t) = f(ax_1, bx_2, \dots, zx_n) \qquad (3\text{-}4)$$

where *the severity of a dzud (t)* is the responsive variable in a dzud event *t*, and x_n is the explanatory variable. Substantial studies have discussed the factors that contribute to the severity of a dzud (Begzsuren et al., 2004; Mellor & Stafford, 2004, Suttie, 2005; Batima et al., 2008; Tachiiri et al., 2008; Sternberg et al., 2009; Stenberg, 2010; Campbell & Knowles, 2011; Fernandez-Giemenz et al., 2012a, 2012b). Harsh weather, subsequent cold weather, the strength of the animals, the adequacy of available forage, and the availability of emergency fodder are often considered. The resource management practices of herders and governments are also risk factors (Stenberg, 2010). Based on an intensive literature review, we identified the following 6 factors:

a) Livestock configuration. Small livestock is thought to be more sensitive to extreme weather than larger animals such as camels, horses, and cattle. The majority of deaths occurred in goats and sheep in the 2009-2010 dzud(Stenberg, 2010; Fernandez-Giemenz et al., 2012a).

b) Forage availability in the summer. The health of livestock depends on the pastureland conditions defined by the snowmelt amount in spring, the rainfall in early summer, grass growth, and grazing pressure. A lack of forage in the summer prevents the fattening of livestock (Tachiiri et al., 2008).

c) Forage availability in the winter. Livestock is especially vulnerable to harsh winters under conditions of overgrazed pastures (Campbell & Knowles, 2011). Mongolian livestock obtains more than 90% of its annual feed intake by grazing year-round on open pastures; however, the animals can consume only 40-60% of their daily feed requirements through grazing because of the decreased quality of forage in the winter (Batima et al., 2008). Except for some soums, particularly in northern Mongolia, most herders rely on winter forage on rangeland.

d) Fodder availability. The distribution of emergency fodder by the government and the preparation of fodder in the winter are essential for livestock survival (Suttie, 2005; Stenberg, 2010). Emergency fodder and fodder for sale are usually provided at the aimag centre in the central region of a province. The timing of the assistance and the accessibility to the aimag centre are therefore important.

e) Increased and decreased rates of livestock. A large loss in a previous dzud year is associated with weakened livestock (Tachiiri et al., 2008). A smaller initial herd size (in general, poorer households lose a larger percentage of their livestock) makes a household more susceptible to a dzud (Fernandez-Giemenz et al., 2011). Cold exposure among young livestock is the primary cause of death as a result of hypothermia (Mellor & Stafford, 2004).

(f) Weather conditions. No association between drought and dzud occurrence has been drawn based on study sites for dzud episodes from 1987 to 2001 (Sternberg et al., 2009); however, we suspect that the severity of the weather conditions is not negligible because dzud events are normally linked with bad weather.

2) Metrics of variables

The explanatory variables are defined by the measurements described below.

a) Livestock configuration: population of small livestock (PSL)

The population of small livestock includes goats and sheep. The data were provided by the National Statistical Office of Mongolia (NSO). We used the data before the dzud year. For instance, in the case of the 1999-2000 dzud, we used the data of the total population of goats and sheep from the national statistical data of 1999.

b) Forage availability in summer: Total number of livestock per unit forage in summer (LFS)

The total number of livestock per unit forage in the summer is calculated by dividing the total population of livestock by the dry weight of average forage in the summer for the months of May, June, July, August, and September. The various animals are converted to the Mongolian Sheep Unit (MSU) stocking unit for comparability (Retzer & Reudenbach, 2005): 1 MSU is equivalent to an intake of 365 kg of dry forage per day; 1 horse is equivalent to 7 MSU, 1 cattle or yak is equivalent to 6 MSU, 1 camel is equivalent to 5 MSU, 1 sheep is equivalent to 1 MSU, and 1 goat is equivalent to 0.9 MSU (Bedunah & Schmidt, 2000; Shurentuja et al., 2002). Forage is the biomass of a species that suits the tastes of the livestock. This variable is measured at the monitoring point in kilograms per hectare; hence, forage is calculated by dividing the total number of livestock by the measurement of total forage.

c) Forage availability in winter: total number of livestock per unit forage in winter (LFW)

March and April are usually the most difficult seasons for livestock; livestock losses are greatest during these months because the animals are weakened and hay and fodder are in short supply (Batima, 2008). The livestock density per unit forage in the winter is calculated by dividing the total population of livestock by the dry weight of forage in the winter for the months of December, January, February, March, and April. The calculation algorithm is identical to that used for the LFS.

d) Fodder availability: the distance to the aimag centre (DTA)

Because of the poor infrastructure in Mongolia, the distance from a soum to the nearest administrative centre of an aimag determines the accessibility of emergency fodder. This variable is calculated based on the sum of the distance from the rangeland to the nearest national road and the nearest point on the national road to the aimag centre by using GIS based road data from WWF.

e) Increased and decreased rate of livestock population: change rate of livestock population (CRL)

In Mongolia, goats and sheep are the main domestic animals, along with a mix of large animals such as camels, cattle and horses. The ratio of a specific type of animal is equal to the percentage of the equivalent number of animals to the total number of livestock. The change rate of livestock is calculated as the rate of decreased equivalent heads of animals between the dzud year and its previous year to the equivalent heads of animals in the dzud year.

f) Weather conditions: climate index (CI)

The climate index expresses the severity of extreme weather. This index is calculated by using an integration of the drought index and the coldness index as follows (Natsagdorj & Sarantuya, 2004):

$$\boldsymbol{S_{summer}} = \sum_{t=1}^{n} \left| \frac{T - \overline{T}}{\sigma_t} \right| - \sum_{t=1}^{n} \left| \frac{R - \overline{R}}{\sigma_R} \right| \quad (3\text{-}5)$$

$$\boldsymbol{S_{winter}} = \sum_{t=1}^{n} \left(\frac{T - \overline{T}}{\sigma_t} \right)_i - \sum_{t=1}^{n} \left(\frac{R - \overline{R}}{\sigma_R} \right)_i \quad (3\text{-}6)$$

$$\sigma = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^{n} (x_i - \langle x \rangle)^2} \quad (3\text{-}7)$$

$$\Delta S = S_{summer} - S_{winter} \quad (3\text{-}8)$$

where T_i and R_i represent the temperature and precipitation, respectively, for particular months at the "i" station; σ_T and σ_R are the fluctuation of the temperature and precipitation, respectively, for particular months at the "i" station; x_i is the "i"-th value of x; <x> is the arithmetic average; and ΔS represents the climate index (Altanbagana et al., 2010). This index depends on the dataset. This study used the GLEWS database, which indicates that the snowfall was not sufficiently included. Therefore, the climate index of this study represents only the conditions of drought, coldness, or black dzud.

3) Modelling the severity of a dzud using Ordinary Least Square regression

The modelling process is designed in accordance with the GWR tutorial (Charlton & Fotheringham, 2009). The variables discussed in the above section are statistically evaluated based on an Ordinary Least Square (OLS) regression. Backward elimination is applied to validate the variables. Here, the significance of the variables is determined according to two criteria: the robust t-value with the p-value and the VIF to express significant multi-collinearities.

Social elements affect the survival rate of livestock, indicating that dzuds are a synthetic consequence of the adverse effects of weather and the actions of herders and the government (Sternberg, 2010). The geographical differences in the vulnerability to dzuds were illustrated through maps of social and ecological parameters (Altanbagana et al., 2010). This approach acknowledges that the loss of livestock is influenced by the geographic location and socioeconomic level of a region. A geographically weighted regression (GWR) is an effective method for considering the spatial autocorrelation in the OLS regression model (Bivand, 2014).

4) Geographically weighted regression

As an extension of OLS regression, GWR modelling is applied in three steps: selection of variables, evaluation of spatial effects, and verification of accuracies (Brunsdon et al., 1996; Fotheringham et al., 2002). We described the variable selection above. For the evaluation of the spatial effects, we checked the stationarity of the variables in the OLS regression models and evaluated the fitness between the prediction and observation according to Koenker's Bruensch-Pagan (BP) test. When this test shows significant heteroscedasticity, the GWR model fits better than the OLS. To select between the GWR and OLS models, we used AICc and R^2 values. Higher R^2 values indicated better model performance. Lower AICc values indicated closer approximations of the model to reality.

The accuracies of the result of GWR modelling were verified by Moran's I test and the condition number. Moran's I test, which verifies the spatial autocorrelations of residuals on GWR models, should not be significantly rejected because the unexpected spatial variation among the coefficients of one or more explanatory variables suggests that the GWR model is mis-specified (ESRI, 2009). The threshold of the condition number was also tested to determine whether it is below 100 (Delaney & Chatterjee, 1986). Below 100, the condition value displayed a "negligible impact" on the performance measures for the coefficients (Mason & Perreault, 1991).

3.2 Construction of the system development of early adaptation tools

In both cases of system development of the tools for supporting citizen's early adaptation, this study conducted 3 steps by referencing the ideas of protocol on tool development for actions of citizen sector (Morville & Rosendeld, 2006): needs survey to the subjects on early adaptation action, tool development and test with workshop, and interview to the subjects who use the tool. In addition, the information on the tool is based on demand-driven and science informed (Lourenço et al., 2015). For the case of Inner Mongolia, this study conducted interviews with the staffs of the regional NPO office in Horqin Sandy Land to survey how the information that is managed in routine operations such as daily planting and management activities, which was organized on spatial dependency. By based on the needs survey, the tool was developed by based on WebGIS, and tested with the brief session such as workshop mainly to the staffs of the subjected NPO. Finally, we interviewed to the staffs about its usefulness and the effects to their daily works of rangeland management, in particular their afforestation.

For the case of Mongolia, this survey conducted interviews to herders and local mayors of each soum about their demands of information to support their early adaptation to dzud, which surveyed to the broad scale because of the lack of previous researches despites the parameter of the subjects in Mongolia. The study area focused on a soum for the test, which was selected from the surveyed soums, and conducted the workshop for the check of the system works and communication with herders and the soum government about the test. Finally, this survey conducted the interview for checks of the effect through developed tool for supporting early adaptation to dzud.

3.3 Significance level

Statistical significance of the Quantitatively is evaluated by calculation of p-value. All the significance levels were set whether p-value becomes lower than 0.05 or not. If p-value becomes lower than 0.05, the model is statistically significant.

4. Analysis of the severity of land degradation in Inner Mongolia

4.1 Results of the analysis

4.1.1 Broad scale analysis

Plotted results of PDSI from 2001 to 2008 (**Fig.4-1**), the severity of drought, and difference of NDVI from 2000-2001 and 2007-2008 (**Fig.4-2**), the severity of land degradation in the grassland, showed some geographical differences. In 2003, 2004, and 2008, although the drought severity seemed to show its relatively serious condition in the western part of Inner Mongolia, the other years showed few differences among districts in Inner Mongolia. On the other hand, although summer NDVI difference from 2000-2001, 2003-2004, and 2006-2007 showed recovery or grows of vegetation in spatially a little bit homogenous, the other years showed the degradation in spatially inhomogeneous. Relatively serious decrease of NDVI seemed to be shown in the increase of livestock population (**Fig.4-3**), which showed the overgrazing degree, in Hulunbeier League, Erdos City, Tongliao City, Chifeng City in 2002-2003, 2004-2005, 2005-2006, in particular.

Results of its correlation analysis between land degradation and drought or overgrazing showed that overgrazing significantly ($p<0.05$) had a weak but negative coefficient ($R=-0.288$) with land degradation, however, drought had insignificant ($p>0.05$) and almost no correlation ($R=-0.098$) with land degradation. The correlation method was Pearson's product-moment correlation, whose alternative hypothesis true correlation was not equal to 0. The calculations were conducted on R commander of R software. Cities of this analysis were focused on Hohhot City, Baotou City, Wuhai City, Chifeng City, Tongliao City, Erdos City, Hulunbeier League, Xingan League, Xilinguole League, Wulanchabu League, Bayannaoer League, Alashan League by following statistical data, however Wuhai City didn’t analyze due to the error data. The results of this analysis said that land degradation in Inner Mongolia had been formed by weak contribution of rapid growth of main livestock population, an overgrazing, but not by the summer droughts.

Table 4-1 Results of the correlation analysis. Explained variable was land degradation, which was shown by NDVI difference in August. Calculations were conducted by using R software (https://www.r-project.org/), the module for the correlation test was included in the module named R commander. (df = 74)

Explanatory Variable	Correlation	P-value
Drought (difference of PDSI)	-0.098	0.343 (>0.05)
Overgrazing (difference of main-livestock population)	-0.288	0.011 (<0.05)

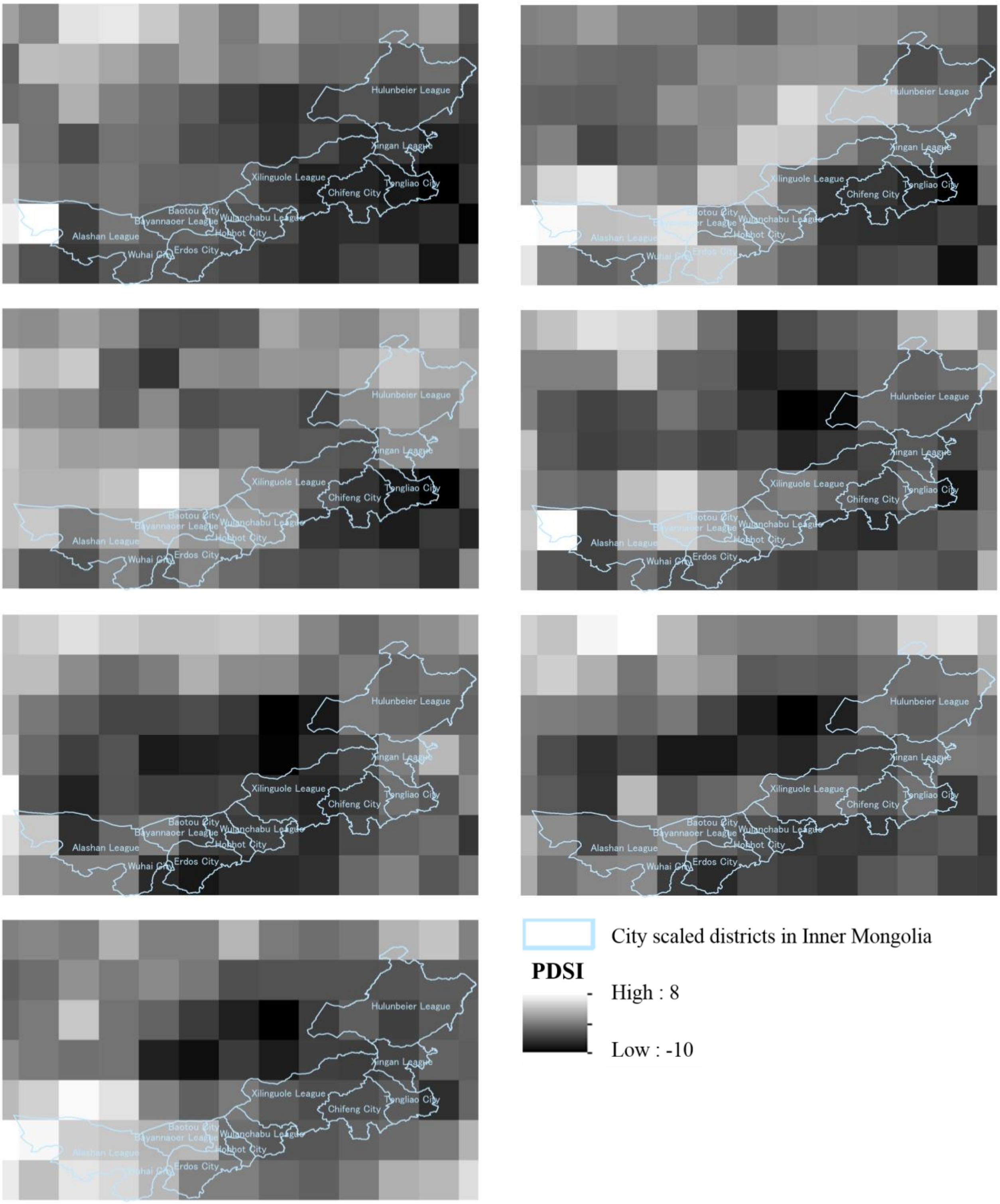


Fig.4-1 PDSI from 2002 (upper left) to 2008 (bottom left) in ascending sequence from top left to bottom right.

All the maps were drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop). Boundary data of the districts were provided by the ArcGIS Online (https://www.arcgis.com/home/group.html?owner=esri&title=esri%20maps%20and %20data). PDSI is downloaded from NOAA http://www.esrl.noaa.gov/psd/data/gridded/data.pdsi.html).

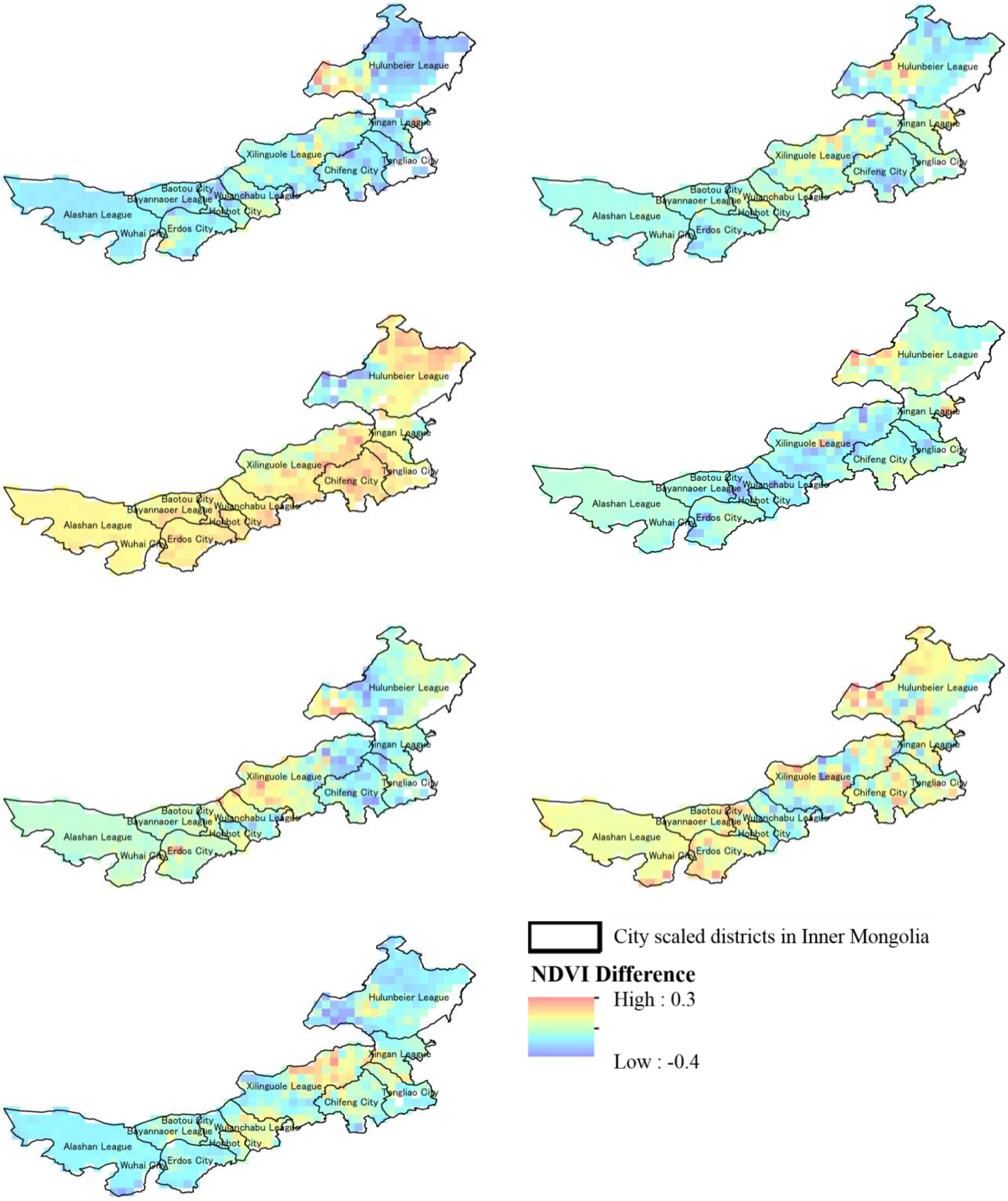


Fig.4-2 Annual difference of NDVI from 2001-2002 (upper left) to 2007-2008 (bottom left) in ascending sequence from top left to bottom right. All the maps were drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop). Boundary data of the districts were provided by the ArcGIS Online (https://www.arcgis.com/home/group.html?owner=esri&title=esri%20maps%20and%20data). NDVI is downloaded from NASA (http://neo.sci.gsfc.nasa.gov/view.php?datasetId=MOD13A2_M_NDVI).

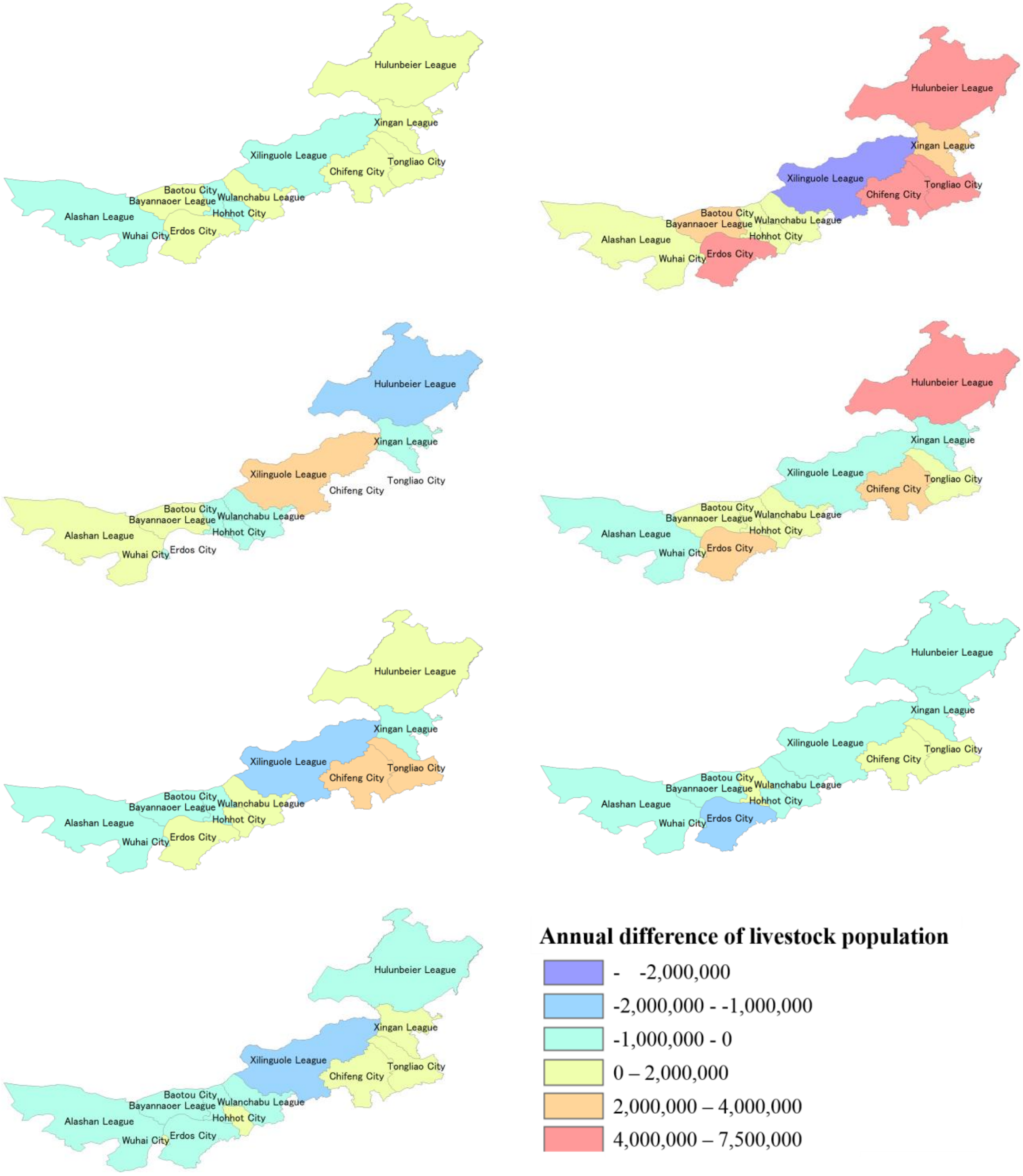


Fig.4-3 Annual difference of livestock population from 2001-2002 (upper left) to 2007-2008 (bottom left) in ascending sequence from top left to bottom right. All the maps were drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop). Boundary data of the districts were provided by the ArcGIS Online (https://www.arcgis.com/home/group.html?owner=esri&title=esri%20maps%20and%20data). Livestock population (heads) is downloaded from ACMR (http://chinadataonline.org/).

4.1.2 Village scale analysis

1) Study area

The study area Duxi Village, Agulazhen, Horqin Zuoyi Houqi, Tongliao, Inner Mongolia, is located N43°17’ - N43°21’, E122°42’ - E122°47’ and has an administrative area of 38.9 km^2 with a population of 255 and 54 households. In the south of the village, there is the Duxi Lake with 2,800 m east-west and 1,000 m north-south length. The community is in the north coast of the lake and 30 m high sand dunes run east to west along the back of the village. The lake is alkaline, and it is thus not used as a water source.

The total area of the village is 45,000 mǔ (1 mǔ = 667 m^2), divided into rangeland 29,000 mǔ, farmfield 2,900 mǔ, woodland 10,000 mǔ, hayfield 800 mǔ, and lake, and more than half the land is used for grazing, according to an interview of the village administrative manager in September, 2005. Sand dunes that run along the back of the village or the lakeside lowlands are used as rangeland. On the north side of the village, a shrub forest is dispersed, with elm, apricot and willow shrubs scattered within, which represent a typical Horqin landscape. Woodlands have been cultivated into bean patches.

Farming and stock raising account for 40% and 60%, respectively, of the income form. The yearly per capita average income is 5,000 yuan and net income is about 1,000 yuan (as of 2006); the village is especially impoverished within the Horqin Zuoyi Houqi district[A)]. The entire village possesses 800 cattle and 3,000 goats.

2) Building landscape ecological zones

Yan (2008) reported that plant species composition of Horqin region is controlled by soil moisture condition that is closely related to topography. Land use, however, is fundamentally formed by the natural productivity of land, and frequency of use is decided by access from the community. Those main factors influence each other and constitute the landscape. Because Duxi Village is composed of water source, village, lowlands (paddies, fields), and rangeland (fixed dunes, moving dunes) the landscape ecological zones were created with three conditions: accessibility which determines frequency of use, natural productivity which forms land use, and topography zones closely related to soil moisture.

A) Accessibility

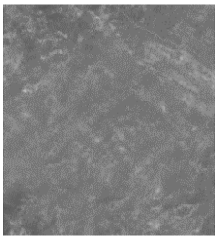
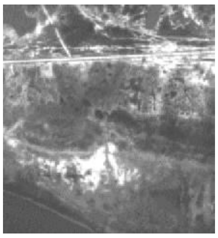
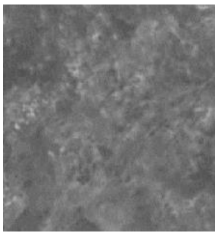
Daily activities of villagers are largely categorized into residential, farming, hay making, grazing livestock and correcting firewood , and are conducted near water source and living quarters. Places where villagers’ usual daily activities and labor are frequently seen are close to the community. Where the community is getting far and the elevation is getting high, livestock grazing frequency and field crops change to tolerant field crops such as beans, and plants such as shrubs become abundant. Since regional landscapes are shaped by land conditions and human activities, lands in the study area were categorized into three zones of high, middle and low, based on the accessibility from the community. High zone was within 30 minutes walking distance from the community and was the base of daily activities, low zone was more than 1.5 hours walking distance and sparsely used during the year, and middle zone was intermediate of high and low.

B) Natural productivity

Natural productivity of the study area depends on land use, such as rangeland, hayfield and farmland. For this reason, shade classification of pixels obtained from ALOS/PRISM nadir view data (processing level 1B2R, 14 August 2006) was conducted. This was used as a reference to visually classify textures of the images as in **Table 4-2**, and land use zone maps were created.

ALOS/PRISM provides panchromatic images; thus, local vegetation is represented by black and white shade. Although information from panchromatic images overlaps with multispectral imaging, excellent results can be expected since vegetation is easily classified by shades. With this advantage, in addition to grassland zones, rangeland and hayfield zones, which differ by plant height and density, were identified. From the above, five zones were created: hayfield, rangeland, farmland, woodland and others. Others included areas such as residential and afforested, which were not used for stock raising.

Table 4-2 Surface Conditions for Classification of Shades and Textures. ALOS satellite PRISM sensor data showed all the below data.

Class	Hayfield	Rangeland	Farmland	Woodland	The Others (Residential areas etc.)
Texture					

C) Topography classification

Topography data was obtained using Digital Elevation Model (DEM) data from ALOS/PRISM images simultaneously taken from forward, nadir and backward views in a travel direction. Location data from field surveys conducted between July 31^{st} to August 12^{th} 2006 were used as ground reference points for images taken during the same period. In the general procedure involved in creating topography data, the same point from each ALOS/PRISM 3 directional view image was used as a ground reference point.

Using field survey results as a reference and visually examining ALOS/PRISM images corresponding to the created topography data, topography characteristics of the study area were categorized into four zones: sand dunes, lowland between sand dunes, lakeside area at moderate elevation and lakeside area in lowlands.

D) Drawing LEZ by overlay

Three categories of topographic classification, land use zones and accessibility were overlaid, and boundaries were visually traced weighing work efficiency. At that time, some of LEZ named “shrub forest -,” a zone which was categorized into hayfield instead of woodland for land use zone, was assigned the name “Shrub forest at Northern Area” because although the land was actually used for cutting the undergrowth to feed to livestock, shrub was the dominant species in this zone.

Totally 23 LEZs in the study area shown in **Table 4-3** and **Fig.4-3** were drawn by using methods described above, overlaying all the zones. The data included four topography classifications, five land use zones and three accessibility zones.

3) Assessment of land productivity by zones

3-1)Data preparation

3-1-1) Land cover classification

In order to determine grassland area by the approach in 2.3 and the equation (3-3), land cover classification was assigned using ALOS/PRISM nadir view data (14 August, 2006). Data for land cover classification was corrected by fieldwork from 31 July to 12 August, 2006. The landscape at the study site, Duxi Village, is composed of sand dunes, saline area, shrub forest, low-growth grassland and high-growth grassland. For data processing, five classifications were used: sand dunes, saline area, shrub forest, high-growth grassland and low-growth grassland. High-growth grassland was strictly composed of two land covers: farmland and high-growth grassland, and the farmland productivity may be overestimated. Land cover classification map was created with six classifications including farmland.

The six land covers are as follows. Sand dunes have the land surface covered with sand. Salinity areas can see salt accumulation covering on the land surface. Low-growth grassland has short herbaceous plants covering grassland and rangeland of sand dunes. High-growth grassland is covered with tall herbaceous plants. Farmland is covered with farmed crops such as corn and buckwheat. And shrub forest have shrub and bush vegetation covering the surface. Of the six land covers, the area of three land covers that are covered by herbaceous plant vegetation: farmland, low-growth grassland and high-growth grassland, were substituted in the equation (3-3) for a particular grass landcover area.

Table 4-3 Relationship between LEZ and its construction factors (above), and the legends (see bottom).

Zone Name	Accessibility			Landuse					Topography			
	1	2	3	1	2	3	4	5	1	2	3	4
Low-Growing Grassland on Sand Dunes at Western Area	●				●					●		
Salinity Area	●				●							●
Farmland	●					●					●	
Shrub Forest on Sand Dunes at Southern Area	●					●					●	
Residential Area	●							●			●	
Woodland at Southwestern Area	●							●			●	
Shrub Forest at Northern Area		●		●						●		
Low-Growing Grassland at Northwestern Area		●		●						●		
Low-Growing Grassland at Southeastern Area		●		●							●	
Sand Dunes at Southeastern Area		●			●				●			
Sand Dunes at Eastern Area		●			●				●			
Sand Dunes at Western Area		●			●				●			
Low-Growing Grassland at Western Area		●			●							●
High-Growing Grassland on the South of Lake		●			●							●
Sand Dunes at Southwestern Area		●				●			●			
Afforestation Area at Northern Area		●						●	●			
Afforestation Area at Southern Area		●						●	●			
Woodland on the East of Main Road		●						●		●		
Woodland on the West of Main Road		●						●		●		
Afforestation Area at Southwestern Area		●						●			●	
Low-Growing Grassland at Northeastern Area			●	●						●		
Shrub Forest at Northeastern Area			●				●			●		
Shrub Forest at Northwestern Area			●				●			●		

【Accessibility】1: high, 2: middle, 3: low.【Land use】1: hayfield, 2: rangeland, 3: farmland, 4: woodland, 5: others.【Topographic zones】1: sand dunes, 2: lowland between sand dunes, 3: lakeside area in moderate elevation, 4: lakeside area in lowlands.

Table 4-4 Comparison of productivity in each grassland cover. All the data is corrected in the field sampling. Grassland covers were classified by NDVI from ASTER satellite VNIR image, which was taken on July 2004.

Grassland covers	Biomass of 1m² grassland cover (g/m²)				Area (ha)
	Total wet weight	Total dry weight	Pasture wet weight	Pasture dry weight	
Low-growth grassland	367	291	104	82	41,867
High-growth grassland	368	332	104	94	2,966
Farmland	6,083	4,540	4,637	1,060	449

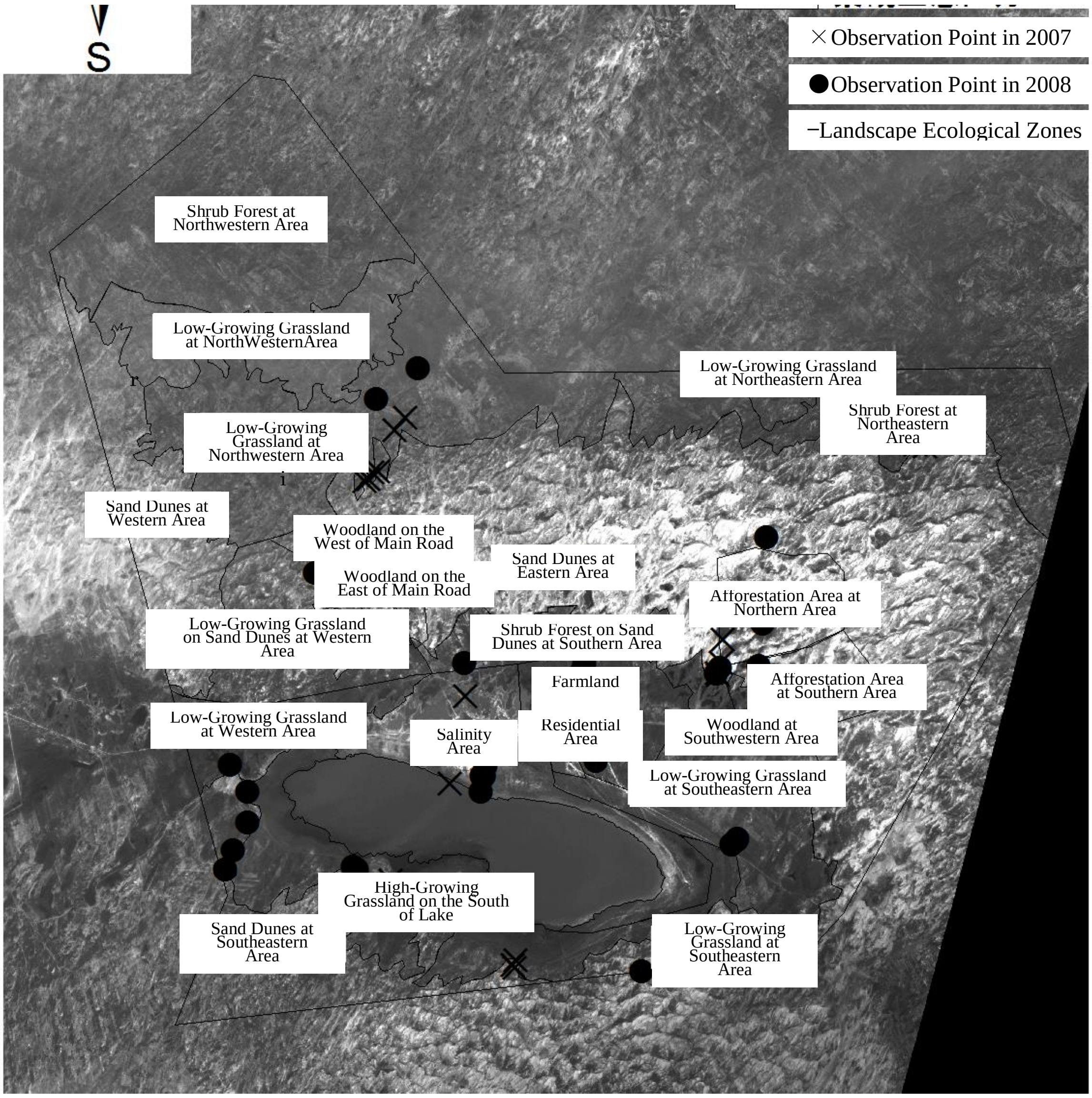


Fig.4-4 Result of Landscape Ecological Zoning (LEZ) in the study area. As a result of overlay of accessibility zones (3 zones), landuse zones (5 zones), and topographical zones (4 zones), 23 zones were classified. All the maps were drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop). All the zones were drown on the ALOS satellite PRISM sensor data.

3-1-2) Field survey

Ground reference of landscape ecological zones in the evaluation zones map and existing forage and grazing period data in the equation (3-3) were corrected from the field surveys. Field survey data acquired during the period of 28 July –12 August, 2006 and 31 August – 3 September, 2007 was used. The workload was estimated in advance by planning survey points that would contain representative land covers of regions like grassland, woodland, farmland using images such as VNIR images from the ASTER sensor taken on 11 September, 2004.

LEZs were created from vegetation surveys of $1m^2$ quadrats that indicated soil conditions, vegetation hierarchy composition, and percent coverage and abundance of that composition. Biomass of the LEZ was estimated by measuring the wet weight of plant species that were reaped above ground.

Topography surveys used Magellan GPS (ProMark) for measuring vegetation survey districts within a maximum boundary radius of 200 m. At points where the topography changed, latitude, longitude and elevation from GPS were recorded. Given the accuracy of topography measurements using ALOS/PRISM is approximately 5 m (Tadono *et al.*, 2007), GPS measurements used in this survey as ground reference points was thought to be appropriate.

Further, access surveys were conducted through interviews of the residents in the community, using satellite imagery as a reference.

At the time of compiling vegetation survey results, all plants that were present at survey were classified either to pasture or others according to Chen and Jia (2002), and pasture productivity was calculated.

3-2)Feed intake

feed intake of livestock in the equation (3-3) was set as the demand for one goat, that is, 1,600 gram of feed per day, according to the Japanese Society of Grassland Science (2004).

3-2-1) Land productivity assessments by grassland cover

Vegetation survey results obtained using the technique in the section 3.1.1 2) were compiled and summarized in **Table 4-4.** At the survey, for each of the three grassland covers, total wet weight, pasture wet weight, total dry weight, and pasture dry weight were measured and compiled. Total wet weight was defined as the wet weight (g) of 1 m^2 total vegetation, pasture wet weight was the wet weight (g) of pasture, total dry weight was the dry weight (g) of the total vegetation at the survey point and pasture dry weight was dry weight (g) of pasture.

Wet weight of the low-growth grassland and high-growth grassland did not substantially differ, but there were differences in dry weight. Most high-growth grassland vegetation could be consumed by livestock. Many farmlands were cornfields. Leaves and stems of cultivated corn were used as wintering fodder for livestock. For this reason, corn stems and leaves were considered all edible, and the total was taken as pasture wet weight.

Biological production for corn and bean patches were assessed based on Takato and Ikeda (2002), respectively. Chinese cabbage fields in farms were approximated by using fodder from Donan Agricultural Trial Horticulture Department (2000) as a reference. Farmland had 10 times more productivity than high-growth grassland. Low-growth grassland was most widespread and farmland was most confined; however, overwhelmingly high biological productivity was seen in farmland.

3-2-2) Grazing capacity by LEZ

Grazing capacity for each category was assessed using the analysis method of the section 2.4. In an actual stock raising, the rest of all grazing days in the year was used for grazing in rangeland and hayfield, so that the grazing period could be set at 183 days in the equation (3-3). One important approach is the virtual example of expected increases in grazing capacity due to rotation. Accordingly, grazing capacity assessments were conducted in two patterns: β1 pattern with provisional rotation and β2 pattern with the present grazing form with no rotation. Realistic rotation times are half of the grazing period left in the year; thus, rotation time in the landscape ecological zone was set 90 days as potential grazing period. For the time being, grazing period of 90 days were established for landscape ecological zones with frequently used rangeland, that is, land with high accessibility or use. Of the remaining 90 days, forage required for grazing needs to be partitioned separately. Accordingly, zones with grazing period set to 0 days and afforested area landscape ecological zones were established as interpolated grazing zones for the equivalent 90 days of grazing (hereafter, rotation interpolation zones), and grazing capacity assessments were conducted.

Based on the above classifications, grazing capacity for rotation interpolation zones and other zones are shown in **Table 4-5**, bottom and top, respectively. Further, for LEZ analysis, unnecessary items such as residential land were removed from the table. Compilation of dominant plant types for each LEZ is also shown in the table. Further, for each landscape ecological zone, grassland cover area is tabulated. Averages for total vegetation dry weight and pasture dry weight were calculated based on herbaceous plant cover area for each land cover shown in **Table 4-4**. The above pasture production per unit area and stocking form were coupled and under each use condition, potential stocking rate for goat was calculated from the equation (3-3). The total of the major land use is shown in the last column of **Table 4-5**. Further, total rotation interpolation zones is presented at the bottom left of **Table 4-5**, and the difference in grazing capacity with rotation is exhibited **Table 4-5**, bottom right.

Table 4-5 Grazing Capacity Assessment for Each Landscape Ecological Zone.

Landscape Ecological Zones	Dominant Species	Total biomass per unit(g/m^2)		Grazing periods (days)		Grazing Capacity (heads)		γ: Landuse		
		Total dry biomass	*f(t)*: Toral dry forage	β1: with rotation	β2: without rotation	with rotation	without rotation	Rangeland	Hayfield	Farmland
Low-growing Grassland on Sand Dunes at Western Area	*Artemisia palustris* L.	37.3	25.4	90	183	90	90	1	0	0
Salinity Area	*Suaeda maritima dumort*	24.5	19.3	183	183	86	86	1	0	0
Farmland	Zea mays	2039.4	1056.8	183	183	3664	1802	0	0	1
Shrub Forest on Sand Dunes at Southern Area	Zea mays	1729.7	1135.7	183	183	1635	1635	0	0	1
Low-growing Grassland at Northwestern Area	*Artemisia mongolia Fisch*	103.5	90.5	183	183	963	473	0	1	0
Shrub Forest at Northern Area	*Digitaria ciliaris Koel*	35.8	29.0	183	183	534	263	0	1	0
Low-growing Grassland at Southeastern Area	*Pennisetum flaccidum Griseb*	692.7	503.1	183	183	7168	3525	0	1	0
Sand Dunes at Eastern Area	*Artemisia ordosica Kraschen*	84.5	27.9	90	183	398	398	1	0	0
Sand Dunes at Southeastern Area	*Suaeda japonica Makino*	79.3	2.6	90	183	6	3	0	1	0
Low-growing Grassland at Western Area	*Lespedeza dauvurica*	117.2	117.2	90	183	342	342	1	0	0
Sand Dunes at Western Area	*Artemisia ordosica Kraschen*	84.5	27.9	90	183	76	76	1	0	0
Sand Dunes at Southeastern Area	Zea mays	665.9	345.3	90	183	3801	1869	0	0	1
High-growing Grassland on the South of Lake	*Carex* sp.	137.4	59.7	90	183	1014	499	1	0	0

Table 4-5 (Continued) Grazing Capacity Assessment for Each Landscape Ecological Zone.

Landscape Ecological Zones	Dominant Species	Total biomass per unit(g/m^2)		Grazing periods (days)		Grazing Capacity (heads)		γ: Landuse		
		Total dry biomass	*f(t)*: Toral dry forage	$\beta 1$: with rotation	$\beta 2$: without rotation	with rotation	without rotation	Rangeland	Hayfield	Farmland
a) Sum of the area grazed with rotation				Σ{(*f(t)*・area(㎡)/1600・β1)・γ} = 7204				2940	4264	5306
b) Sum of the Area Grazed without Rotation				Σ{(f(t)・area(㎡)/1600・β2)・γ} = 5753				1489		
Woodland at the East of Main Road	*Setaria viridis Beauv.*	84.0	72.8	90	-	61	-	1	0	0
Woodland at the West of Main Road	*Artemisia mongolia Fisch*	103.5	90.5	90	-	76	-	1	0	0
Woodland at the Southwest of Main Road	*Artemisia palustris* L.	37.3	25.4	90	-	90	-	1	0	0
Afforestation Area at Southern Area	*Chloris virgata Swartz*	138.9	134.5	90	-	212	-	1	0	0
Afforestation Area at Southwestern Area	*Chloris virgata Swartz*	200.6	197.7	90	-	121	-	1	0	0
Shrub Forest at Northeastern Area	*Digitaria ciliaris Koel*	35.8	29.0	90	-	534	-	1	0	0
Low-Growing Grassland at Northeastern Area	*Artemisia mongolia Fisch*	103.5	90.5	90	-	76	-	1	0	0
Shrub Forest at Northwestern Area	*Digitaria ciliaris Koel*	35.8	29.0	90	-	534	-	1	0	0
c) Sum of the area grazed with interpolated rotation = 1704						c - (a - b) =		253		

4.2 Discussion of the analysis

4.2.1 Relationship between the severity of drought, overgrazing and land degradation

Result of the correlation analysis showed that almost no relationship between drought and land degradation, however a weak but significant negative coefficient had in the relationship between overgrazing and land degradation in 2001 to 2008, which meant that the annual growth of main livestock population decrease vegetation in a year. This results supports the results of lots of previous studies, which concluded the overgrazing is one of the important factor to form land degradation / desertification in Inner Mongolia (Zhang et al., 2007a, 2007b; Qian et al., 2014), however, the relation was not strong. At the same time, considered theory of the effects of frequent drought after 2000 (Briske et al., 2015; Huang et al., 2015) has almost nothing to land degradation / desertification.

However, the effects of the continuous and long-term drought to the land degradation in Sahel (Nicholson et al., 1998) or Zimbabwe (Prince et al., 2009) were reported, so Inner Mongolia should be care it with the monitoring by following the serious future predictions of continuous frequent drought (Huang et al., 2015).

4.2.2 Actual conditions of overgrazing in the entire village

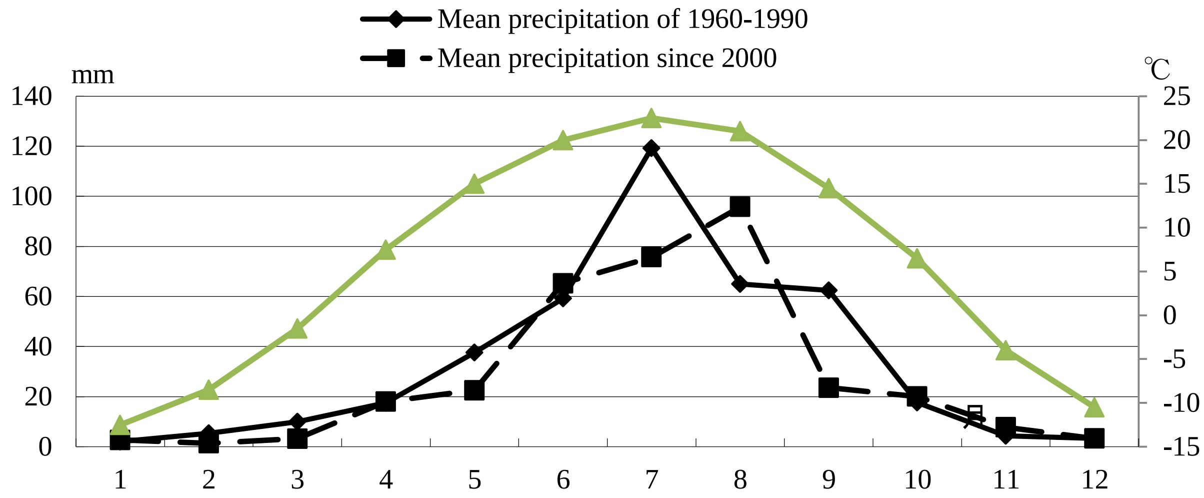
As described in 3.1, present livestock grazing population of the village is 800 cattle and 3,000 goats. Generally, cattle ingest approximately five times the vegetation of goats, and the total grazed population is thus the equivalent of 7,000 goats (equivalent sheep unit).

However, as presented in **Table 4-5**, the grazing capacity for the entire village, which is the total of rangeland and hayfield without rotation, is only for 5,753 heads. The grazing capacity for farmland is for 5,306 heads. In other words, grazing pressure on the rangeland and hayfield was found to be high, and during non-grazing times, the lands provided supplements when shortages of agricultural crops occurred. Further, if rotation is implemented in landscape ecological zones under conditions of 2.3.3, grazing capacity raises to 7,204 heads, surpassing the current 7,000 heads. However, for rotation to occur, 90 days of equivalent pasture productivity is required to compensate for the remainder of the grazing period. Accordingly, grazing capacity of the interpolation zones with rotational grazing was estimated to be 1,704 while that of zones with rotational grazing was 1,451 ([total grazing capacity with rotational grazing] – [total grazing capacity without rotational grazing]). The difference of 253 heads was found to exceed. Thus, even if provisional rotation is implemented, at present, grazing capacity is in a state of overgrazing, close to the limits determined quantitatively. Since overgrazing is dependent on stocking form, pasture productivity without rotation is unsustainable in the current state.

Pasture productivity is easily influenced by outside major factors such as natural and societal factors in a particular year, or the survey period. To determine whether the results indicate individuality of survey years, or multi-year trends, precipitation data and statistics of livestock numbers were employed. The data used was from places closest to the study area. Precipitation observation data was from Tongliao weather station. And Kanjika town point, and livestock data was from Agra town livestock basic survey.

Fig.4-5, left, shows average monthly precipitation per decade from 1960 to 2000 and yearly from 2000 to 2007, and monthly average temperature for 20 years since 1984. As indicated by the graph, precipitation peaked in July from 1960 to 1990, and in August from 2000 and thereafter. The dry seasons started in September and October. Precipitation peak is commonly found in July. Maximum pasture productivity then occurs in August, and after September, plant reproduction is not expected. In this study, surveys were taken in August, corroborating that the acquired biological production was at maximum.

In addition, **Fig.4-5**, right, presents livestock numbers in the higher administrative district that includes the village. Large livestock are the total of cattle, donkeys, horses, mules and camels, and small livestock refers to the total of sheep and goats. Without exception, both have increased since 2000. Small livestock have especially increased to more than 7 times that seen in 2000, and is consistent with grazing capacity and overgrazing calculated in this paper. Based on the trends in the number of livestock, it is believed that overgrazing is chronic and will become more severe under the current grazing methods with no specific measurement.



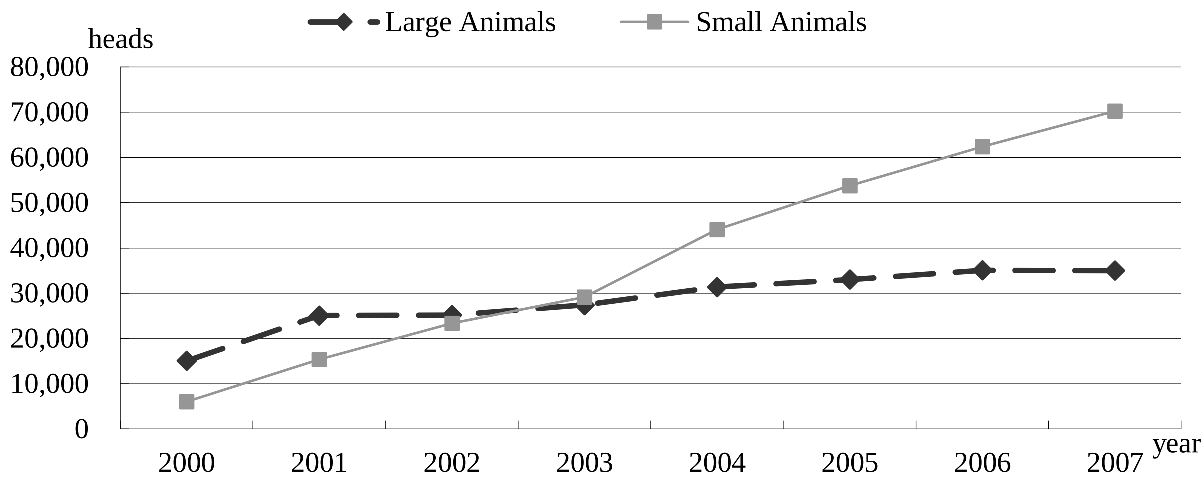


Fig.4-5 Changes in Precipitation, Temperature (upper) and Livestock Numbers (bottom). X-axis of the temperature data shows the monthly timeline from January from December, Y-axis (left) shows precipitation (mm), and Y-axis (right) shows temperature (Celsius degree). X-axis of the livestock number data shows the yearly timeline from 2000 to 2007. Y-axis shows the number of livestock population (heads). All the data is corrected the government of Agura, Inner Mongolia.

4.2.3 Grazing capacity of each landscape ecological zone

Trends and factors of the total grazing capacity of each landscape ecological zone at present are explored below in terms of the characteristics of topography, natural productivity and accessibility.

1) Low grazing capacity zones and their factors

Low grazing capacity zones are defined as where the potential grazing capacity is less than 100 heads according to

Table 4-5. Four landscape ecological zones that fit are Sand Dunes at Western Area, Low-growth Grassland on Sand Dunes at Western Area, Sand Dunes at Southeastern Area and Saline Area.

Low-growth Grassland on Sand Dunes at Western Area and Saline Area are used as rangeland with low accessibility and high frequency of use. Sand Dunes at Western Area and Sand Dunes at Southeastern Area are rangelands characterized by sand dunes with small grassland areas. Sand Dunes at Eastern Area also have same conditions but are different from these zones due to the large grassland area of lowland between sand dunes.

From the above, conditions for the low grazing capacity of landscape ecological zones are rangeland land use with high accessibility or rangeland use with sand dune topography.

According to **Table 4-5**, this is assumed to be because landscape ecological zones categorized as sand dune tends to have low percentage of pasture dry weight in the total dry weight. Especially in Sand Dunes at Southeastern Area, the plant community is composed of species that are rarely used for pasture. Drought resistant plants such as *Artemisia* genus and annuals like the thorny *Chenopodiaceae* family root more easily in sand dunes than other plants, but livestock do not prefer to feed on these plants. Also, in salinity areas, as the salt content rises, coverage with salt tolerant plants increases; livestock does not eat these plants, thus grazing capacity is expected to further decline.

2) High grazing capacity zones

First, high grazing capacity zones are mostly presumed to be farmland land use, thus they are excluded to focus on rangeland and hayfield. Further, potential grazing capacity of more than 500 heads is set as a condition for high grazing capacity. Landscape ecological zones that fit are Low-growth Grassland at Northwest Area, Low-growth Grassland at Southeast Area, and High-growth Grassland at South of Lake.

Low-growth Grassland at Southeast Area and Low-growth Grassland at South of Lake are characterized with topography classifications of lakeside area at moderate elevation and lakeside area in lowlands, with relatively low elevation, moderate accessibility, and moderate grazing frequency. Further, Low-growth Grassland at Northwest Area is characterized with lowland between sand dunes topography and hayfield land use, but positioned at lower side of accessibility among moderate accessibility zone, and has low frequency of use.

From the above, conditions for the high grazing capacity are topography classification of lakeside area at moderate elevation or lakeside area in lowlands, or hayfield land use with moderate or low accessibility.

First, this could be associated with rich soil moisture in low areas close to the lake, such as at lakeside area at moderate elevation or lakeside area in lowlands. Second, productivity increases in well-managed districts by fencing around hayfields in preferred natural conditions. Lowland between sand dunes is also a relatively favored natural location, and grazing capacity also increases in hayfields, which are well managed.

3) Grazing form of village

The current situation of the grazing capacity described above is involved in the grazing form of the village. Generally in this region, immediately after the end of corn harvest around mid-October, grazing is carried out in arable land that no longer support agricultural crops, from morning until sundown. Further, at the time of the field survey that we conducted in September 2007, grazing was observed in hayfields where the fence was removed, and previous to September, the opening of cultivated lands and hayfields were also observed in September, the time before arable land was opened. From the above, it is found that within the grazing period at Duxi Village, grazing is mainly conducted in rangeland and hayfield, and fodder from harvest of the farmland are used in a complementary manner other than at grazing time.

4.2.4 Suggestion for land use with landscape ecological zones

1) Management using rotatial grazing by following LEZ

Policies with rotational grazing using LEZs to manage livestock grazing capacity and grazing period can be formulated. Based on the results of grazing capacity assessment in **Fig.4-5**, grazing capacity with rotation exceeds the current livestock numbers owned by the village compared to without rotation. However, as described in 4.2.2, additional forage is required to support increased grazing capacity due to rotation at rotation time. For this reason, LEZs such as an afforested area or low accessibility conditions, namely, land that usually cannot be used, will need to be adopted. If these lands are used for rotational grazing, adequate grazing can be conducted.

For this purpose, management of an afforested area should be considered at the same time. As mentioned above, proposal of rotational grazing and grazing in afforested areas are absolutely necessary. Close analyses are required to determine whether an afforested area should be used as such, or for rotational grazing to avoid overgrazing from mutual point of views in terms of the economic and ecological points based on grazing capacity.

2) Shift to responsible grazing from agricultural income

Even if rotational grazing is conducted according to **Table 4-5**, grazing capacity of the land is almost the same as the limit of potential grazing capacity. Thus, farmland with high grazing capacity may be used more often than at present. In fact, in the village, the effect of overgrazing has led local livestock to be thin and withered, and the low quality of livestock is found. Instead of increasing income by proliferating the livestock population, measures to expand income by raising the value per livestock, the livestock quality in other words, is really important.

Table 4-3 shows that grazing capacity of the farmland is overwhelmingly high compared to other zones. Although this opinion could be debatable, this would be an appropriate conclusion. Corn is mainly cultivated on farmland as commodity crops or for feed. Corn grown as commodity has a longer cultivation period compared to that for fodder, thus the harvest time approaches September or October. In this period, as seen in **Fig.4-5**, left, the dry season has started, and stems and leaves that for fodder lose most of their freshness. If the corn grown as commodity crops is all shifted to fodder crops and stored and distributed in the highest nutrient condition, quality improvement of livestock could be achieved. This offers the long land recovery period, increased land operational efficiency and relief of environmental pressure on rangeland.

3) Use and improvement of species paired with zone characteristics

According to the results of unit area biological production of LEZs, it has a possibility to improve in pasture productivity of Salinity Area, Low-growth Grassland on Sand Dunes at Western Area and Shrub Forest at Northern Area. In Salinity Area, in order to limit the dominance of plant species such as *Suaeda maritima* that livestock cannot eat, weeding and management of species composition by afforestation of other plant types are required. Specifically, seeding aggressively salt-tolerant plants such as the *Carex* genus of the *Cyperaceae* family and the *Juncaceae* family that livestock can eat, is conceivable. In addition, Yamamoto (2008) reported that flora considered halophilic plants can be effectively used as food and fodder, and among those, plants of *Salicornia* class of the *Chenopodiaceae* family are highly salt tolerant and serves as promising fodder.

For rangeland with fixed dunes and low capacity such as Sand Dunes at Western Area and Low-growth Grassland on Sand Dunes at Western Area, and hayfield with low capacity such as Sand Dunes at Southeastern Area and Shrub Forest at Northern Area, Species that do not require much moisture for growth, such as *A. ordosica* and *A. sphaerocephala* of the *Artemisia* genus can be candidates for the seeding. Since plants of the *Artemisia* genus can be also used as fodder in winter if dried, it is suggested to seed them in the summer and correct them for winter use.

As described above, by expanding hayfields and fodder crop fields, introducing preserving techniques for fodder, and comprehensive pasture management, grazing pressure on rangeland can be reduced. Thus high valuable livestock is raised, and this should help achieve the objectives of sustainable land use of Duxi Village.

5. Analysis of dzuds in Mongolia

5.1 Analysis and the results

5.1.1 Study Area

The study area is illustrated in **Fig.5-1** with the main ecological zones in Mongolia. The extent of the study area included the major soums that displayed effects from the dzud and was also defined by the availability of GLEWS datasets, including 114 soums of 8 aimags (Bayankhongor, Dornogobi, Dundgobi, Gobi-Altai, Gobisumber, Omnogobi, Ovokhangai, and Tuv) and the Gobi (**Fig.5-1**). All of these areas displayed serious damage resulting from the dzud (UNDP, 2010). The Gobi desert zones have relatively low production of vegetation because of the arid climate. Steppe or forest steppe zones have better primary productivity than the Gobi or desert zones. The correlations between the livestock population and NPP (net primary productivity) were not significant in most aimags (Wang et al., 2013). Arid or semiarid areas of ecological zones may be more variable with respect to climate conditions but with less snow coverage during white dzuds.

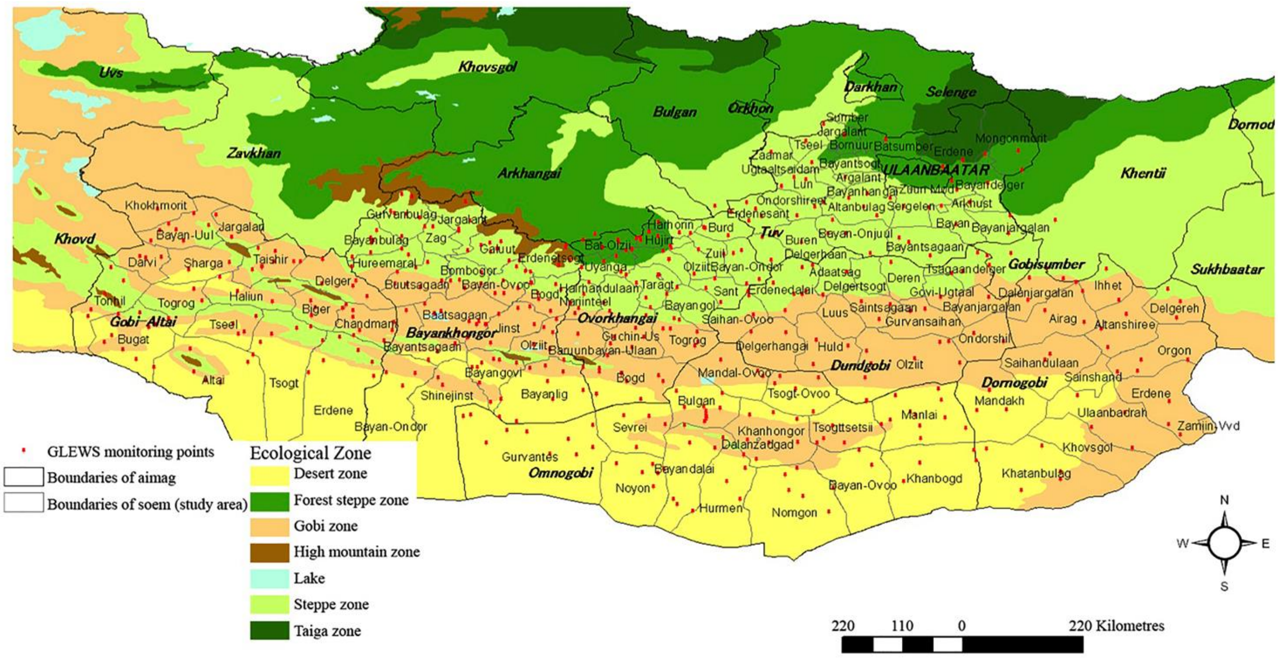


Fig.5-1 Study area and analysis unit (soum) with ecological zones in Mongolia. The map was drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop). Zoning and boundary data were provided by the National Development Institute, Mongolia.

5.1.2 Datasets

We retrieved livestock population data from the National Statistical Office of Mongolia for the PSL and CRL variables. For the forage data for LFS and LFW, monitoring data were published on the website for the Global Livestock Early Warning System (GLEWS, http://glews.tamu.edu/Mongolia). GLEWS provides daily pastureland forage growth and forage availability (average forage yield, forage yield, deviation from normal forage yield, forecasted forage yield, and historical average forage yield), daily vegetation growth (standing crop yield and standing herbaceous crop yield), and daily climatic conditions (rainfall, temperature, solar radiation, weather, historical average rainfall, and historical average temperature) (Sheehy, 2012) in the United States, East Africa, and Mongolia. In Mongolia, 502 monitoring points in the region from Ulaanbaatar to South Gobi are available. The forage is estimated by PHYGROW (Phytomass Growth Simulation Model) every 15 days based on monitoring data for the soil, plants, weather conditions, satellite imagery data of the climate, and NDVI (Normalised Difference Vegetation Index). Ground-monitoring sites were visited periodically in the years following the initial establishment to collect forage biomass data for the calibration and validation of the model (Angerer et al., 2009). The distribution of a plant (*Caragana microphylla*) and its factors (aridity versus grazing and fire versus interspecific interactions) in Mongolia was examined using plant species data from GLEWS (Narantsetseg et al., 2014). The data on crop and forage yields from GLEWS was used to examine the effects of climate change on crops, forage, and livestock in the Republic of Mali (Butt et al., 2005). We used the average dry forage data (kg/ha) of a soum with multiple monitoring points and the average of vegetation per aimag unit.

The monitoring data for temperature and precipitation also originated from GLEWS for the CI calculation. According to the definition in Formula (3-2), CI is a combination of the drought index and the cold index. This index is more sensitive to black dzuds than white dzuds because snow accumulation is not considered.

Finally, for the DTA variable, we retrieved road data from WWF Mongolia (http://gis.wwf.mn).

As an example of our datasets, the severity of dzuds in each dzud year is shown in **Fig.5-2**. The spatial pattern of the severity of dzuds in different dzud years is shown. The locations of the aimag centres and transportation networks and the names of the aimags are also shown.

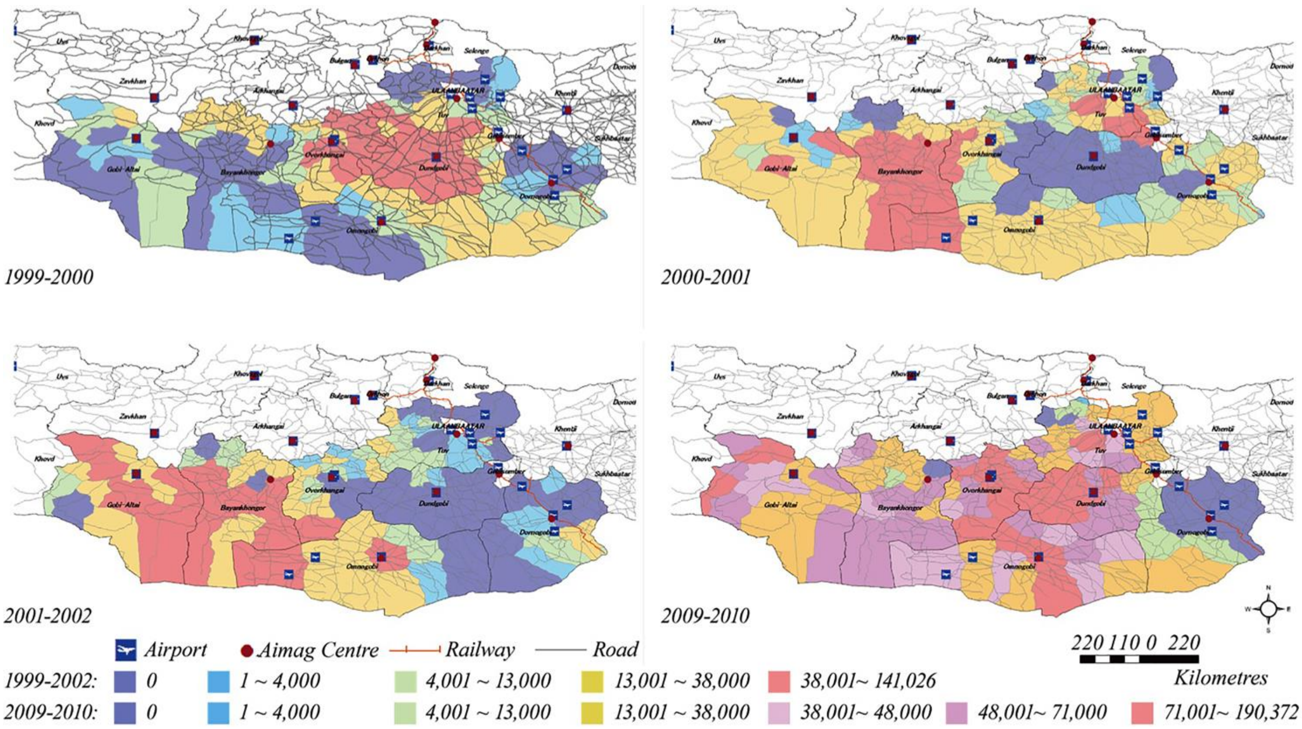


Fig.5-2 The severity of dzuds by soum in dzud years. The map was drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop). Airport, railway, soum centre, and boundary data were provided by the National Development Institute, Mongolia.

5.1.3 Regression Modelling

Table 5-1 shows the results of the modelling of OLS and GWR (with a robust t-value, p-value, and VIF (variance inflation factor)) and for Koenker's BP (Breusch–Pagan) test. The OLS models selected the variables in each dzud year without multi-collinearity using backward elimination following the 1st and 2nd model at 95% confidence levels for significance in the robust coefficient standard errors and probabilities.

In the 1999-2000 case, the 1st OLS model rejected 3 variables: LFW (total number of livestock per unit forage in winter), CI (climate index) and CRL (change rate of livestock). The p-values for these variables exceeded 0.05. As a result of the 2nd model, the PSL (population of small livestock), LFS (total number of livestock per unit forage in summer, and DTA (the distance to the aimag centre) were selected as the significant variables. In the 2000-2001 case, the 1st model rejected the variables LFS, LFW, DTA, and CI. The 2nd model selected PSL and CRL. In the 2001-2002 case, the 1st model rejected LFS, CI, and LFW. The 2nd model selected PSL, DTA, and CRL. In the 2009-2010 case, the 1st model rejected LFW, and the 2nd model selected the remaining variables: PSL, LFS, DTA, CI, and CRL.

In summary, PSL was significant in all models. LFS was significant in the initial dzud years 1999-2000 and 2009-2010. LFW was not selected in any of the models, and DTA was significant in three of the dzud years (but not 2000-2001). CI was significant in the last dzud, 2009-2010, and CRL was significant in three dzud years but not in 1999-

2000.

5.1.4 GWR Modelling

The rejection by Koenker's BP test signifies that OLS models have heteroscedasticity. This fact implies that the accuracies of all of the models have geographical nonstationarity. By contrast, GWR is more effective than OLS (**Table 5-1**). Based on the higher R^2 and lower AIC (Akaike information criterion) values, the GWR models performed better than OLS in all of the dzud cases, with proportions of 78-88%.

The accuracies of the models were considered to be high according to Moran's I (Index) test and the condition number. The results in **Fig.5-3** show that Moran's I test was significantly not rejected when using residual errors in each GWR model. This finding indicates that the numbers of explanatory variables in the GWR models were sufficient under the condition of nonstationarity. All of the models in **Fig.5-3** show low condition numbers, except for a slightly high condition number in the eastern region during the 2001-2002 dzud.

In addition, geographical coefficients were calculated based on the exponential function of the distance from the other soums divided by the fixed number of neighbours. We assigned 19 neighbours to the bandwidth parameter based on the average number of soums in each aimag, which is the longest distance for a relationship involving the policies or markets of local herders. **Fig.5-4** is a collection of maps expressing the geographical coefficients of a GWR for an explanatory variable in a dzud year.

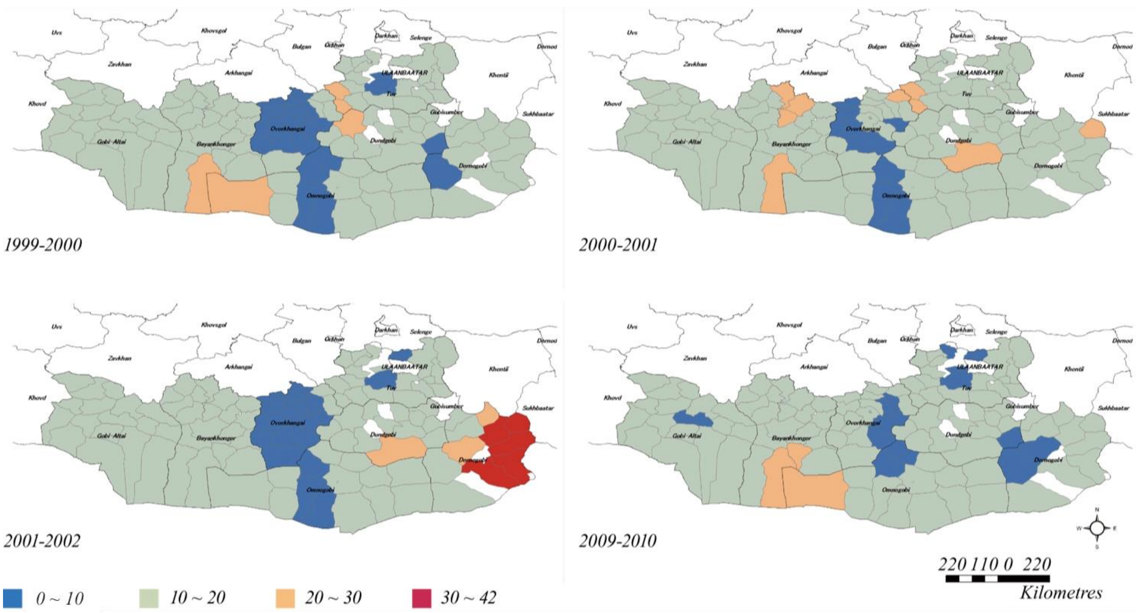


Fig.5-3 Condition numbers of the GWR models in each dzud year. Boundary data were provided by the National Development Institute, Mongolia. The map was drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop).

Table 5-1 Results of the Variable Selection and Model Comparison between OLS and GWR.

Name of Variables, Test and Analysis				Severity of Dzud (1999-2000)		Severity of Dzud (2000-2001)		Severity of Dzud (2001-2002)		Severity of Dzud (2009-2010)	
				OLS 1st	OLS 2nd	OLS 1st	OLS 2nd	OLS 1st	OLS 2nd	OLS 1st	OLS 2nd
Test for Spatial Stationary		Koenker's BP Test	t	46.7	48.4	27.3	21.7	27.1	22.6	17.3	17.2
			p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.008	0.004
Explanatory Variables	Results of OLS Modelling	PSL	t	4.8	4.9	3.0	3.5	5.3	5.5	9.8	9.7
			p	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
			VIF	1.1	1.0	1.2	1.0	1.2	1.2	1.0	1.0
		LFS	t	1.6	3.4	-1.2		-1.2	-	3.3	3.5
			p	0.011	0.001	0.22	-	0.25		0.001	0.0008
			VIF	1.1	1.0	1.0		1.0		1.0	1.0
		LFW	t	0.41	-	-1.2	- -	1.7	-	-1.1	-
			p	0.68	-	0.23		0.09	-	0.30	-
			VIF	1.0	-	1.0		1.0	-	1.0	-
		DTA	t	-5.0	-5.3	0.36		4.5	4.5	-4.9	-4.9
			p	<0.001	<0.001	0.72	-	<0.001	<0.001	<0.001	<0.001
			VIF	1.1	1.0	1.3		1.1	1.1	1.3	1.3

Table 5-1 (Continued) Results of the Variable Selection and Model Comparison between OLS and GWR.

Name of Variables, Test and Analysis				Severity of Dzud (1999-2000)		Severity of Dzud (2000-2001)		Severity of Dzud (2001-2002)		Severity of Dzud (2009-2010)	
				OLS 1st	OLS 2nd	OLS 1st	OLS 2nd	OLS 1st	OLS 2nd	OLS 1st	OLS 2nd
Explanatory Variables	Results of OLS Modelling	CI	t	-0.6		-1.6		0.13		4.3	4.3
			p	0.55	--	0.1	-	0.90	-	<0.001	<0.001
			VIF	1.1		1.1		1.0		1.2	1.2
		CRL	t	0.8		-7.0	-7.0	5.2	5.1	4.8	4.7
			p	0.4	--	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
			VIF	1.1		1.1	1.0	1.2	1.1	1.2	1.1
Modelling		Adjusted R^2 Value (OLS)		-	0.40	-	0.45		0.47	-	0.63
		AIC (OLS)		-	2602.3		2540.5		2558.8		2613.9
	Results of GWR Modelling	Adjusted R^2 Value (GWR)		-	0.88		0.80		0.84		0.78
		AIC (GWR)		-	2491.7	-	2471.0		2410.0	-	1649.7
		Moran's I of GWR Residuals	I	-	0.03		0.02		0.002		-0.03
			p	-	0.42		0.49		0.81		0.62

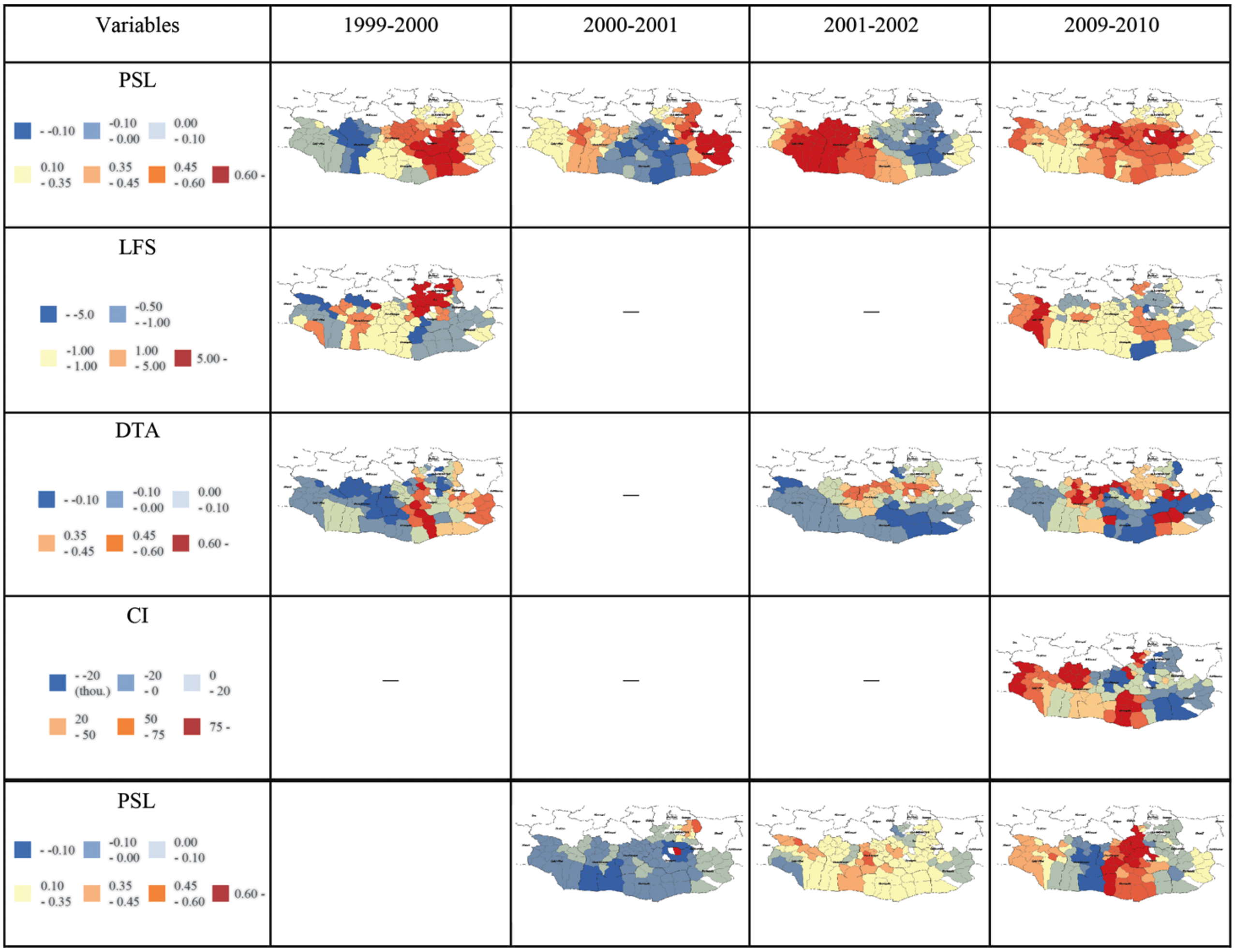


Fig.5-4. **Coefficients of each GWR modelling for the severity of all dzuds from 1999-2010.** The map was drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop). Soum centre, and boundary data were provided by the National Development Institute, Mongolia.

5.2 Discussion of the analysis

5.2.1 Examined Factors and Statistical Significance

The severity of a dzud were effectively modelled by GWR modelling with the presented variables, and these effects were verified by Koenker's BP test. The statistical significance of the GWR models was tested by Moran's I test with residual errors and condition numbers of the models according to the thresholds of the condition numbers (Delaney et l., 1986; Mason et al., 1991). **Table 5-1** shows the results of the tests, in which higher R^2 values and lower AICc values indicate a better performance of the models. Based on the comparison of the R^2 and AICc values between the GWR and OLS, the GWR models performed better than the OLS models in all of the dzud years, with accuracies of 78-88%. In a previous study, a statistical model at the aimag level concluded that a linear model could not adequately represent the livestock loss rate as a result of the dzuds (Tachiiri et al., 2008). Our study supports this assertion, with a relatively low value for the R^2 of 0.40 to 0.47 produced by the OLS in the dzuds of 1999-2002. This result is also consistent with another previous finding that the dzud impact factors vary by geographic locations (Sternberg, 2010). The present study quantitatively clarified the geographical variations of each factor according to geographical coefficients. The random residual errors of the GWR models show that the explanatory variables of the GWR models effectively describe the geographical differences in the severity of the dzud. The explanatory variables of every GWR model explain the factors that contribute the severity of a dzud at the unit of a soum.

The significant variables in each dzud case in **Table 5-1** are summarised below.

The PSL was significant in all models. Dozens of goat and sheep were frozen during the winters from 1999 to 2002 (Siurua & Swift, 2002) and 2009-2010 (Fernandes-Gimenez et al., 2012a). The mortality of small animals was the highest in all types of livestock (Sternberg, 2010). Herders prefer small animals because they are more economically productive, display faster breeding, and are more marketable than large animals (Murphy, 2010).

The non-significance of the LFW indicates that the dzuds are not directly affected by foraging in the winter. This result should be understood in reference to the phenomenon itself, notably white dzuds. Regardless of the amount of forage in pastureland, the forage is unreachable when covered by heavy snow or ice.

The LFS was significant in the initial dzud years, 1999-2000 and 2001-2001, but not in the subsequent years, 2000-2001 and 2001-2002. In these subsequent cases, the animals, particularly small livestock, were already weakened by the harsh weather in previous seasons.

DTA was significant in three cases but not in the 2000-2001 case. The practical mitigation effect of emergency assistance is largely dependent on the accessibility to aimag centres from the soums. Poor infrastructure limits the accessibility to remote soums and isolated herders (Sternberg, 2010). The State Reserve Agency, a department of the National Disaster Management Agency of Mongolia under the direct supervision of the prime minister, provided emergency fodder in the early spring of 1999-2000, 2001-2002 (Siurua & Swift, 2002) and 2009-2010 (Addison et al., 2014). In the dzud of 2001, the international involvement was small because the severity of the dzud was limited to fewer provinces, and no appeal to donors was put forth by the Mongolian government. Small amounts of food and fodder were provided early in the dzud by the State Reserve Agency to all affected areas, but the recipients were required to pay for the transport costs, leaving the poorest unable to afford the aid (Siurua & Swift, 2002).

The CI was significant only in 2009-2010 in the GWR model. In the dzud of 2009-2010, a drought occurred in the summer of 2009 and the winter was severely cold (UNDP & NEMA, 2010). However, the combination of the drought and cold index do not properly reflect the weather conditions of a dzud when a drought is not followed by severe cold. This result supports the assertion in a previous study of no association between the summer drought and winter freezing weather in the study sites for the dzud episodes from 1987 to 1999-2001 (Sternberg et al., 2009). A relatively dry period was noted in the summer of 2007, and the following winter was cold in our study area (**Fig.5-5**), similar to the climate conditions of 2009-2010. A similar pattern was also observed in 1980-1981. However, no severe dzud was reported in those years.

A rapid growth of livestock population mentioned above is essentially caused by a sharp increase of newborn animals. A positive coefficient of CRL reflects the effect of newborn animals whereas a negative coefficient reflects the effect of dead animals. New-born animals are vulnerable to environmental changes (Derry, 2009), and they are prone to die during harsh winters. This variable was significant in three dzud years, including the initial case of 1999-2000. Additionally, we noted that the CRL was significant in 2009-2010. This gap might result from the differences in the increase in the livestock population over these 10 years. The increase in the total population of animals over 1998-1999 was 671,371 head, 469,083 head of which were small animals. However, the increase was 735,434 head over 2008-2009, of which 594,513 head were small animals. Physically smaller animals were born in 2009 than in 1999, with this large increase in the number of goats over the last decade resulting from the potential income from cashmere (Sternberg, 2010). By contrast, the number of dead animals was high in 2000-2002. Results of our modelling show that dzud was more severe when there the increase in the number of newborns in the initial dzud episodes was larger. Said in another way, there was an increased number of deaths in the successive dzud episodes, which contributed to the spatiotemporal heterogeneity of the severity of dzuds.

In summary, the GWR models examined the contributing factors to dzud with an R^2 over 0.8. The residuals of the GWR models may result from two sources: the contribution of snow or ice coverage and geographic differences. The precipitation data of GLEWS were based on satellite weather data from NOAA, and the amount of snowfall might not be entirely accurate. The above analysis showed that the variables affecting the severity of the dzud are primarily social, in contrast to the currently held view that a dzud depends on climate conditions such as extreme weather. This result supports the assertion that social factors more strongly influence the severity of a dzud than natural factors (Sternberg, 2010).

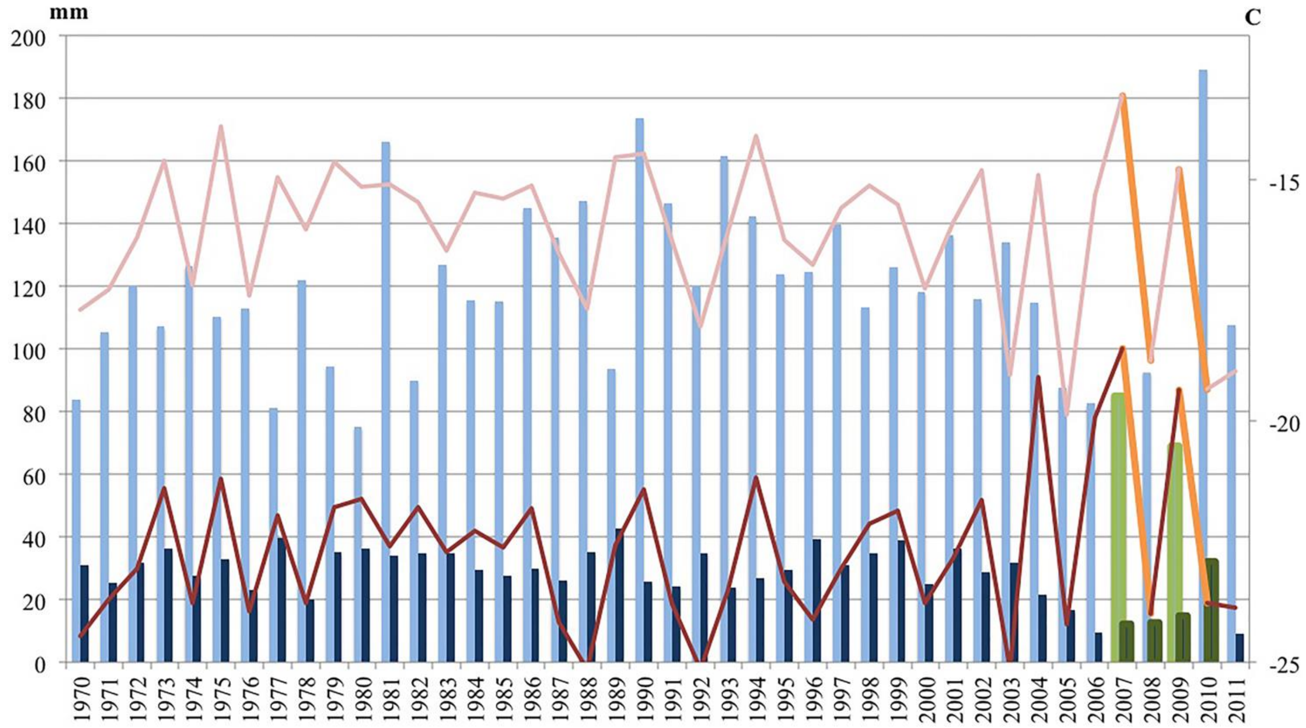


Fig.5-5 Precipitation and temperature in the study area. Colour: Aqua, Precipitation from May to November; Dark Blue, Precipitation from December to April; Pink, Average Temperature from December to April; Dark Red, Minimum Temperature; Orange, Temperature Changes from 2007 to 2008 and 2009 to 2010; Green, Precipitation from May to November in 2007 and 2009; Dark Green, Precipitation from December to April from 2007 to 2010. Data were provided by GLEWS (http://glews.tamu.edu/Mongolia).

5.2.2 Geographical Examination of the Consistency of Factors Influencing the Severity of Dzuds

The results of condition number showed that the models geographically fit to the actual dzud. Statistical data (available at: http://www.1212.mn/en/) and previous studies and materials support the geographical consistency of the modelling results in this study.

First, in terms of the PSL, the statistical data showed the identical trend in the loss of small animals in all dzud cases. In 1999-2000, a serious loss of small animals was noted in most soums of Dundgobi and in the eastern part of Omnogobi Aimag, and severe loses were noted in most soums of Bayanhongor Aaimag. The loss of small animals in the soums in the eastern part of Dornogobi Aimag was more severe than in the soums of Dundgobi Aimag in 2000-2001. Small animals in most soums in the Gobi-Altai and Bayankhongor Aimags had more serious damage than the soums in the Dundogobi or Dornogobi Aimags in 2000-2001. In 2009-2010, whereas most of the study areas lost a serious number of small animals, Dundgobi and the northeast part of Bayankhongor displayed the most severe losses.

Second, in terms of the LFS, the Global Livestock Early Warning System (GLEWS, http://glews.tamu.edu/Mongolia) showed a decreasing trend in the forage in Tuv and some soums of Bayankhongor. In particular, the forage for cattle in Tuv and for small animals in most soums of Banakhongor Aimag decreased. The majority of soums in Dundgobi Aimag and the eastern part of Omnogobi Aimag did not display this trend because no substantial decrease in forage was noted in the summer of 1999. In the summer of 2009, soums in the Gobi-Altai experienced a serious foraging problem, whereas the southern part of Tuv did not exhibit these foraging limitations.

Third, in terms of the DTA, the absence of emergency fodder and the poor condition of the infrastructure for accessing the aimag centre undermined the effect. In the soums with higher DTA coefficients, the fodder aid was speculated to be insufficient or unreachable (Heltberg et al., 2012). The closure of the State Emergency Fodder Fund has also forced herders to rely on their own resources (Suttie, 2006) because of poor road infrastructure. For instance, the soums with the highest coefficients in the case of 1999-2000 suffered because of their disconnection from national roads until 2001 (Dugerjav, 2009). However, the road conditions were partly improved after 2004 along with the development of mineral or mining resources. This change caused the coefficients of this variable to decrease in 2009-2010. The coefficients of the soums in northern Bayankhongor Aimag and Dundgobi Aimag were high in 2001-2002 and 2009-2010. The soums in the Khangai Mountain region are prone to heavy snows in the winter and spring (Batjargal et al., 2002), hindering the deliverability of emergency fodder.

Fourth, as noted above, a high CI signifies the possibility of black dzuds. Geographical differences among soums are reflected by the coefficients shown in **Fig.5-4**. In 2009-2010, soums in northern Bayankhongor Aimag, such as Bayantsagaan Soum, experienced a black dzud, whereas Jinst Soum, in the same aimag, suffered from a white dzud (Altanbagana et al., 2010). Select soums also reported a black dzud in 1999-2001.

Finally, the CRL examined the difference between the successive and initial dzuds. The CRL showed decreasing livestock populations in successive dzuds and increasing populations in initial dzuds. Negative coefficients indicate greater losses. In 2000-2001 and 2001-2002 (the successive cases), negative coefficients were observed in most of the soums. **Fig.5-2,** produced by statistical data, shows that the excessive decrease in the livestock population in the initial dzud reduced the severity of the dzud in consecutive years. However, in 2009-2010, the increased livestock population contributed to a greater loss because of the high number of new-borns. This result is shown in the statistical data; the rate of livestock in Omnogobi Aimag and Dundgobi Aimag remarkably increased from 2008 to 2009.

Therefore, the holistic analysis with a GWR clarified the factors driving the severity of the dzud and their spatiotemporal heterogeneous patterns at a regional scale.

5.2.3 Spatial Autocorrelations of Geographical Coefficients

The geographical coefficients in the GWR models of the severity of a dzud can be categorised into several classes (**Fig.5-4**). The spatial autocorrelation of the coefficients with each variable is evident. In addition to the geographical-temporal pattern of the DTA and the CRL as discussed above, a type of temporal shift in the coefficients in the dzud cases is noted. For instance, the coefficients of PSL were higher in the east than in the west in the initial dzud years of 1999-2000 and 2009-2010. However, the areas with the highest coefficients in the west in 1999-2000 were the lowest in the following year, 2000-2001, and the areas previously with lower coefficients became areas with higher coefficients. These temporal patterns increase the complexity of the dzuds. The severity of the loss rate in the case of successive dzuds is consistent with the conclusion of previous studies (Tachiiri et al., 2008), namely, a large loss in a previous year is associated with a large number of weakened livestock. Hence, the spatial pattern of the PSL is deemed temporally correlative in successive dzud events. Moreover, the influence of the variable changes with the composition of the livestock every year.

In terms of the LFS, the condition of overgrazing and preparation of forage in summer strongly affects the pattern of the coefficients. Overgrazing in the central (Tuv) aimag had been restricted for years (Marshall et al., 2004); as a consequence, large numbers of rural people and livestock moved to Ulaanbaatar beginning in the 1990s (Sheehy & damiran, 2012). The Altai mountainous regions, such as Gobi-Altai Aimag, experienced serious overgrazing problems, reducing the livestock productivity (Laurie et al., 2010). In those areas with high LFS coefficients, chronic overgrazing has been confirmed, and 70% of pastureland in Mongolia has been degraded. This condition has contributed to the severity of the dzud and reduced the pastureland resource (Rasmussen & Dorlig, 2011). In 2009-2010, soums such as those in Bayankhongor Aimag (**Fig.5-1**) were confirmed as having experienced hoof dzuds (Fernandez-Gimenez et al., 2012a). Recently, however, herders are becoming aware of the importance of stocking forage during the summer and autumn, notably around Tuv Aimag (Rasmussen & Dorlig, 2011). Therefore, the preparation of forage in the summer mitigates the severity of the dzud.

In addition, spatial pattern of CRL has a possibility to consist of livestock species. Below figure showed almost perfect match between the geographical coefficients on CRL and livestock distribution of main small animals in 1999 (Barzagur, 2002). Current version for 2010 version, not published, has also has a possibility to fit to the coefficients on the result of 2009-2010 case. If the fit would show in both case, the livestock distribution should be additionally considered in dzud adaptation, for example, weak type on physics to survive winter on overgrazing.

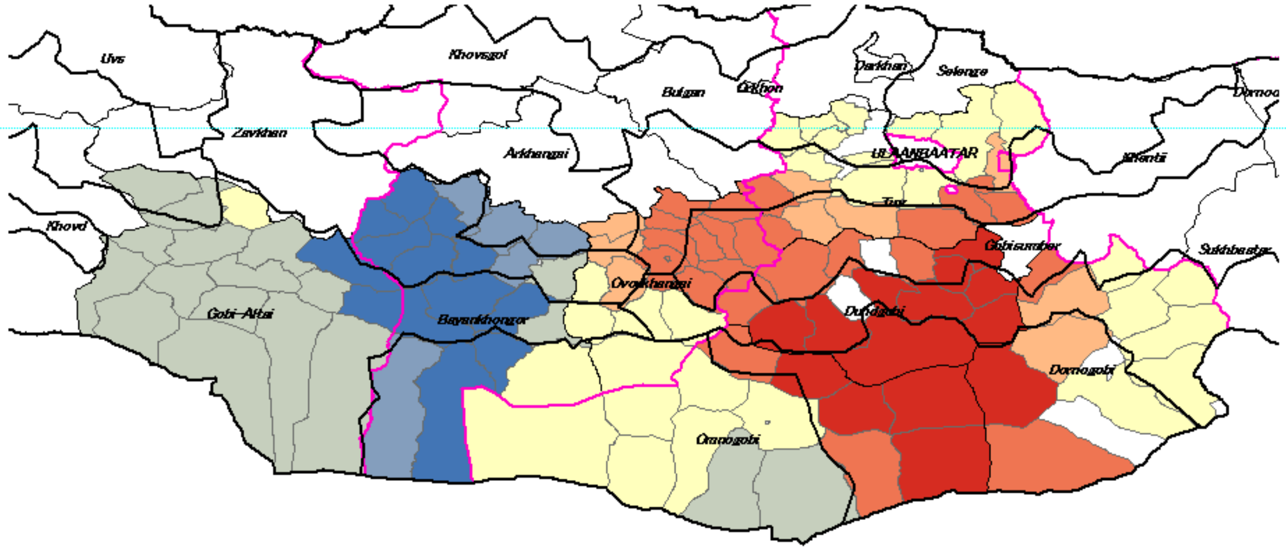


Fig.5-6 Spatial distribution of dominant animal-species of sheep and goat (Barzagur, 2002) with geographical coefficients on PSL from GWR model of 1999-2000 dzud. Each zone drawn by black line show the spatial distribution of animal species. Colors show the coefficients on PSL, whose legend is same as shown in **Fig.5-4**. The map was drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop).

5.2.4 Limitations and Recommendations for Future Research

This study showed the major factors contributing to a dzud with high determination of coefficients at a regional scale. Select factors, such as landscape features, land use, herd size, and mobility (Batima et al. 2008; Murphy 2011; Fernandez-Gimenez et al., 2011; Fernandez-Gimenez et al., 2012a), were not included. These factors might be important at the local level but are difficult to model at larger scales.

Our results allowed us to determine that the climate index is not always a contributing factor to the severity of a dzud. This is particularly so when a severe winter is not followed by a drought summer. This study also did not discuss whether the climate index influences dzud as the threshold or not, which means that most of livestock animals die if the index is over the threshold for instance. Therefore, an index to show weather conditions that contribute to the dzud remains to be examined (Tachiiri & Shinoda, 2012; Rat et al., 2015)

Regardless of its limitations, this study verified the performance of strategies for mitigating the severity of dzuds as well as for adapting to dzuds at the national and the regional level.

First, based on the results of the PSL and CRL, soums should control the population of small livestock such as goats and sheep (in particular, new-borns) as a fundamental strategy to mitigate the severity of a dzud event. Hedging against current risks of livestock loss causes herders to keep as many living animals as possible in the winter. Consequently, more new-borns and small livestock populations die in comparison to adults or large livestock because they are vulnerable to environmental changes (Marshall et al., 2004; Derry, 2009). Herders should manage the population of livestock with consideration of the capacity of the grassland and strengthen the livestock to adapt to harsh environments. Herders could reduce small livestock by selling to markets at the beginning of the winter. A soum in Selenge Aimag, Sant, located in the northern part of the country and outside of our study area, has benefited from the practice of this strategy. Groups of herders in Sant engaged in early offtake to reduce livestock numbers before the dzud of 2009-2010 (Rasmussen & Dorlig, 2011).

Second, based on the results of the LFS and DTA, soums should improve their preparedness by stocking fodder for the winter. This process has partially been implemented. For instance, funding for the fencing of hay fields and for hay-making equipment was valued at MNT 1.2 billion in many aimags. Select soums in the western part of Omnogobi Aimag prepared emergency fodder, resulting in decreased losses (Suttie, 2005) during successive dzuds. The fodders are often stocked in shelters at a winter campsite. Whereas this strategy may improve the overwintering rate, the situation of overgrazing would also be carried over, increasing the vulnerability of the herd in the next year.

Therefore, we strongly recommend the first strategy, controlling the animal population, particularly of new-borns and small livestock.

6. System development to support early adaptation in Mongolian Plateau

6.1 Development of a WebGIS Tool for rangeland management in Inner Mongolia

6.1.1 Methods

1) System requirement

Accordingly, in recent years, there are increased cases where geographical information is managed and distributed using the Web and WebGIS (Kelly and Tuxen, 2003; Dragicevic and Balsam, 2004; McCall and Minang, 2005; Auer et al., 2010; Lucas et al., 2011). For WebGIS development, Web applications have been developed using ESRI ArcIMS commercial software (http://www.esri.com/software/arcgis/arcims/index.html) in many cases (Kelly and Tuxen, 2003; Dragicevic and Balsam, 2004; McCall and Minang, 2005; Mathiyalagan et al., 2005). In the development, a large initial cost was required for technical knowledge and skill of geographical information, such as the preparation and processing of GIS special files including vector data and raster data, and software introduction. Moreover, the data delivery method is according to OGC (The Open Geospatial Consortium) standard specifications, and while the method can deliver the display area of data as an image, it is unsuitable for display of continuous space. However, since the start of GoogleMaps in 2005, WebGIS suitable for display of contiguous space has been developed, in which data delivery system called tile layer method is installed. Since this is an open source for which the initial cost of the development is small, development and dissemination of the WebGIS has been increased (Morris, 2006; MacEachren et al., 2010; Auer et al., 2010; Lucas et al., 2011).

The spread of the WebGIS is not only due to low initial cost, but also the increase in development know-how through publication of Web contents such as blogs and lowered technical wall (Morris, 2006). Development of the open source WebGIS is basically a JavaScript language or the like used for Web script; however, because it does not support server loads due to large data volume and object-oriented complex language processing (Zukuan et al., 2010), it needs some technical adjustment such as, dividing Web pages into multiples for detailed processing.　Thus, on the client side, an inconvenient situation arose since processing was divided into multiple pages, accordingly, on the development side, establishing multiple similar scripts were necessary. Therefore, when developing a Web application that is integrated as a management tool, the use of such Web scripts is unlikely to be suitable.

To improve the development environment, Flex based WebGIS application provided by Adobe Systems can be used. Flex-based Web application can be developed using object-oriented language with ActionScript, compiled with the development environment, Adobe Flex Builder, provided free by Adobe Systems, and compressed in the swf file format that is specialized for the development of Web application. The reproduction requires, a reproduction software for the browser, Adobe Flash, provided by Adobe Systems, but in comparison to conventional Web scripts,, the reaction rate is about 1.4 times faster in processing scripts of the same WebGIS (Zukuan, 2010), and approximately 1.5 times faster than the commercial software ArcIMS (Peng et al., 2010). Combining various existing open source GIS platforms with these development environments, WebGIS application that visually displays the attribute data of GIS has been developed (MacEachren et al., 2010). Further, applications with improved usability have been developed by receiving data through the WebGIS application from clients, and applying high design performance of Flex to a method of displaying attribute data (Auer et al., 2010). However, as a future issue, Auer et al. (2010) indicated that the importance of spatial databases that can link to data tables within a variety of spatial scales. Data tables for narrow areas are often included in the global data table. For example, the spatial range where certain species is planted is included in a broader spatial range, afforestation, and the spatial range of this afforestation is included in a further broader spatial extent, village. Data of plant species and afforestation area assumed to be included in species or afforestation data table depends on the size of village area, which is spatial-dependent. The challenge is how to define and effectively systemize these nested structures.

As a Web delivery method, the development environment by Apache was used. In order to use satellite images and maps that clearly show the status of desert afforestation activities throughout by the NPO, GoogleMaps for Flash was adopted as the mapping interface platform. The operating platform used in our study is software that is required for application frames and runtimes as defined in statements by Yano et al. (2004). The development language for mapping interface was ActionScript, and to embed publically available Google maps into Flash applications, API (Application Program Interface) for Flex developers, GoogleMaps API for Flash (http://code.google.com/intl/en/apis/maps/documentation/flash/) was used. Further, the code described by ActionScript language was compiled into swf extension files using Flex Builder, and for the swf files to be viewed by browser, JavaScript was employed. Images from GoogleMaps were incorporated into background images for the mapping interface, and to visually confirm the effect of desert afforestation, we enabled originally acquired multiple satellite image data to be published by the data entry staff. For reading raster data such as satellite images and vector data such as administrative district boundaries, the open source GIS platform MapServer was used. The processing relationships of multiple GIS data was described with MapFile, and by using MapServer structure that can use MapServer CGI for imaging, it was possible to overlay the images on the GoogleMaps layer.

In addition, for the data entry staff to submit text and image data to the database through the mapping interface, CGI, which allows data submission, was developed using Perl language. Data submitted through CGI was stored in a database using MySQL, and this constructed the spatial database. In the spatial database, data tables were prepared according to spatial scale, and for these to be arranged and shown as figures on the mapping interface, display files of XML format text were built with PHP language.

The system generated by this development environment could be used by the data entry staff to store information on the group activity histories and activity location in MySQL database through the browser and the GoogleMaps based mapping interface. The data entry staff and site and external viewers can use the same GoogleMaps interface to access GoogleMaps and obtained satellite images as background, allowing them to visually view submitted information on activity location and other spatial locations. Thus, by using only one GoogleMaps interface, spatial information can be prepared and viewed.

Table 6-1 Development Environment for a WebGIS Tool of rangeland management.

OS	Windows XP 64-bit Edition
Web construction	Apache1.3.33
Map engine	MapServer 5.2.0
Definition of the mapping	MapFile
Database	MySQL 5.0.67
Coding environment	ActionScript 3.0
	JavaScript
	Perl 5.10.1
	PHP 4.4.2

2) Study Area

In the development of this system, we received cooperation from the NPO Green Network as a test case. Green Network is an organization started in 2000, and engaged in desert greening and desert prevention activities. Main activity region is the Horqin sand dunes of eastern Inner Mongolia, China. The organization has 4 or more on the Board (currently 6), and 1 or more (currently 1) manager(s) that compose the Council and the executive body. The headquarters are in Tokyo and the regional office in Tongliao, Horqin Zuoyi Houqi, Inner Mongolia, China.

The regional office is staffed by local residents and is divided into the information bureau, and green land management and general affairs sections. The green land management section plants trees in sand dunes and manage fences and afforestation. Further, it is responsible for collecting overall information of target villages in addition to greening operations. The information bureau digitizes and manages the data collected locally by the green land management section. In this study, NPO staffs were referred to as data entry staff, and heads of target village and parties who donate to the NPO were referred to as site viewers and external viewers, respectively in this study.

3) Preliminary survey on operation contents and data management

The results of the interview to NPO about their operation were shown in **Fig.6-1**. To correspond with geographical space, we could categorize space into 6 spatial scales. As the spatial scale decreases from a wide to narrow area, a space including multiple villages was indicated by “zone”, a village and its internal orientation were indicated by “area”, afforestation fences that are managed from the year the trees were actually planted were indicated by “block”, fenced areas with planted trees were indicated by “planting block”, a forested lot which was owned by each donor was indicated by "unit", and a point where plant growth, biomass amount, and vegetation cover percentage have been observed over many years was indicated as "fixed point". Further, data on plant growth, biomass amount and vegetation cover percentage were surveyed and obtained using the quadrat method (Japanese Society of Grassland Science, 2004) by the Green Network local staff.

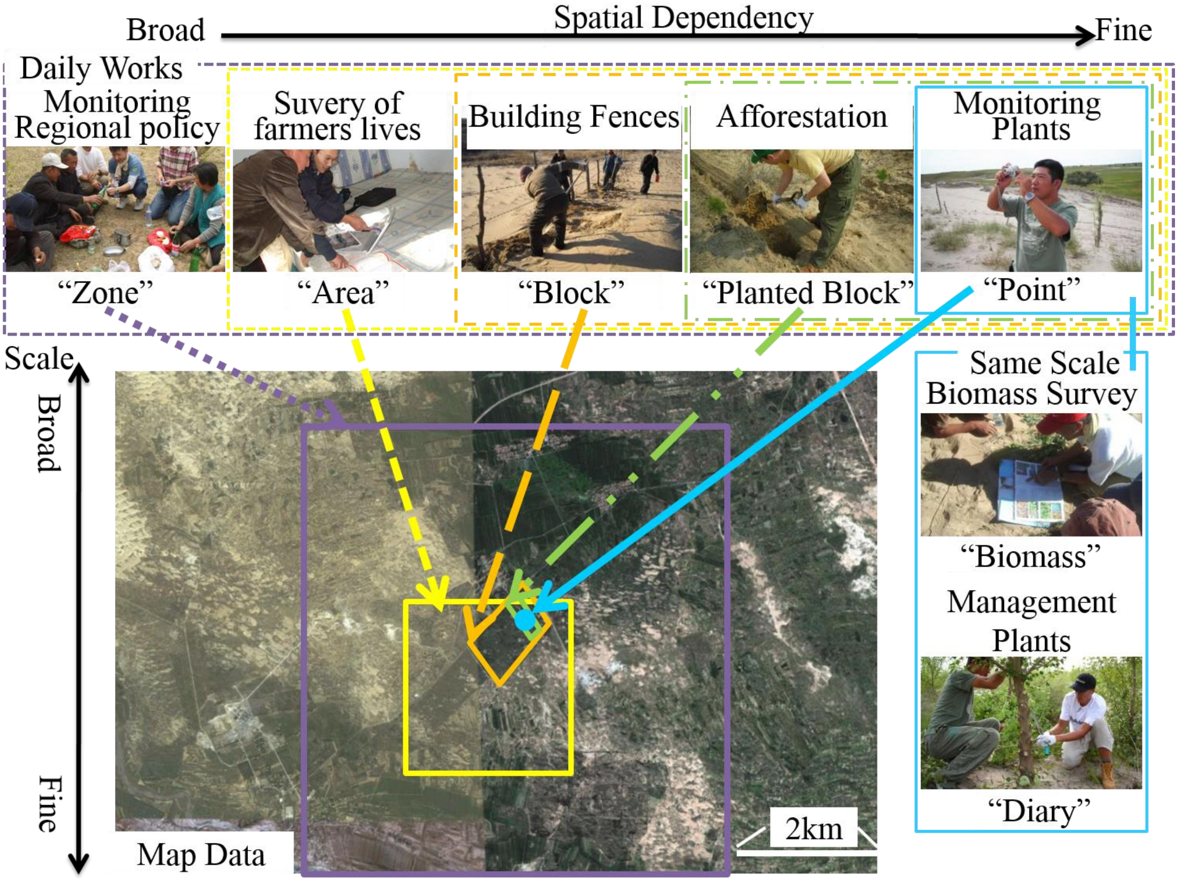


Fig.6-1 Relationship between operations contents and spatial scale (area of the image: 140 km^2). NPO named Green-Network provided all the photos.

4) Design of spatial database

Methods for hierarchical management of information by WebGIS were investigated. The prepared spatial database was arranged in the GIS data format, geometry, and main attribute information. The results are indicated in **Table 6-2**. Since data managed by the NPO is reported mainly to the village manager on the site, and in Japan, to the donors for the NPO activities, the covered spatial scales differ as shown in **Table 6-2**. For this reason, when data for each hierarchy is displayed, it is necessary for the spatial scale to be cross-profiled and the data record referenced, extracted, and outputted. Further, the size of zone and area of district boundaries shown in **Table 6-2** are not accurate, and local residents also have taken areas approximately; geometry type is set to point and crossing spatial scale by this way when the geometry differs, is a consideration.

Accordingly, a hierarchy structure that contemplated operations and management form was defined, and within upper and lower bounds, a data structure with spatial inclusion relationship was designed. In each table, key items that indicate the spatial inclusion relationship were prepared and composed so that tables with the spatial inclusion relationship can be linked. An example of a linked table is shown in **Fig.6-2**. By this method, the key items were set to indicate spatial scales, so as to manage spatial data using a relational database.

Table 6-2 Structure of spatial database.

Scale	Data Table	Geometry	Attributes	Subjects
Broad	Zone	Point	Regional policy	Governors and their staffs
	Area	Point	Village policy	
↓	Block	Polygon	Fences for fodders	
	Planted Block	Polygon	Date of planting	
	Unit	Polygon	Donor	Donors
Fine	Point	Point	Height of the plant	
	Biomass		Each plant biomass	
	Dairy		Daily report	

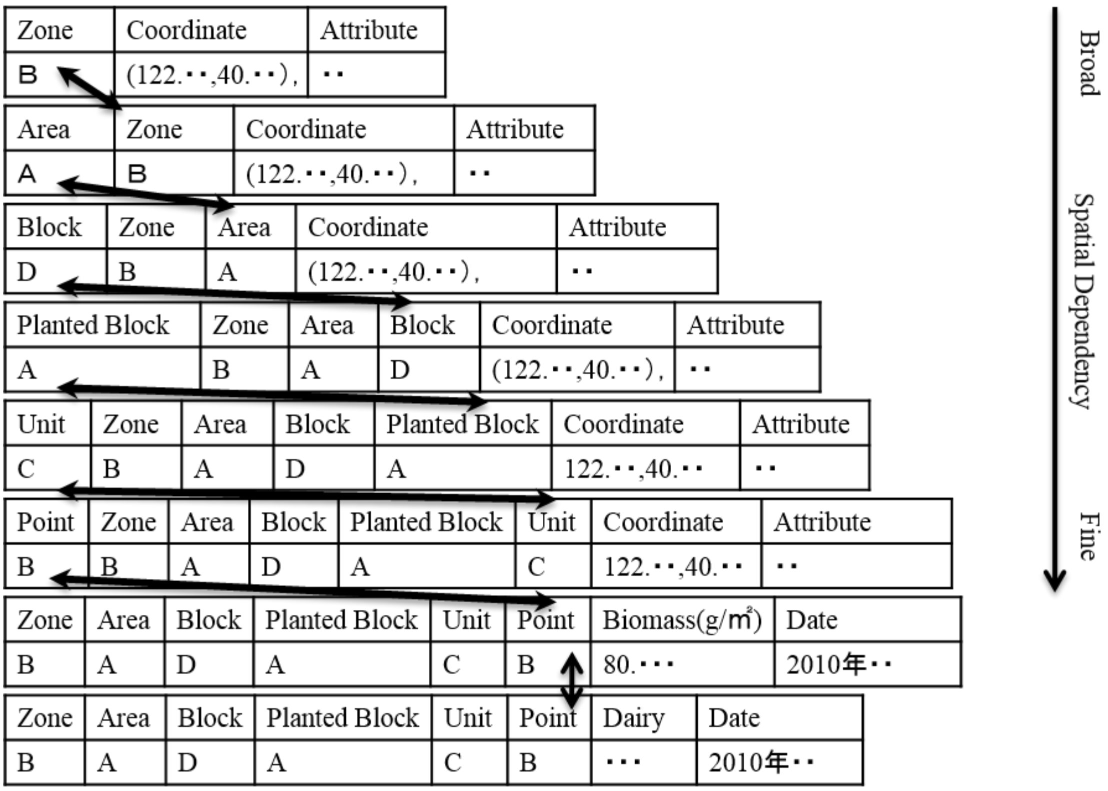


Fig.6-2 Spatial relationships among tables of the spatial database. Construction of each table is shown in **Table 6-2**. Arrows between each field name has a relational structure on the database.

5) System Structure

The system structure is shown in **Fig.6-3**. In this system, a map displayed on the GoogleMaps interface is composed of 3 layers. The bottom layer is the GoogleMaps base map (① in **Fig.6-3**) which displays a map and satellite image data delivered from GoogleMaps, the middle layer is the MapServer base map (② in **Fig.6-3**), constructed and transmitted with MapServer CGI using raster data such as satellite images and vector data such as district boundaries stored in the original server, and the topmost layer (③ in **Fig.6-3**) shows location information of afforested lands using GoogleMaps API. Data managed by the database shown in **Fig.6-2** corresponds to the topmost layer and prepared based on GoogleMaps and MapServer. Further, the server was established in Japan.

The MapServer base map was constructed to be able to deliver multiple GIS data as one image in the WMS (Web Map Service) format that is a standard specification of the Open Geospatial Consortium (OGC), an organization that decides Web maps delivery specifications. GoogleMaps is defined by a geodetic reference system named EPSG:900913 that takes 6,378,137 m for the radius of sphere form of earth, and a coordinate system based on the Mercator projection. Thus it is not included in the coordinate system defined by MapServer which delivers WMSdata. For this reason, ActionScript class package that provides a method converting the projection method to that used in GoogleMaps, was prepared for data to be overlaid.

GoogleMaps preparation layer is a drawing that displays data prepared on the mapping interface and location information contributed through the process using the GoogleMaps API.

These structure layers enable to create spatial data using GoogleMaps API while viewing various maps and image data. Further, it is possible to set the image transparency for filter display on the mapping interface of the MapServer base map layer, and view the location relationship with the GoogleMaps base map layer while operating.

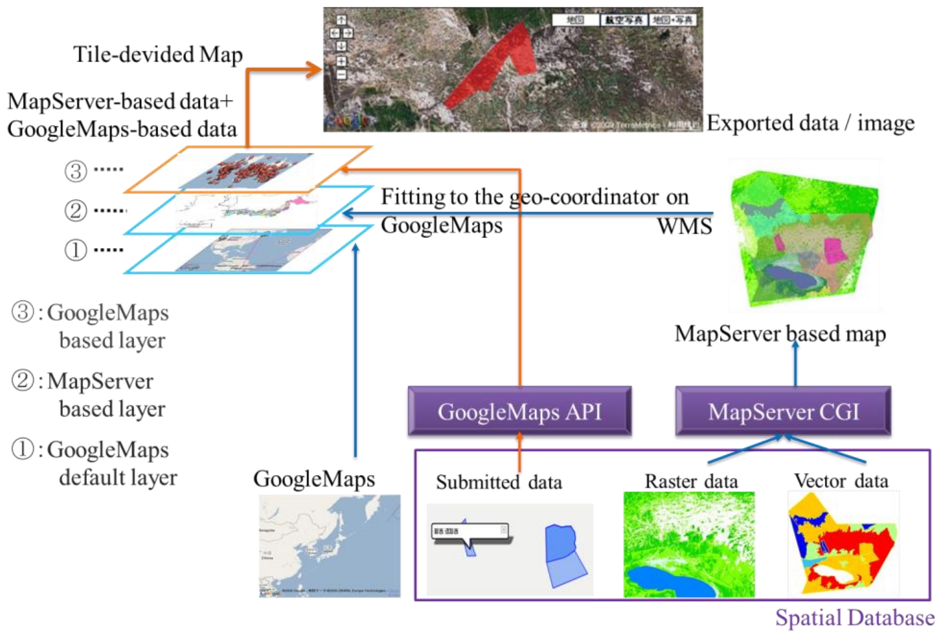


Fig.6-3 Layer structure of a WebGIS tool for rangeland management. Three types of the GIS data were overlaid, which could control on the Google Maps based interface.

6) Data processing script

Data processing script can be broadly divided into data generation using the MapServer and data transmission using the GoogleMaps API. As the GIS data used on the MapServer base map shown in **Fig.6-3** is used for background images, and it is managed by the MapFile directly from the source directory. For this, GIS data is processed by calling through the GoogleMaps interface, but writing process to original data, such as attribute alterations and geographical information processing are not performed.

For the data prepared on the GoogleMaps preparation layer, latitude, longitude and attribute location information are submitted as text information via CGI, to MySQL database. Modification of the stored data is processed by casting data from CGI to the database through the mapping interface.

Submitted and stored data is managed in the MySQL database, but when data is displayed by GoogleMaps, results should be sorted such that each hierarchy record matches, and represented in a hierarchy structure format. Accordingly, data was called from the database using PHP script to display on the GoogleMaps in XML format.

XML formatting was written as shown below. The XML syntax is similar to the nested structure of spatial structure shown in **Table 6-2**, and the highest tag is <data>, and within that, there are many <zone> tags which indicate zones. The <zone> tag contains <area> tags indicating areas, and the <area> tag contains <block> tags indicating blocks. Tag termination is indicated by a slash inserted into the tag name, and <data> concludes by </data> in the last line. Each tag <> contains attribute data and in each table in the database, field name is found in the left of =, and data content is in the right. Due to the large amount of the actual data, only simple example of description of the spatial nested structure in XML was shown here.

```
<data>
<zone zone_id='1' zone_latlng='42.・・・、122.・・・' zone_name='gabou'・・・>
    <area area_id='1' area_latlng='42.・・・、121.・・・' area_name='～(gs)' zone_name='gabou'・・・>
        <block block_id='4' block_latlng='(42.・・・、 121.・・・)、(42.・・・)' block_name='gsc03' zone_name='gabou'
area_name='～(gs)'・・・>
        </block>
        <block block_id='3' block_latlng='(42.806120494030075、 ・・・>
        </block>
    </area>
</zone>
<zone zone_id='2'・・・>
    <area ・・・>
    </area>
    <area ・・・>
        <block・・・>
        </block>
    </area>
</zone>
</data>
```

With the nested structure from wide to narrow range, relational data table structure in the MySQL was output in a hierarchy data format; display order and search on the GoogleMaps interface became feasible.

Based on the above data transceiver method, the system was constructed to allow interactive data transmission of the data on the GoogleMap preparation layer between the data entry side and the server side so that data entry staff could manage geographical information only via the mapping interface.

6.1.2 Results of system development of WebGIS Tool for rangeland management in Inner Mongolia

1) User Interface

The user interface was designed as shown in Figures of **Fig.6.1.1-4** and **Fig.6.1.1-5**. As described above, given different users for by each data hierarchy, an afforested land chart interface as shown in **Fig.6.1.1-4**, which can integrate and visualize data of each hierarchy record, was introduced. **Fig.6.1.1-4** presents the input and basic operation interface for preparation of the chart interface; for data to be submitted by the user into each designed spatial hierarchy, the interface was designed to generate a writing object for the selected spatial scale by preparing spatial scale options on the data entry tab part. Thus, when the spatial scale was designated through a mapping interface by a data entry person, written data based on attributes indicating certain hierarchy prepared on the database can be stored.

The mapping interface shown in **Fig.6-4** applied the GoogleMaps interface, and menu and navigation, and animation slider were prepared using ActionScript. The afforested land record interface depicted in **Fig.6-5** used the GoogleMaps interface only for the map display part and the rest were prepared using ActionScript.

Details of each function are described as follows. Further, ① to ⑤ of 1) and ① to ④ of 2) match the numbers in **Fig.6-4** and **Fig.6-5**, respectively.

A) Input and basic operation

① Maps screen: map can be moved or modified in scale by mouse operation. It can be displayed reflecting overlay or switch of maps selected in ⑤.

② Scaling navigator: map scales can be zoomed in and out. The class used in the GoogleMaps was used as is.

③ Animation slider: animations for changes in satellite images from Landsat satellite ETM+, TM sensor, ASTER satellite VNIR sensor, ALOS satellite PRISM, AVNIR sensor of target areas during multiple past years from 1961 to 2007 can be switched and viewed.

④ Map navigator: switching between GoogleMaps and MapServer, overlay and selection of all GIS data including maps and satellite images taken at separate times in the same year other than periods specified in ③ is possible.

Further, destination can be specified by place name search with texts.

⑤ Data registration tab: contents can be selected for data registration of an afforested land. Data registration not only by drawing on maps with a mouse, but also bulk registration using Excel is available.

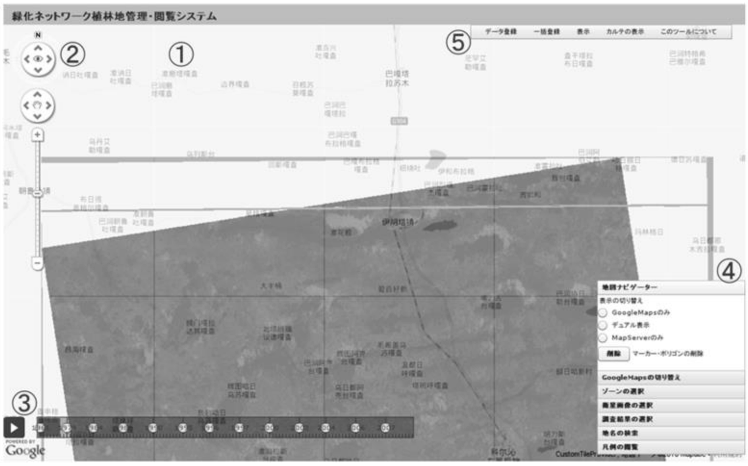


Fig.6-4 WebGIS based interface for data inputting. ① Maps screen, ② Scaling navigator, ③ Animation slider, ④ Map navigator, ⑤ Data registration tab. Each detail was shown above.

B) Afforested land chart

Information on the afforested land can be displayed in a chart style and is composed of four items below. When space hierarchy is selected on ⑤ of **Fig.6-4**, the map disappears from **Fig.6-4** and **Fig.6-5** is displayed on the interface.

① Basic information: information such as area of afforested land and vegetation coverage at target location is displayed as text in a table format.

② Vegetation coverage graph: changes in vegetation coverage of afforested land can be viewed in the graphs.

③ Target location image: With the satellite image selected in ④ of 1) as a background, spatial information, such as points or polygons, indicated by the chart can be viewed.

④ Fixed point image: transition of images taken at a fixed point over the years can be viewed.

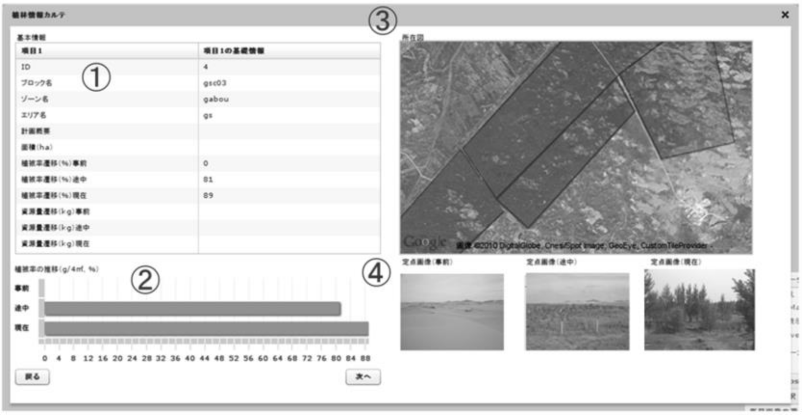


Fig.6-5 WebGIS based interface for data visualizing. ① Basic information, ② Vegetation coverage graph, ③ Target location image, ④ Fixed point image. Each detail was shown above.

7) Input and operation of spatial data

Table 6-3 summarizes the actual input results of the spatial database input from the interface depicted in **Fig.6-2**. The number of fields in each designed table, the attribute data year indicating when the entered data occurred, and the number of records of the input data for each designed table are shown as three items in the table. The “resource amount” data and the “daily report” data have a table structure in which data is added to the existing “fixed point” data table in the same location; these tables were prepared separately from each spatial scale table and spatial scale managed by tables was organized in the most narrow “fixed point” scale.

The number of entered records was 6 points for “zone” data, 15 points for “area” data, 39 polygons for “block” data, 471polygons for “planting block”, 943 points for “unit” data, 581points for “fixed point” data, 1042 for “daily report” data and 581 for “resource amount” data.

Table 6-3 A result of the inputted data to the developed database in this study. Construction of each table is shown in **Table 6-2**.

Scale	Data Table	Number of the fields	Years of Attribution	Number of the records
Broad	Zone	6	2000 - 2015	6
	Area	14		15
↓	Block	17		39
	Planted Block	14		471
	Unit	13	2001-2008	943
Fine	Point	11	2000-2014	581
	Biomass	14	2000, 2005-2014	1042
	Dairy	24	2001, 2009-2014	581
	Photos	2	2000-2010	122

The completed system was explained using a manual to actual personnel and was incorporated into actual operations. Staff responsible for implementing the operations was from the information bureau and the general affairs section. This staff was resident who grew up in the farming family and joined the organization in 2009. In day-to-day operations, she manages information obtained from field staffs, and prior to introducing the present system, her duty was to read the boundaries of afforestation fences by viewing visible images from GoogleEarth as initial information.

Further, for system maintenance, database user accounts, and data management was all handled by a Green Network manager. Since data deletion and management were relatively frequently updated, phpMyAdmin (http://www.phpmyadmin.net/ home_page/index.php), a system that allows management of MySQL from the browser was introduced and the maintenance was directly performed from MySQL that constructs the database. For this reason, the security level was dependent on the login system with ID and password.

6.1.3 Discussion on the WebGIS system development

1) Development environment as a Greening Management Tool

In this study, a structure that allows NPOs to manage geographical information data of afforested land via a mapping interface for afforestation activities was developed. For a development environment of the mapping interface, when compared to other WebGIS development examples using Flex, the present system focused on the data management via the Web. To describe the differences between development environment of our system and that of MacEachren et al. (2010) and Auer et al. (2010), a comparison table is shown in **Table 6-4**.

MacEachren et al. (2010) provided a service to display maps of data on various illnesses and infections, and Auer et al. (2010) offered a service to view time-series data of detailed observation points of plant species from vegetation survey data. Both services are for data users from a relatively wide public audience, thus data management is directly conducted on the data server by a system manager. Our system serves to manage and browse the state of afforested lands in response to users, in which NPO staffs manage data on the interface and village manager, donors, and NPO staffs browse the data. The largest difference is that the system manager is different from the data manager. For this reason, compared to previous studies, one characteristic of the present system is that data can be managed without having particularly skills or knowledge.

The systems developed by MacEachren et al. (2010) and Auer et al. (2010) therefore focus on browsing, but not for processing contributed data. Thus, in these systems, PostgreSQL and PostGIS that specializes in GIS data management are used for the database, and designed to directly store GIS data locally instead of the Web. While our system takes into account the contribution processing, GIS data is used just for display and MySQL is used to manage editable location information data in a text format, and takes advantage of the characteristic of smaller server loads at the time of submission.

Further, the system is constructed of multiple spatial hierarchies. Our system is characterized by high number of spatial hierarchies, by which viewers can browse high volume of data in each hierarchy in an organized manner.

Table 6-4 Comparison of Previous Studies and the Present System.

	MacEachren et al. (2010)	**Auer et al.(2010)**	**This study**
Environment of the interface		Adobe Flex	
Managed data	Literatures about infection	Species of herbaceous plants	Afforestation / rangeland management records
Main contents	Number of literatures, titles, published data, keywords	Detail information of the plants, monthly species of the plants	Planted species, their survival rates, each biomass, areas of the planted zones
Managers of the data	System manager (researcher)		NPO staff
Viewers of the data	Researchers		Citizen sector such as NPO staff, donors, and governmental staffs
Data management	Directly in the server		Mapping interface through web browser
Spatial Database	PostGIS		MySQL
Data source of the base-maps	Researchers vector data		Downloaded or purchased satellite imagery data (e.g. from NASA, JAXA)
Map Engine	Geoserver		MapServer
Mapping interface	Openlayers	Google Maps for Flex	
Spatial layers	1		6

2) Platform generalities

When applying the spatial database built in this study to other uses, the data to be managed needs to be arranged into spatial scales and the dependent relationships of each scale organized in advance. During development, building a database without any research and discussion on workflow and data management with stakeholders is impossible. If the spatial scale is a nested structure, using the database construction method described in this study is feasible, and can be applied to a number of cases.

For the entire platform, if a file, which was compiled using GoogleMaps and MySQL, a data table by SQL, and WMS used for the MapServer base map, was delivered by other servers, migration to another server without complex server installation technology would be straightforward. Furthermore, by employing a text-based database using MySQL in the future, for example, it may be feasible to enter data locally using portable devices. Our system can offer a platform where variety of data transmission methods can be functionally added if location information is converted to text data. Thus, the WebGIS platform developed in this study can be generalized while adding future technologies. In addition, compared to the commercial software based on the development by Kelly and Tuxen (2003) and Mathiyalagan et al. (2005), development using an open source platform has low initial costs, and easier to implement financially.

For operational administrative costs as Wang et al. (2005) have pointed out, since data management is made possible from the GoogleMaps interface, staff can manage without outsourcing, but it is not considered at this time that the rental costs are avoidable unless own server is prepared. Moreover, it does not take into account to address for increased number of viewers and entry person, or concurrent access. Future improvements can be, for example, developing a data management form based on data access that is not heavily concentrated on one server, and using free cloud service provided by Google, Inc. that does not require a user fee for a third-party server.

3) Possibility as a Greening Management Tool

A) Introduction of system operations and evaluation of hearings regarding the system

Training for the operation method of the system was conducted at the regional office, with a 2 hour explanation in the evening of 18 August, 2010, 2 hours of actual exercises in the morning of the 19th, followed by 10 days of work. During that time, although there were one or two questions and consultations on the contents of the data to be entered, basically there were no questions on the operation. After 10 days of work, to survey the effects of the implementation in a simple manner, about a 2-hour hearing from the operation staff was carried out on 29 August, 2010. Opinions and impressions were obtained for the three categories of work, contents and functions of the system. Further, the Secretary General of the Green Network, donors involved with Green Network, and the village manager of the target afforestation lands attended similar hearings (**Table 6-5)**. Since these three parties had not done any data entry work, the hearings were only on the two categories of contents and functions of the system. Moreover, the internet environment was maintained in the villages and using the system was found to be feasible. "-" denoted a question, which could not be asked due to lack of time in the table.

From the hearing results on the system contents, four parties indicated that by using the system, changes in afforested land could be easily seen, afforested land could be deeply understood, and the utility of the system for management work of their operation and their planted areas was confirmed. In addition, among the responses of the Green Network Secretary General, the spatial heterogeneity of the growth process and conditions of seedlings were confirmed. Based on this, it was noted that detailed information of afforested land could be obtained through the system. Originally, there was a difference in the volume of information that each of four parties had. Local viewers and external viewers involved in the work had few gains or thoughts on the system, and it was additionally found that the information sought differs depending on the various standpoints of greening activities.

From individual responses, we obtained requests for the system function, but the specific requests were on enhancement of contours, past satellite images and ground images and the like since there was a required increase in the variety and number of published data. In addition, there was little difficulty in the image loading speed in Japan, but in China, the image loading took a long time, which gave stress to data entry personnel. This was likely due to the physical distance between China and Japan at present, and countermeasures such as establishing a server in China can be considered.

Further, from responses on data entry and local viewers' responses on system function, it was pointed out that operation and perspectives of WebGIS is difficult for personnel who does not frequently encounter it. Explanations of use and the development of further user-friendly interface are required in the future. Continuing the hearings to determine the specific improvement method must be important.

B) Expansion of WebGIS tools

By introducing this system for daily work, activity information for the Green Network could now be managed by WebGIS. From this, WebGIS appears to be useful for the environmental activities of NPOs. The reason for companies and organizations to introduce a new system is to improve operational efficiency as the main objective; however, in order to introduce the system to daily work, it is time consuming for training and costly, and there are still a number of hurdles in the introduction of WebGIS. In such situations, the present system required only total of 4-hour lectures. For the explanation, it is thought that less time may be required for implementation. If a maps application on a simple mobile terminal and map operation by a Web browser are available, there are increased opportunities to become more familiar with its use increases, and less time is potentially required for implementation of operations than at present.

Although specialized GIS technology and knowledge was needed for implementation prior to popularization of WebGIS, work carried out by the local staff with the introduction of this system was feasible. This means the potential use of WebGIS has been broadened. Thus, it became possible to develop the use of layers that thus far, have been distant from use.

From the hearings, responses received from users indicated that by employing the system, better understanding of circumstances for improving planting conditions of afforested lands was gained, and that it can also be thought of as a teaching tool for local staff. In the future, similar work will be continued, and awareness of afforestation lands overall is expected to increase rather than be limited to observations at a local site. More training within Green Network or use cases by other environmental groups verified the usefulness of the system in the future.

Table 6-5 Results of the posterior interview on early adaptation by using a WebGIS tool for rangeland management developed in this study.

Topic of the Question	Items of the questions	Staff of NPO	Director of NPO	Donors on NPO activity	Governors of the village
Basic information	Affiliation	Information department of *Green-Network*	*Director of Green-Network*	Department of corporate enterprise at NTT DoCoMo, Inc.	Wafang village in Horqin, Inner Mongolia
	Years, which has relation with *Green-network*	2 years	10 years	3 years	10years
	Role on the system	Data inputting	Management of whole data	Viewer as Japan side	Viewer as citizen side
	Other information	1. Born in 1985 2. Farmer	Founder of *Green-Network*	Three times experiences to visit for planting as CSR of the company.	1. Born in 1958 2. Farmer
Data contents	Was the change of planted areas easy for you to understand? - If you answered yes, please tell us the actual change you found.	Easy to understand the information. Planting area was getting green on the satellite imagery data.	The process of the growth of planted species, in particular native or planted trees. Also, fences and their process of plant growth were clear.	Spatial distribution of the desertification area and the process was clear in the time-slider of satellite imagery data.	It was easy to understand the process from white desert to green land.
	Did your understands to the planted area become deeper than before you start? - If you answered yes, please tell us the actual things you understood.	Understand of the planted areas became deep. Friends and relatives felt that desertification was not so changed but satellite imagery data clearly showed the planted area and its effects to the deserts.	The system was useful to check the spatial heterogeneity of plant or vegetation growth by the works of *Green-Network*. In addition, satellite imagery data provides the manmade spatial-feature in visual. All of the visual information on the system is necessary for consideration on the rangeland management in all the spatial scales from the "point" to "zone" scale in Horqin area.	The difference before and after the works of planting, whose results provided necessary information in visual to as CSR activities.	In particular, the areas, which decreased the sand dunes, were able to understand in visual. This information understood me deeply about the effect of planting and its management.

Table 6-5 (Continued) Results of the posterior interview on early adaptation by using a WebGIS tool for rangeland management developed in this study.

Topic of the Question	Items of the questions	Staff of NPO	Director of NPO	Donors on NPO activity	Governors of the village
Data contents	Please tell us the current understand of the desertification in this area.	Currently desertification is decreasing because of the planting.	Strength of the intensity on farming and grazing has degraded rangeland ecosystem, which was possible to visually check the spatial expanding as the result in desertification. Green-Network estimated its cause as the mix of the highland's usability for grazing but the worse condition on water resources, which had concluded us the difficulty of its recovery. However, the rangeland management with not only planting but also monitoring visually provide us positive effects our works.	Desertification / land degradation was possible to visually check its spreads in non-management areas.	When I was the child, animals and plants were lots in this area. After I became 30 years old, desertification became serious. Since 1999, local governments had started the planting, and since 2000, Green-Network also had started planting and its management. Although I could not understand where those works conducted, the system could provide me its information from 1988.
	Whether will this tool be necessary or not?	Important tool, which can show everything of our works.	It's impossible to work without this system. In current, the system is using for long-term planning of not only the working areas but also other areas, which can also present them to the citizen. The system is the only one for the works. In particular, hundreds of theories were hard to understand them enough but one image could reach to them.	Necessary.	Meaningful. It's a record to understand temporal change.

Table 6-5 (Continued) Results of the posterior interview on early adaptation by using a WebGIS tool for rangeland management developed in this study.

Topic of the Question	Items of the questions	Staff of NPO	Director of NPO	Donors on NPO activity	Governors of the village
Data contents	Did you feel to tell other staffs or friends what you understand in the system?	Yes, I'd like to tell the staffs and toured people its importance for understand the visual effects on our management works.	Our organization has already started the information provided by the system through website.	Yes, because the system provides the effects in visual, not textual.	PC is still not popular in each home in this area, however, the governments support to provide those information from the system to citizen.
	Do you have any ideas you'd like to do on daily works by using information, which you understand in the system?		Below 3 points have already started on works. 1. Planning 2. Evaluation 3. PR, presentation	New ideas except CSR are difficult to come across right now, but such a tool should apply to other NPOs.	Use case for regional planning with concrete quantitative areas of planting and deserts, and specific site for priority.
Function of the system	Did you feel slow in showing the imagery data?	It annoyed me to show the satellite imagery data.	The system was a little bit slow to show the imagery data, but it didn't feel us stress.		-
	What were the most difficult things you felt when you used the system?	Explains from researcher who talked how to use the system were difficult for me in the first time, but I could work well after the communications.	More fine resolution satellite image and topographical data such as contour would provide detail information and useful for our works.	Nothing special.	How to read the map was difficult to understand in the first step; therefore we asked it to the staffs.
	Did you feel something change in the planted area by just operating tool?	It was easy to understand it through just operation by imaging on-site fields.	It's hard to understand it by just operation, however I felt it is cruel to ask to the system.		-
	Do you have any suggestions to the system?	Nothing special in the system. I'd like to try to get used to it more.	More topographical data can support us.		Constant displays of Direction and distance.
	Do you have any ideas you expect for the better future of this area?		More satellite imagery data to understand more detail effects of our management works.	Old web browsers could not show the system. Please consider requiring this system to be able to access through them.	More links with local photos in specific sites on satellite imagery data can much deeply support people the spatial understand on the areas with their knowledge.

Table 6-5 (Continued) Results of the posterior interview on early adaptation by using a WebGIS tool for rangeland management developed in this study.

Topic of the Question	Items of the questions	Staff of NPO	Director of NPO	Donors on NPO activity	Governors of the village
About the works for inputting data to the system		1. Works of inputting data was finally fan for me, however, the first time to start the work was hard for me. 2. I didn’t feel unfulfilled because I could learn new things from the information on the system. 3. I anticipatively work for more understands with citizen. Bosses asked me this inputting work with the possible speed for me, I can work with this team in a new identity.		-	

6.2 Development of a SMS communication tool for herders' preparation to dzud

6.2.1 Methods

We designed the flows to design systems through referencing on Morville & Rosendeld (2006) as following: 1) preliminary survey 2) database design 3) technical system development 4) workshop with system test 5) posteriori Survey. Details of each section are listed as following.

1) Preliminary survey

At first for consideration of salience, we interviewed to nomadic herders to perceive information demand. Fernandez-Gimenez et al. (2015) surveyed same types of questions at 4 soums (counties) in 2 aimags (prefectures): Jinst and Bayantsagaan soum in Bayankhongor aimag, and Ikhtamir and Undur Ulaan soum in Arkhangai aimag. Interview answers of this study were corrected at 8 soums in 3 Aimags in August 2012, which were though to have wide range of opinions: Tuv aimag（Altanbulag, Batsumber soum）, Omnogobi aimag（Khankhongor, Bayan-Ovoo, Tsogt-Tsetsui soum）, Gobi-Altai aimag（Biger, Chandmani, Erdene soum）. Question items were set up as follows: "What information do you need for preparation to cope with dzud?" "What do you want to prepare before dzud if you get information you need for preparation through mobile phone?" Style of interviews in this survey was open discussion to get wider range of answers.

2) Database Design

We surveyed availabilities of information for nomadic herders by comparison of data sources for consideration of credibility. In case of which we have some options in data sources such as weather forecast, we set criteria to choose one data source as follows: spatial resolution, accuracy, frequency of data update, adequacy of data quantity. At the begging, we simply evaluated accuracies of each data, however, long-time accuracies should be evaluated by users. Therefore, we interviewed them to nomadic herders at the final step of this study. Its detail was discussed later. And then, we contacted to the data manager whether we can access their data sources that we assumed accurate for providing to nomadic herders.

Database on this study was designed to get data from some data sources on online. The database was designed by based on PostGIS, an object-relational database system on extension of PostgreSQL (Zhang & Yi, 2010). Script file was developed to access above data sources, and then it post downloaded data to our database.

Location data table was also designed on the database. Spatial structure consisted of 3 layers: aimag, soum, and place name which nomadic herders use. Each layer is designed to be able to connect to the same scale of each data source, therefore we devised to be able to understand multiple scale data for nomadic herders, particularly by using place name.

3) Technical System Development

Technical development of this system is consisted of 3 parts: database, transmission method, and interface. Database part was already described above. We used SMS (Short Mail Service) as transmission method on mobile phone company, Mobicom, since the type of mobile phones of nomadic herders were not so-called smart phone, which can send email. SMS on the service of Mobicom had 3 characteristics for transmission. At first, one message can transmit 160 characters. Second, one message can transmit in one hour. Third, message can transmit to all mobile phone users of Mobicom in one soum.

Therefore, interface needs to be devised with concise information by using place name, limited number of data, or international system of unit (SI) that Mongolian had learned in school. Interface is everything to get information for herders in the system. Thus, interface should make users ensure legitimacy on the interface. It had been decided that the system is collaborated with National Development Institute, Mongolia (former NDI), a public research institute which works under Office of the President of Mongolia and Mongolian Academy of Sciences. Therefore, we added a name of the institute to the system interface. Users can ask for questions to NDI.

In addition, replies from users through Mobicom's mobile phone can archive to the database. Not only staffs of NDI can see the replies from nomadic herders, but also it is possible to share those replies in the same soum. We also provided those replies to users on the same interface.

4) Workshop with System Test

Interface on mobile phone has limitation to make nomadic herders understand concise information through the interface. Therefore, we held a workshop to support them help their understands about the system. Workshop consisted of 4 parts: communication with the mayor before the workshop, presentation to participants, technical test, and discussion. In the communication part, we discussed with mayor for facilitation of herders' habitual preparation to cope with dzud through the system. After the discussion, we presented the concept, illustration of each part on the interface (ex. unit). And then, we technically tested whether the message would come or not to herders' mobile phones through the system. Finally, we made time for discussion with herders, and we got some feedbacks.

5) Posteriori survey

Posteriori survey was conducted by phone survey style in June and July 2015 for two months. Number of the targets for the questionnaire was 293: 167 users who had got information through mobile phone, and 126 herders who had not got information.

Questionnaire items constructed by A) basic information including literacy level, B) lifestyle change during a test term, and C) the change of preparation actions to dzud by referencing provided information. Although most of the items were commonly questioned to herders both who got information and did not get information, C) was basically questioned to only who got information through mobile phone. Those concrete questionnaire items referenced previous studies who studied the importance of information providing to citizen (Cash et al, 2003; Fernandez-Gimenez et al., 2015).

6.2.2 Results of the system of SMS communication system

1) Herders' demands on information system

Herders demands on information system was conducted by field interview to herders through open discussion style, or exchanges of questions and answers. Term of field survey was from 17 Sep. to 30 Sep. in 2012. Actual areas for field survey were mainly 3 areas such as **Fig.6-6**. Each life style of Mongolian herders was different in ecological zone, mainly Gobi zone, a part of Gobi Desert, steppe zone, and forest steppe zone because of different grassland production. Steppe zone is basically lifestyle is herd. Gobi zone is now changing style from herd to mining, but still herders are about a half of workforce. Forest steppe zone is mainly herding, however land production is even better than other ecological zones, so management of pastureland is also one of main works for herders. Capital city that names Ulaanbaatar locates in forest steppe zone and there is big livestock market and information infrastructure in forest steppe zone; therefore herders in forest steppe zone is possible to sell out livestock animals in steady. However, herders of other areas don't have such big market and good information infrastructure, thus the level of adaptation to climate change like early sales of livestock animals seems to be low in these ecological zones. It becomes difficult to send Information from national level to local herders.

This study conducted to visit each gel one by one, and got 72 answers from study area in August, 2012. Summarizing, the answers were weather forecasts (the forecast of dzud was the best), fodders distributions (to find out good pastureland for storages of fodders), current situations of other nomadic herders (ex. social bulletin boad), past snowed area in dzud (to find out non-snowed area), market prices of local markets on livestock products (to find out the best season to sellout unproductive animals in tactics). As a result of this survey, we listed those 5 types of information as candidates for the contents of information providing. Moreover, as the premise for the system in addition, it was shown that current communication channels were used by mobile phone. The information is assumed to effectively transfer to nomadic herders. All of the results on this survey was shown in Appendix 1.

In the process of this demand survey, we decided the study site for the tests, which names Biger soum, Gobi-Altai aimag, Mongolia, in the steppe zone (see **Fig.6-6)**. Total population of this study soum is 2,216 including about 1,200 Mobicom users.

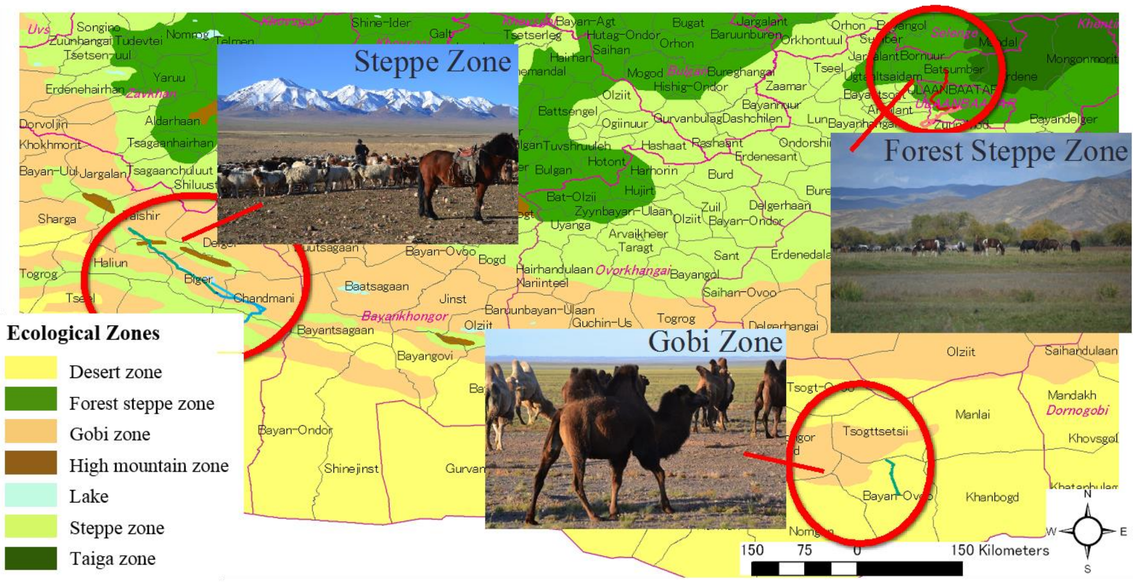


Fig.6-6 Location of the study area in Mongolian territory. The map was drawn using the software ArcGIS Desktop: Release 10.2.2 (http://www.esri.com/software/arcgis/arcgis-for-desktop). Ecological zone was provided National Development Institute, Mongolia.

2) System interface

We accessed to each data source to check the data availability as following. First, we checked weather forecast service on some websites and Institute of Meteorology and Hydrology, Mongolia (IMH), who provide weekly weather forecasts at each soum. Candidates were listed as follows: meteoblue (provided by University of Basel, sourced by NOAA/NCEP), World Weather Online (provided by European Centre for Medium-Range Weather Forecast etc., source by NOAA GFS2 model etc.), MirBig.net (provided by MirBig.net, LLC.), yr.no (Norwegian Meteorological Institute [NMI] and Norwegian Broadcasting Corporation [NBC], sourced by ECMWF and EUMETSAT), and IMH. As a result of supports to evaluate its accuracy by citizens in the study area, but which were not quantitatively evaluated, yr.no was selected as the data source of weather forecast. Second, we checked the service, which provides fodders distributions. GLEWS (Global Livestock Early Warning System), a web service to provide current pasture distribution on 803 monitoring points in Mongolia that is provided by Texas A&M University (Angerer et al., 2008; Angerer, 2013) was selected as the data source of fodder distribution. Third, we decided to provide users' replies as the data source of current situations of other nomadic herders. However, we could not find out and build online services, which provide current market prices of local markets on livestock products and snowed area though we contacted to IMH and mayors who had such information. Thus it was that the system would provide weekly weather forecasts on yr.no, pasture distributions on GLEWS, and users' replies through Mobicom service. In importing the data of weather forecasts from website, which was the html style data, regular expression on Perl computer language to extract focused information by referencing on Friedl (2006). Perl language also styled text-based SMS message through imported texts from database, which sent to mobile phone company (Mobicom) in Mongolia. The company finally sent to SMS to subscribing users in whole the areas of selected soum, in this case, Biger soum.

1st version of the system interface was designed as **Fig.6-7**. System had started transferring information since August, 2013. First messages of every time transfer weather forecast, second messages transfer pasture distributions at three monitoring points with the name of local places, and third messages transfer replies from herders. 1st version was the trial version; therefore we changed the version step by step while taking into account herders' requests through replies.

The first requests, which were received in September 2013, was to add more points of monitoring points; therefore we added 4 more monitoring points which were located at the nearest points but outside of the study area. Second requests, which were also received in September 2013, were to add wind speed and current disaster situations. We decided to add wind speed information, however we could not respond to the latter request. Third requests, which were received in October 2013, were to add maximum temperature for prediction of the adverse effects to herders' livestock by the temperature difference. The fourth requests, which were received in December 2014, were to add the unit to the information. As the results of reflecting those all requests, current interface was designed as **Fig.6-8** and **Fig.6-9.**

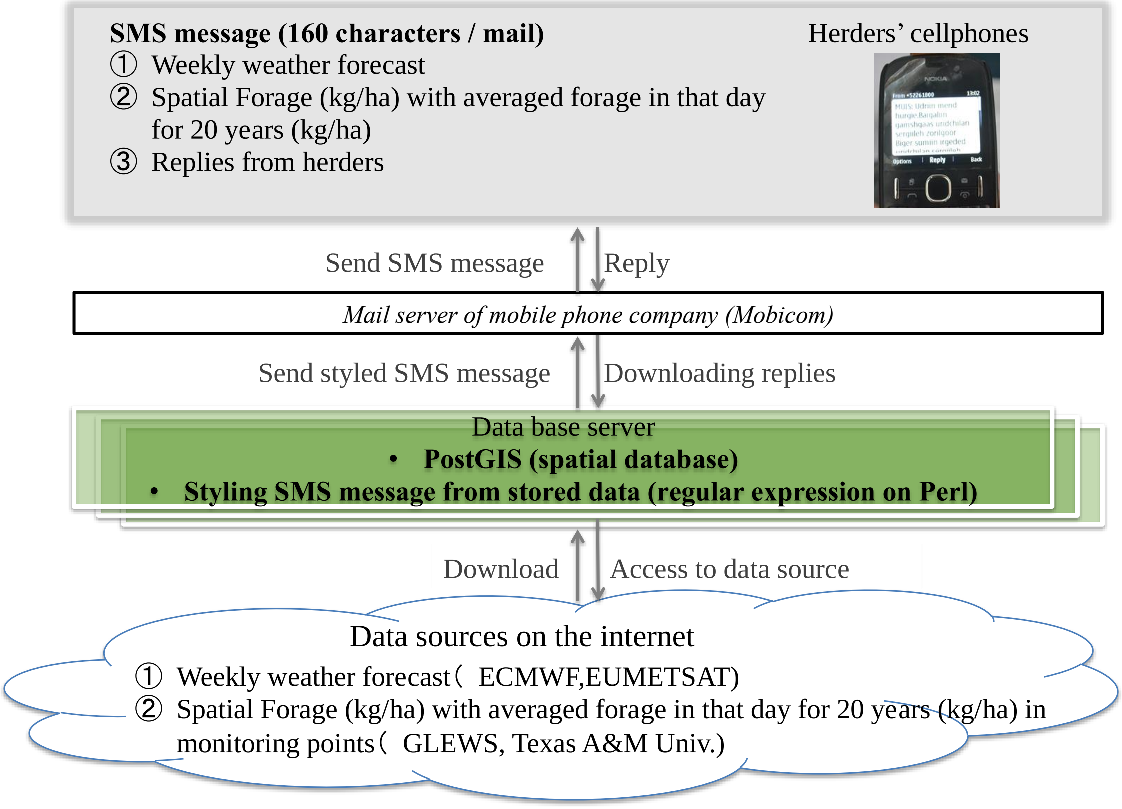
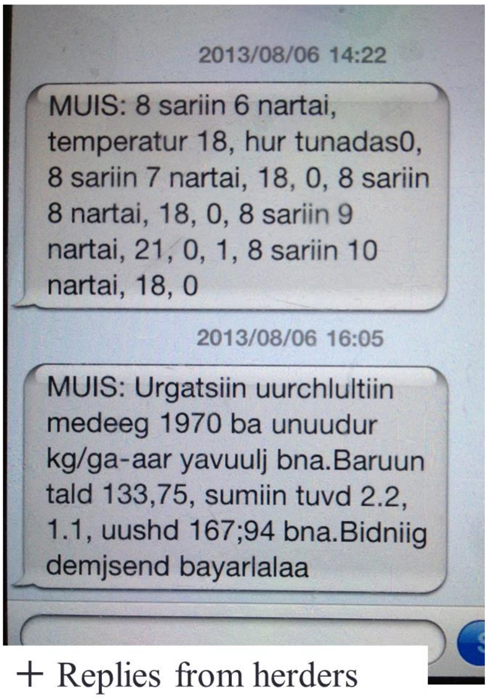


Fig.6-7 Data flow of the system development of SMS based information communication system in Mongolia.



Data Name	Weekly Weather
Data Contents	Daily Weather, Minimum Temperature(℃), Precipitation(mm)
Data Source	the Norwegian Meteorological Institute and the Norwegian Broadcasting Corporation (http://www.yr.no/place/Mongolia/)
Data Level	Sum (County) Level

Data Name	Daily Forage
Data Contents	Forage (kg/ha), Rate of Change between the averaged forage from 1970 to current and current forage (%)
Data Source	Texas A&M University, and National Agency for Meteorology and Environment Monitoring (http://glews.tamu.edu/Mongolia)
Data Level	Point (7 points in Biger Sum)

Fig.6-8 Interface of the system and details of the provided data.

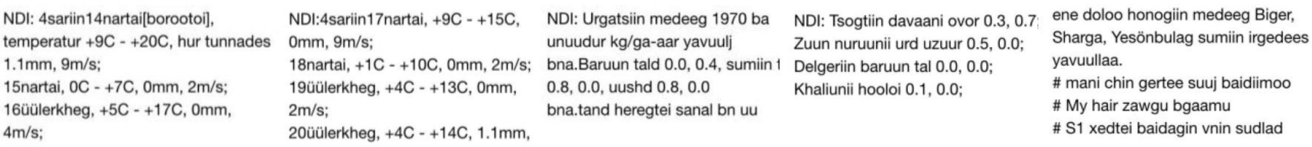


Fig.6-9 Current Interface after 1 year and 8 months later from 1st version (April 2015).

From left to the right, weather forecasts, weather forecasts, forage distribution, additional points of forage distribution, replies from herders.

3) Workshop result

2 times of workshops were conducted in August 2013 and 2014 at Biger soum center, Gobi-Altai aimag, Mongolia. First workshop was consisted of 4 steps (see above), and second was consisted of only discussion with users. Number of participants of the first workshop was 74, which included 30% of government officers. Its number of the second workshop was 26, which included 70% of government officers.

In the discussion of the first workshop, we encouraged questions about how to use the system and perspectives to the participants. As the results of the discussion of first workshop, participants talked about their perspectives more than questions about the system itself. Moreover, the perspectives were almost about weather forecast, not forage distribution. For example, we would like to use weather forecasts for seasonal moves or going to the market. The variety of their perspectives was less than the results of demand survey. Those opinions were not different between herders and government officers.

In the discussion of second workshop based on 1-year test, we encouraged questions, evaluations of data accuracies, and requests about the information provided through the system to the participants. Common opinions were the accuracy of weather forecast, which were not bad. Government officers also appreciated to us since they obtained not to move to mountain areas by based on the weather forecast. Sometimes blizzard has come to mountain areas and some people die, however, this year has no damages to the people. However, spatial accuracy of forage was evaluated that it was not good, which meant the spatial accuracy was too rough to understand. About this point, herders had opposite point of view that spatial accuracy was appropriate for them since they can predict other areas by based on the information with traditional knowledge. Too much information will confuse them to understand, herders answered.

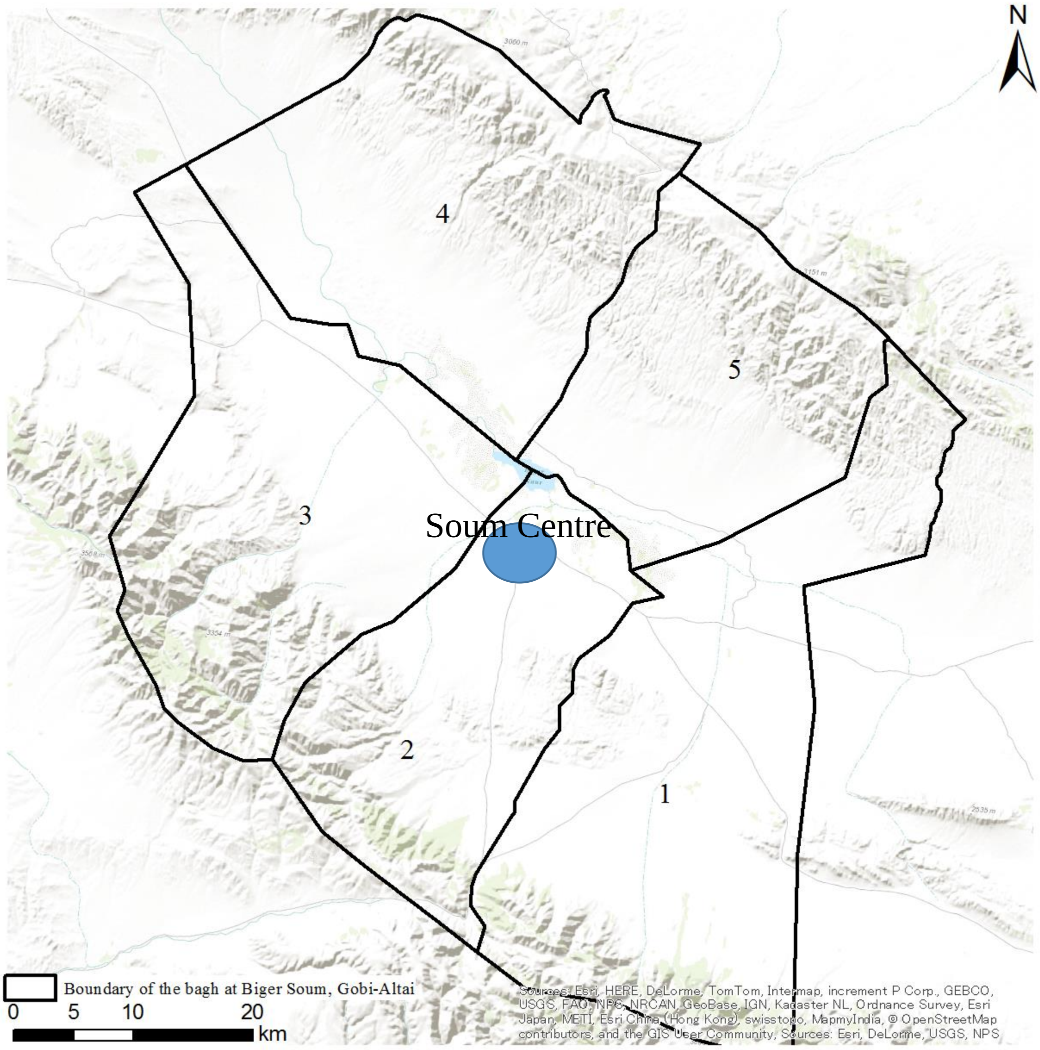


Fig.6-10 Study Area for workshop and system test (Biger Soum at Gobi-Altai Aimag).

Label-number shows the bagh name (ex. 1 shows 1-r bagh).

Maps are drawn by using ArcGIS, Boundary data was provided by National Development Institute (NDI)

4) Result of the posteriori survey

Main results of the posteriori survey were summarized in **Table 6-6**. (All the questions and answers were in Appendix 2.) In the basic information, mobile phone was still not the main tool to get information such as weather forecast or forage distribution; in particular, citizen who did not get information through this project had almost no use of mobile phone, which means the subjects seemed to have almost no bias in using mobile phone.

In the questions on lifestyle change of citizen during the test term, distinct differences between citizen who got information through the test and did not get information was seen in store of fodders, slaughters of stocks before winter, and changes of seasonal migration routes. Also most citizens who got information habitually learned to check the information. In addition, the trust to information through media was completely difference between who got information and did not get information after the test. Not only the traditional lifestyles related with dzud but also the new habits and attitudes on information became changed in most of the subjects.

On the other hand, the number of subjects who referenced the information for the lifestyle change was around 30% in citizens who got information. One reason of this seemed that the lack of number of monitoring points on forage distribution, shown in the result that 34 % subjects did not satisfy it although over 90% of answers satisfied other information. At the same time, the subjects of over 80 % communicated with people throught the system, which has a possibility to fill above gap of low references but high ratio of lifestyle change.

Table 6-6 Main results on posteriori survey on SMS based information system for Mongolia.

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
A) Basic information						
Do you feel something different between the information you had ever got and current information you get every week through mobile phone? (N=293)						
I don't feel something different between the information I had ever got and current information I get every week through mobile phone.			13	8%		
I feel something different between the information I had ever got and current information I get every week through mobile phone.			154	92%		
What do you usually use for getting information such as weather forecast / forage distribution? (Multiple answers allowed. Options; A: Local house holders, B: Individually go to places, C: TV, D: Mobile phone, E: Others) (N=293)						
Friends	1	1%	1	0%	2	1%
Government office	0	0%	24	11%	24	6%
Individually go to places	3	2%	3	1%	6	2%
Local house holders	102	59%	89	39%	191	48%
Mobile phone	1	1%	86	38%	87	22%
Neighbors	61	35%	13	6%	74	19%
TV	0	0%	10	4%	10	3%
Social workers	4	2%	0	0%	4	1%
B) Lifestyle change during a test term						
Did you store pastures for winter/spring after you checked information on mobile phone? (for interviewees who get info) / Did you learn to store pastures for winter/spring after you had dzud ? (for interviewees who don't get info) (N=287)						
I didn't store pastures for winter/spring after I checked information on mobile phone / after experienced dzud.	125	99%	70	43%	195	68%
I stored pastures for winter/spring after I checked information on mobile phone / after experienced dzud.	1	1%	91	57%	92	32%
Did you slaughter the weaken livestock after you checked information on mobile phone? (for interviewees who get info) / Did you learn to slaughter the weaken livestock after you had dzud? (for interviewees who don't get info) (N=286)						
I didn't slaughter the weaken livestock after I checked information on mobile phone / after experienced dzud.	125	99%	78	49%	203	71%
I slaughtered the weaken livestock after I checked information on mobile phone / after experienced dzud.	1	1%	82	51%	83	29%

Table 6-6 (Continued) Main results on posteriori survey on SMS based information system for Mongolia.

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
Have you habitually learned to check weather forecast or forage distribution? (focused on answers who got information through mobile phone) (N=162)						
I didn't habitually learn to check weather forecast or forage distribution			66	41%		
I habitually learned to check weather forecast or forage distribution.			96	59%		
Have you habitually learned to prepare something earlier than usual to cope with dzud since you got information on mobile phone? (for interviewees who get info) / Did you habitually learn to prepare something earlier than usual to cope with dzud after you had dzud? (for interviewees who don't get info) (N=288)						
I didn't habitually learn to prepare something earlier than usual to cope with dzud since I got information on mobile phone / after experienced dzud.	126	100%	79	49%	205	71%
I habitually learned to prepare something earlier than usual to cope with dzud since I got information on mobile phone / after experienced dzud.	0	0%	83	51%	83	29%
Have you changed your seasonal migration sites where you usually do not use since you got information on mobile phone? (for interviewees who get info) / Did you change your seasonal migration sites where you usually do not use after you had dzud? (for interviewees who don't get info) (N=288)						
I didn't change your seasonal migration sites where I usually do not use since I got information on mobile phone / after experienced dzud.	125	99%	78	48%	203	70%
I changed your seasonal migration sites where I usually do not use since I got information on mobile phone / after experienced dzud.	1	1%	84	52%	85	30%
Have you learned to build fences for pasture storage or ponds, or to cultivate plants? (for interviewees who get info) / Did you learn to build fences for pasture storage or ponds, or to cultivate plants after you had dzud? (for interviewees who don't get info) (N=289)						
I didn't learn to build fences for pasture storage or ponds, or to cultivate plants / after experienced dzud.	124	98%	68	42%	192	66%
I learned to build fences for pasture storage or ponds, or to cultivate plants / after experienced dzud.	2	2%	95	58%	97	34%
Do you trust weather forecast you get on mobile phone better than on TV? (N=292)						
I don't trust weather forecast I get on mobile phone better than on TV?	122	97%	15	9%	137	47%
I trust weather forecast I get on mobile phone better than on TV?	4	3%	151	91%	155	53%
Do you trust temperature forecast you get on mobile phone better than on TV? (N=292)						
I don't trust temperature forecast I get on mobile phone better than on TV.	122	97%	21	13%	143	49%
I trust temperature forecast I get on mobile phone better than on TV.	4	3%	145	87%	149	51%

Table 6-6 (Continued) Main results on posteriori survey on SMS based information system for Mongolia.

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
Do you trust wind forecast you get on mobile phone better than on TV? (N=292)						
I don't trust wind forecast I get on mobile phone better than on TV.	122	97%	10	6%	132	45%
I trust wind forecast I get on mobile phone better than on TV.	4	3%	156	94%	160	55%
Do you trust those forecasts you get on mobile phone better than the message came from NDI since December 2014? (focused on answers who got information) (N=165)						
I don't trust those forecasts I get on mobile phone better than the message came from NDI since December 2014.			16	10%		
I trust those forecasts I get on mobile phone better than the message came from NDI since December 2014.			149	90%		
C) Actions after users get information						
Did you refer the information you got on mobile phone for decision to migrate seasonal campsite last year? (focused on answers who got information) (N=156)						
I didn't refer the information I got on mobile phone for decision to migrate seasonal campsite last year.			95	61%		
I referred the information I got on mobile phone for decision to migrate seasonal campsite last year.			61	39%		
Did you refer the information you got on mobile phone to find out pastureland for preparation of winter/spring fodders? (focused on answers who got information) (N=157)						
I didn't refer the information I got on mobile phone to find out pastureland for preparation of winter/spring fodders.			117	75%		
I refered the information I got on mobile phone to find out pastureland for preparation of winter/spring fodders.			40	25%		
Did you refer the information you got on mobile phone to avoid overgrazing? (focused on answers who got information) (N=156)						
I didn't refer the information I got on mobile phone to avoid overgrazing.			74	47%		
I referred the information I got on mobile phone to avoid overgrazing.			84	53%		
How do you communicate with people who are not family or relatives? (Open-ended style) (N=280)						
To meet and talk with people directly	72	44%	65	31%	137	36%
To meet and talk with people by using mobile phone	89	54%	148	69%	237	63%
No communications	4	2%	0	0%	4	1%

Table 6-6 (Continued) Main results on posteriori survey on SMS based information system for Mongolia.

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
Have you communicate with people who usually have no communication with you by using information providing system on mobile phone? (focused on answers who got information) (N=167)						
I have never communicated with people who usually have no communication by using information providing system on mobile phone.			26	16%		
I have communicated with people who usually have no communication by using information providing system on mobile phone.			141	84%		
Is the amount of information enough for you to support your herding or lifestyle? (focused on answers who got information) (N=166)						
The amount of information is not enough for me to support your herding or lifestyle?			9	5%		
The amount of information is enough for me to support your herding or lifestyle?			157	95%		
Do you satisfy the number of monitoring points for forage distribution on the information from the system? (focused on answers who got information) (N=163)						
I don't satisfy the number of monitoring points for forage distribution on the information from the system.			55	34%		
I satisfy the number of monitoring points for forage distribution on the information from the system.			108	66%		
Do you satisfy the frequency of information providing (once a week)? (focused on answers who did not understand the meaning of the information) (N=167)						
I don't satisfy the frequency of information providing (once a week)			6	4%		
I satisfy the frequency of information providing (once a week)			161	96%		

6.2.3 Discussion on the system development

1) Possibility to support citizen's early adaptation to dzud

The result of preliminary survey to herders and governors in 12 soums of Mongolia showed the demands on information providing and possibility of use case for their early adaptation to dzud. Citizen needed weekly weather forecast, forage distribution, trends on other herders in the soum, current market prices, and snow distribution. Those local voices are no difference with the result of previous study (Fernandez-Giemenez et al.,2015). Considering the possibility of the point of view on existing database of science-informed but available providing technologies, developed system on this study provided weekly weather forecast from Norwegian Meteorological Institute, forage distribution from Texas A&M University, and trends on other herders in the soum through communication system. Although the third one was not science-informed information rather than use-informed one, it was demand-driven information. Although previous test to provide information was limited in its variable, only weather forecast (Velnooy et al.,2013) by the development based on regular expression coding, this study provided those three information to citizen in a soum.

Through the test and workshop, we concretely resulted that around 30% of the subjects changed their early adaptation on their livelihoods or lifeworks by referencing provided information, which were seasonal migration routes, sites to search fodders, for avoidance of overgrazing. In Summarizing, this study approached demand-driven method, which consisted of preliminary survey to citizen with open-ended style, designing the interface and system, workshop, test through upgrading interfaces by based on the replies from users, and finally the results of this approach on their early adaptation was confirmed through posteriori survey. This results would not only support but build concrete case of the argues that mentioned demand-driven and science-infomred information to support citizen's adaptation and Lourenço et al. (2015) and information would facilitate herders' adaptation to dzud (Fernandez-Giemenez et al.,2015).

Avoidance of overgrazing were shown as the effective approach to mitigate dzud impact in the session of analysis part on this study; therefore, our system has a possibility to not only support citizens' early adaptation to dzud but also mitigate dzud impact. This possible result needs to monitor in long-term study.

Additionally, this system could facilitate herder's communication. Current herders' communication has been weaken (Fernandez-Giemenez et al.,2012a, 2012b, 2015), so such communication tool through mobile phone in a soum scale can support their less-communication.

2) Limitation of the system

Although this study showed the additional step on the possibility to support citizens' early adaptation to dzud, three limitations were held as below. First, demand-driven information could not provided in snow distribution and market prices due to the technological issue on SMS. Although NASA had provided snow distribution by estimation using

MODIS, its information needed to change text for SMS message. In technical point of view, for instance, the PostGIS using on this study is possible import satellite imagery data, which is possible to extract their values (ex. this area had deep snow or not). Amount of information on SMS has limits, so it should wait expands of smart-phone, which is possible to show the data by WebGIS technology such as previous part of this study.

Second, number of monitoring point could not satisfy citizen, which was consist of only 7 points in a soum. Although this dissatisfaction supposed to fill with the communication tool on the system of this study, the fact was its limitation on the database, which was provided through GLEWS on Texas A&M University. The forage was estimated through PHYGLOW system (Sheehy, 2012) that can download on their website, which is possible to install for more points. In detail, although they use satellite imagery data to estimate the parameter of NDVI, the future study should get data on ground based NDVI technique using field-monitoring technique.

Third, this study only tested in two years, not long-term result. Although Lourenço et al. (2015) concerned that citizen had no interests on long-term issue such as climate change adaptation rather than short-term issue related with their daily lifeworks, at the same time, they suggested that *"we argue that, to be successful, climate services need to move (much faster) towards a demand-driven and science-informed approach. For a climate services market to develop, providers will need to adopt the terminology of their potential clients and understand their regulatory and cultural conditions. This requires more intensive (and potentially different) means of collaboration and communication between users, service providers and scientists, setting additional challenges for climate change researchers"*. Concrete methods to approach this long-term issue not only how to continue project but also how to evaluate its effects on climate related impacts are ongoing topic. The former topic has a possibility to solve a future trend showed in below session.

3) Spreading the system for dzud preparation in whole Mongolia

Continuous issue on the sustainable project of this tool application from study site to whole Mongolia, it is already started in 69 soums with corroboration of Mongolian governmental institute, National Development Institute (NDI), and Mercy Corp Mongolia. The system was based on developed system on this study, however the providing SMS technology was based on the application from Mercy Corp Mongolia. The project is already 2nd year, so the project completed those study soums, those institutes has a plan to spread whole Mongolia.

In addition, same type of impacts has around Mongolian Plateau such as Republic of Kazakhstan, "juto" a dzu din this country, and GLEWS has the same data system on such countries. First, analysis between the severity of climate conditions and livestock loss should be conducted, and then, such technology has a possibility to support through demand-driven and science-informed approach, which would apply our study approach to those areas.

7. Discussions

7.1 The cause of the spatiotemporally heterogeneous difference of the severity of livestock loss in Mongolian Plateau

As the results of this study showed the cause of spatiotemporally heterogeneous severity of livestock loss in Mongolian Plateau, which was not primarily caused by climate extreme-driven but overgrazing-driven factors (**Table 7-1**). Although almost no contributions of climate extremes of drought was shown in case of Inner Mongolia, summer drought directly had a small contribution to sever livestock loss of dzud in Mongolia. This conclusion of this study supports the assertion of previous study, severe livestock loss in Mongolian Plateau was social-phenomena rather than climate extremes based phenomena Miao et al.(2015), which also supports the assertions of each specific studies in Inner Mongolia (Zhang et al., 2007a, 2007b; Qian et al., 2014) and Mongolia (Sternberg, 2010; Fernandez-Giemenz et al., 2012a, 2012b, 2015) respectively.

In case of Inner Mongolia, overgrazing weakly but significantly conduced land degradation, which resulted in severe livestock loss (Huntsinger 2011; Liu & Wang, 2012; e.g. Derry, 2009). In case of dzud in Mongolia, although extreme weathers such as summer drought directly had a significant contribution to dzud impact on livestock, however other 3 years cases were not contributed by climate extremes. Both cases had the same factor, overgrazing. Those chronic overgrazing has a strong possibility to lose livestock fats (Derry, 2009), which damages livestock as a fatal shot (Tachiiri et al., 2008). In particular, in case of dzud, climate data was not shown the winter severities in both dzuds in 1999 to 2002 and 2009 to 2010;therefore, the result of this study can argue that summer drought facilitates dzud if livestock extremely take insufficient forages before winter due to extreme overgrazing. Livestock population of Mongolia in 2015 was recorded in the national history as the maximum; therefore people needs to be careful summer condition rather than winter.

However, temporal policies such as not only emergency fodders from international aides or governments and preparation of fodders might be effective in one winter, however it is not fundamental solution. Results of this study strongly argues that avoidance of overgrazing such as management of rangeland itself through consideration of the relationship between intensity of livestock density or species and pasture conditions in grazing areas is the critical but actual-fundamental solution for severe livestock loss in Mongolia. Such solutions already consisted of current early adaptation in the local herders and farmers in Mongolian Plateau, which is necessary to support through information systems and enable to change their livelihoods resulting overgrazing showed in this study.

Table 7-1 Summary of this study. ○: primal factors shown the strong contribution to spatiotemporally heterogeneous difference of the severity of livestock loss. △: not primal factors shown weak contribution to spatiotemporally heterogeneous difference of the severity of livestock loss. ×: factors shown no contribution to spatiotemporally heterogeneous difference of the severity of livestock loss.

	Factors	**Mongolia**	**Inner Mongolia**
Contribution factors on spatiotemporally heterogeneous difference of the severity of livestock loss	Climate extremes-driven	△	×
	Overgrazing-driven	○	○
Supporting tool for early adaptation	WebGIS based management	-	Developed in this study.
	SMS communication based information providing	Developed in this study.	-

7.2 A Demand-driven and science-informed adaptation

System development successfully supported early adaptation to livestock impact in Mongolian Plateau because of the design for satisfaction of the users in the grassland systems; citizen sectors such as farmers/herders or NPO. In the previous studies, although the protocol on tool development for actions of citizen sector (Morville & Rosendeld, 2006), which reached to importance of demand-driven and science-informed information providing on climate change adaptation (Hewitt et al., 2012; WMO,2014; Lourenço et al., 2015), the actual case and its effects has not been shown yet. This study clarified them through the case of severe livestock loss in Mongolian Plateau, by not only system development but also analysis on impacts.

Providing climate information in a way that assists decision-making by individuals and organizations, whose services require appropriate engagement along with an effective access mechanism and must respond to user needs (Hewitt et al., 2012; WMO,2014; Lourenço et al., 2015). Although the concept on previous study about demand-driven and science-informed information stayed in the stage of providing (Lourenço et al., 2015), this study actually changed daily works of citizen sector such as farmers, herders, NPO, which can call as demand-driven and science-informed adaptation, which was clearly different in science-driven and science-informed top-down approach or demand-driven user-informed bottom-up approach.

In this study, staffs changed their management method from internal paper based database to communicational digital (WebGIS) based database, which could support not only their management but also communication with internal / external stakeholders on rangeland management by NPO. In addition, nomadic herders changed their seasonal migration and harvesting sites to avoid overgrazing. The actual effects of those early adaptations by based on information tools of this study have not shown yet, however this demand-driven and science-informed adaptation could show its capacity for fundamental solution to severe livestock loss in Mongolian Plateau.

In details, as the feeling, both cases of system tests in Horqin Sandy Land in Inner Mongolia and Biger soum in Mongolia had the conscious citizens in the study areas. The effectiveness of this unclear bases or the workshops would contribute to support our study results, so more cases are necessary to conduct through other areas, which would make clear the detail but more important factors to adapt their lifestyles on severe livestock losses.

7.3 Possibility of the universality on whole methods of this study

This study has a possibility to apply for some other scales or areas in the point of view on livestock based cultures. Concretely, this study suggests 3 areas: whole Mongolian Plateau, Asian countries that has a cultures on livestock, and African countries. Firstly, argued in above sections, Inner Mongolia and Mongolia has a same lifestyle by based on livestock-based economics. Inner Mongolia has lots of NPO who works on rangeland management not only Horqin Sandy Land. At the same time, Mongolia has already started the continuous project to apply for whole scale of Mongolia, at least, 69 soums. Not only the system development, but also the analytical method on this study might be applicable for those areas. This study conducted analysis by using PDSI for Inner Mongolia as drought condition and GLEWS data for meteorological and pasture-condition monitoring. The former dataset is available in whole world scale, and the latter one is available in the US, Ethiopia, Kenya, Tanzania, Uganda, Afghanistan. Although some of those countries are hard to correct statistical data on livestock in detailed district-scales, those data has a possibility to apply our analysis method for livestock overgrazing system and its impact on livestocks.

In particular, as secondly, Asian-countries such as Kazakhstan and Afghanistan have same phenomena called “dzhut", a serious livestock loss in winter season, which had been traditionally driven by extreme winter conditions (Robinson et al., 2016). Those countries also has a difficulties to correct accurate dataset, so GLEWS in Afghanistan has a possibility to solve one of data problems.

In Aftrica, as thirdly, drought has been a possibility to strongly contribute to rangeland degradation such as Inner Mongolia, however, piospheres, a serious rangeland degradation phenomena around water resources resulted strong livestock mortality after their livestock fatless (Derry, 2009). Previous study already build this livestock dynamics model in Kenya (Derry, 1998), however Mongolian dzud has a difficulties to directly apply its model due to the difference of ecological conditions, which means that forage condition of study area in African countries were much better than Mongolian case. Dr.Angerer, who belongs to GLEWS database project in Texas A&M University, has already started SMS providing system to those countries for this issue. Therefore, this study method of not only data analysis part but also the system development through SMS has a possibility to support their adaptation of livestock mortality loss.

8. Conclusion

This study analyzed the cause of spatiotemporally heterogeneous severity of land degradation in Inner Mongolia and dzuds in Mongolia, whose causes were considered as the severity of climate events such as droughts or severe winter weathers for a long time. The results of this study concluded that those severe climate events was not primarily contribution factor to both land degradation in Inner Mongolia and dzuds in Mongolia; anthropogenic factors mostly contributed. Therefore, such a spatiotemporally heterogeneous difference of the severity of livestock loss was not mainly caused by naturogenic such as climate-driven, rather than anthropogenic, in particular, overgrazing-driven factors. Overgrazing was the common factor of both cases, which can conclude the overgrazing was a main factor on the damage on livestock grassland system in Mongolian Plateau.

Furthermore, this study showed the concrete feasible solution through information tools. WebGIS based rangeland management system for Inner Mongolia could support not only NPO's management works from in-situ daily planting and monitoring to governmental support but also its understands on the CSR of Japanese company. SMS communication system was developed and tested in a soum of Mongolia, which resulted the change of herders lifestyles such as seasonal migration sites, fodder searching, with avoidance of overgrazing. Both system approached through demand-driven but science-informed method consisted of preliminary survey to citizen sector, designing interface and system, workshop and test, and the effects on early adaptation was clarified through posteriori survey to the subjected users. Those technological approaches have already started to using for sustainable works on Mongolian Plateau, which has a possibility to spread more areas of Mongolian Plateau.

Each part of the conclusion was summarized below. At first, analysis on land degradation in Inner Mongolia, drought was no correlation to land degradation by using MODIS NDVI data and PSDI, however, a weak coefficients with livestock increasing, which showed overgrazing. In village scale analysis, quantitative assessment of pasture productivity was conducted by Landscape Ecological Zoning (LEZ) determined based on, the grazing behavior of livestock and pasture growth factor in addition to topography and soil conditions. From the results, overgrazing conditions were determined in Duxi Village, and were quantitatively confirmed to tend to be chronic. For the grazing form, we pointed out that the village did not conduct rotational grazing by LEZ, but grazed in all zones at equivalent grazed days; the current grazing practice appears to be unsustainable. The grazing capacity for LEZs in the village of this study area had the following characteristics. Areas with low grazing capacity were zones with rangeland land use and high accessibility or zones with rangeland land use and sand dune topography. Areas with high grazing capacity were zones with topography classification of lakeside area at moderate elevation or lakeside area in lowlands, or with hayfield land use and moderate accessibility. To solve the problem of chronic overgrazing, based on the characteristics of each LEZ shown in this study, we proposed the shift to responsible grazing from agricultural income in addition to land management by rotational grazing, and adopting and improvement methods of species matched to characteristics of LEZs. Further, for an improvement plan for future land use, Close analyses are required to determine whether an afforested area should be used as such, or for rotation to counteract overgrazing from mutual standpoints in terms of the economic point and grazing capacity. These findings offer practical countermeasures against desertification to the village, which actually implements them, as they are corresponding to local land use zones. Therefore, the effectiveness of assessment using the landscape ecological method could be confirmed. The technique based on multiple functions of ALOS/PRISM satellite data is the lowest cost with the highest accuracy in the world, and by integrating with ground surveys; it has potential for extensive application. In the future, under a cooperative network of local governments, NPO groups, residents and researchers, we plan to feedback information on findings including regional overgrazing conditions and land use improvement confirmed in this study, create village land use plans and practice them in the fields of desertification countermeasures.

Second, in information tool development part for support management of rangeland by NPO, a WebGIS platform was developed using Flex based coding for NPOs involved in desert afforestation, to manage via the Web, geographical information data of the afforested land. In development, a method for the NPO to arrange multiple spatial scales in a spatial database was newly developed. For construction of spatial inclusion relationships in a relational database to be feasible, the work operations of the NPO were surveyed, work was arranged in a spatial hierarchy and tabularized, and hierarchy established from attributes indicated from inclusion relationships within the table. The developed system was implemented for NPO work, and the utility for managing the WebGIS system confirmed by hearings. At that time, the feasibility of using the system not only as a management tool, but also an educational tool was suggested. The outcome of this study can provide an effective method on the whole, of developing WebGIS applications for handling multiple spatial scales, in addition to the subject of desert afforestation by NPOs. The time required for displaying satellite images and infrequent encounters with WebGIS by users were addressed by explaining in an understandable manner, the method of use and image viewing. Improving the interface was also addressed. To address these, additional server should be established overseas to solve image loading time and dedicated surveys should be conducted for interface improvement in the future.

Third, dzuds, the loss of livestock in harsh weather conditions, have been widely discussed, but the driving factors and their relationships have not been clearly examined because of the complexity and insufficient analytical tools available. This study holistically analysed the causes and the severity of dzuds by focusing on the major dzud regions in the country and clarified the geospatial associations of the driving factors using GLEWS (Global Livestock Early Warning System) data and a geographically weighted regression (GWR). As a result, this study showed that the climate conditions were not a major driving factor in the recent dzud episodes in 1999-2002 and 2009-2010. Although the analysis tenuously supports the conventional understanding of the dependence on weather severity, the dzuds were mainly driven by the population of small livestock (goats and sheep), the forage availability in the summer, the distance from the aimag centre, and the rate of change in the livestock population. The severity of the dzuds was also spatially and temporally auto-correlated in successive dzud episodes. The spatial and temporal differences among dzuds were primarily caused by overgrazing and a lack of adequate forage. With emphasizing, those findings conclude that a dzud is not a naturogenic climate event but, rather, a anthropogenic phenomenon.

Fourth, SMS communication tool, which provided weekly weather forecast , forage distribution, and replies from uses, was developed and tested to a soum. The result of its test for 2 years changed herders' lifestyles such as not only their seasonal migration roots but also circled areas for pasture storages.

The approaches of this study consisting of impact analysis and development of the information provided the basic case for Mongolian Plateau. Although whole areas in Mongolia were not tested in this study, concrete methods to apply and monitor whole Mongolian Plateau would need for the future.

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Appendix

Appendix A: Questionnaire sheet and the result on preliminary survey of SMS communication tool to dzud

A-1 Questionnaire sheet

A-1.1 For Herder

ID: Date:		Name:
Aima Name:	Sum Name:	
Interviwer Name:	Interviewee Name:	Interviewee's Occupation:

Questionnair:

●Basic Information (Red:High Priority)

I. How many people do you have in your family?

A.

II. How many animals do you have within your own family?

A.

III. How is the composition of livestock animals in your family? - Why that composition?

A.

IV. How many families are there around your gel?

A.

V. How many times do you move a year?

A.

VI. How do you get fresh water for family and livestock animals?

A.

VII. Where do you sell your livestock animals?

A.

VIII. When do you sell your livestock animals?

A.

IX. Who is the first for you to ask for help? Relatives? Neighbors? Or community?

A.

X. How do you sell your livestock animals in market season?

A.

XI. How do you get the grazing information about other herders now? - any change in comparison with the past.

A.

XII. What is the biggest misgiving in your life?

A.

XIII. Do you have any suggestions regarding government policy?

A.

●About Zud

I. How did you act after the last zud?

A.

II. How do you adapt to zud in general?

A.

III. Do you watch weather forecast?

A.

IV. How will you act if you can get information about zud prediction in winter?

A.

V. Suppose you have 5 choices for preventing from zud in winter: move your current herding area to other areas or early killing, early selling, buying additional hay, other, which do you prefer for the herders in your sum?

A.

	Ⅵ If you take action to implement Ⅵ that you chose, what type of information should we transport and when do you need? A.
●System	(Open Discussion Style, with showing image of interface) I. Do you need web system(like this) for risk management to zud? A.
	II. Do you have anything demands to system?(ex. Additional information, access cost) A.

A-1.2 For mayor of sum

ID:	Date:	Name:
Aimag Name:	Sum Name:	
Interviwer Name:	Interviewee Name:	Interviewee's Occupation:

Questionnair

:

●Basic Information

I. How many families (or gels) are there in your soum?

A.

II. How does your soum counter number of livestock animals, herder income and grassland condition each year?

A.

III. How does your soum get information? in your soum or other soums?

A.

IV. What is the general preference of livestock animal composition in your soum? - Why that composition?

A.

V. Does your soum have any costumes about livestock animals composition?

A.

VI. How many families does your soum have around each gel in average?

A.

VII. How many times does your soum move your gel to other points in a year?

A.

VIII. How does your soum get fresh water for family and livestock animals?

A.

	IX.	Where do herders in your soum go for selling their livestock animals?
	A.	
	X.	Which month does your soum sell your livestock animals or go for market?
	A.	
	XI.	How does your soum sell your livestock animals in market season?
	A.	
	XII.	How does your soum get the information about anything of other herders? - Past and Present.
	A.	
	XIII.	Does your soum have any suggestions regarding government policymaking?
	A.	
	XIV.	Which do citizens in your soum prefer? flesh meat or dried meat?
	A.	
●About Zud		
	I.	How did your sum act in zud occurred?
	A.	
	II.	How does your sum adapt to zud in general?
	A.	
	III.	Does your soum use weather forecast for zud?
	A.	
	IV.	Does your soum has any emergency reliefs for heavy snow or extreme cold weather?

A.

V. How will you indicate to herders if you can get information about zud prediction in early winter?

A.

VI. Suppose you have 5 choices for preventing from zud in winter: move your current herding area to other areas or early killing, early selling, buying additional hay, other, which do you prefer for the herders in your soum?

A.

Ⅶ If you take action to implement Ⅵ that you chose, what type of information should we transport and when do you need?

A.

●System (Open Discussion Style, with showing image of interface)

I. Do you need web system(like this) for risk management to zud?

A.

II. Do you have anything demands to system?(ex. Additional information, access cost)

A.

A-2 Answers

A-2.1 Vulnerability to dzud

1) Local-governmental level

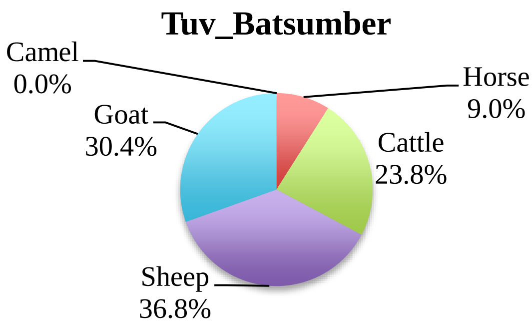
1-1) Economics

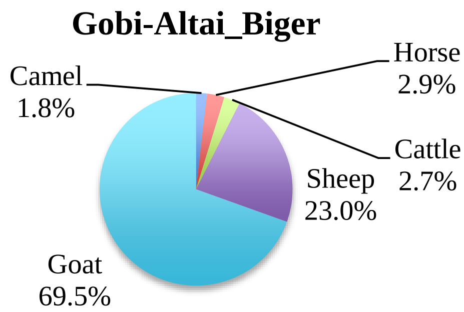
To estimate economic vulnerability in Sum scale, we interviewed to mayors about in their own districts, we surveyed to soum mayors

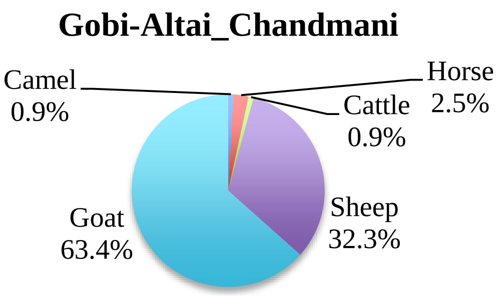
Table A1 Answers from each mayor in the study area for the question "who is the first for you to ask for help"? Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	Aimag and Ulaanbaatar (Aimag to Ulaanbaatar) help us in case of extreme weather, zud. In zud of 2010, they gave high-quality pastures for herders.
Omnogobi	Bayan- Ovoo	Mogoit	Companies in countryside help Bag government to give economic support or something information that relates zud and situation around their district.
Gobi-Altai	Chandmani	-	We have no contract with businessmen. sometimes they come and Aimag center
Gobi-Altai	Erdene	-	We have selling market in Bayan-ondor sum of Bayankhongor province. Most of business men come from China
Gobi-Altai	Biger	-	We Gold mining company and also mining company from Tseel Sum

1-2) Ratio of Small Animals







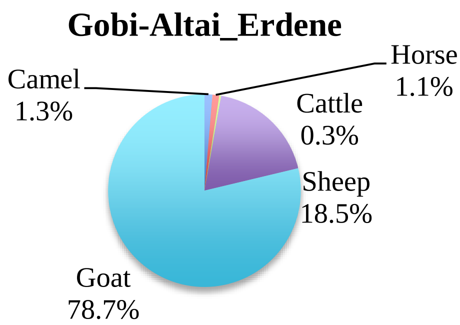


Fig. A1 Livestock composition of in each soum of study areas.

(Aimag name_Sum name)

Total number of livestock (heads)

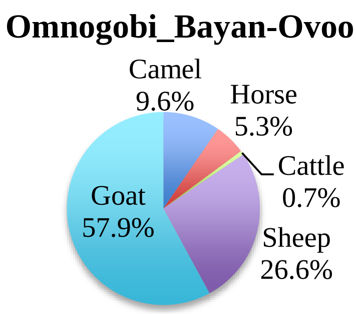
Batsumber, Tuv: 69096

Biger, Gobi-Altai: 69906

Chandmani, Gobi-Altai: 63453

Erdene, Gobi-Altai: 96391

Bayan-Ovoo, Omnogobi: 46611



1-3) Location

Table A2 Summary of the interview answers from mayors of each soum about their locations at study area.

Interviews were conducted by the open-discussion style.

Aimag Name	Soum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	This sum has lost of coals, therefore lots of mining companies come to this sum. However, much water is wasted in this region, so it becomes difficult to keep pasture system that consists of 3 ecolgical zones: pasture land for camels, horses, and sheep/goat. Herders confused this environmental change. We don't have common areas and land ownerships for residents and herders, so it's possible to make a fence for winter fodders by each person. However plant production in this sum is not so good, so it's difficult to make winter fodders. We have market for sales of livestock animals, however workers in mining companies don't buy them from this market directly. They buy meat from UB.
Omnogobi	Bayan- Ovoo	Mogoit	Ecological zone of vegetation in this area is for sheep and goat. Pasture land productivity is not so good, so it's difficult to make fences for winter fodders. Herders usually move to other rangeland instead of making fences. We don't have any markets in our Bag, so herders sells livestock animals in Sum center.
Gobi-Altai	Chandmani	-	Basically ecological zone of vegetation is surrounded by pastures for goat and sheep. In country side of this Bag, it's possible to get fodder and food materials for winter seasons. There are no landownerships in this Bag, people can make fences for winter pastures. Some herders make this kind of fence during summer season. There is a market in Sum center during winter season for livestock sales. Herders usually sell their animals in Sum center or Aimag center that is far from this Sum.

Table A2 (Continued) Summary of the interview answers from mayors of each soum about their locations at study area. Interviews were conducted by the open-discussion style.

Aimag Name	Soum Name	Bag Name	Answer
Gobi-Altai	Erdene	-	This sum has vast pasture land not only Gobi steppe but also desert zone. Vegatation type for Gobi steppe is for sheeps and goats. There are good pasture areas in this Sum, however they are quite far from Sum center. Herders usually don't use these pasture lands. There is a market for livestock sales in Sum center, so herders usually sell their animals in Sum center. However, some herders go to Aimag center for sales.
Gobi-Altai	Biger	-	Ecological zone of this sum has 3 types: Steppe zone, Gobi zone, Desert zone. This ecological zone is different between northern area and southern area. Herders use northern area during summer season, and also use southern area during winter season because southern area is warmer than northern area. There are no land ownerships in this Sum, so herders make fences for pastures in winter season. Market for livestock sales opens during winter season, however some herders go to Aimag center to sell them because of market size.

1-4) Transportation

Table A3 Summary of the interview answers from mayors of each soum about their transportation condition at study area. Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	This Sum has some paved roads in Sum center and coal mining area. Latter one is a main load between China to Ulaanbaatar, therefore coal mining companies use this road for transportation.There are no railways in not only Sums but also whole Aimag. Herders use these road not only transportation of livestock for market but also move to sum center. Other areas have also lots of roads that is well-trodden by cars. Herders usually use bike from rangeland to cities, sometimes they use horses or cars. People in mining company use cars or jeeps for transportation.
Omnogobi	Bayan- Ovoo	Mogoit	This Sum has only trodden path for transporatation. Herders usually use bike or horse, sometimes cars.
Gobi-Altai	Chandmani	-	There are no paved pathes: only trodden pathes. There are no railways in not only this Sum but also whole Aimag. Therefore people use car, bike horses for transporation. There are some well-trodden pathes, so people use this path from rangeland to cities. Of course there are vast rangelands in this Sum, so herders usuallly uses bikes or horses within rangelands in grazing time.
Gobi-Altai	Erdene	-	This sum doesn't have not only paved pathes but also railways. However, this Sum has quite vast rangelands, so it costs much time from Sum center to other areas.

Table A3 (Continued) Summary of the interview answers from mayors of each soum about their transportation condition at study area. Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Gobi-Altai	Biger	-	There are no paved pathes and railways: only well-trodden pathes. It costs too much time from country sides to Sum center, so school children go to school on Monday, and they come back to each home on Friday. They stay in dominitry house of school in Sum center. Herders usually use bike, cars, or horses for transportation. On a shopping expedition to Sum center, herders basically use well-trodden pathes, so rangeland is not so affected by tread power by cars.

1-5) Community

Table A4 Summary of the interview answers from mayors of each soum about their community condition at study area. Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	There are some kinds of community groups for herders in this Sum; mainly these 2 kinds of community groups: sales and exchange of information. Former one is to support to sell livestock animals alternatively. Latter one is to support to take information to herders about anything.
Omnogobi	Bayan- Ovoo	Mogoit	Basically, information from government is sent to herders by mayors of each Bag directly by phone. There are 2 kinds of community: mining center and Sum community. Former one is to communicate with mining company, but it does not work well. Latter one is to exchange information among herders: not only this Bag but also all of the Sum.
Gobi-Altai	Chandmani	-	This Sum has a community group to exchange information among herders. In country side, it is difficult to get information, particularly elder people. This community group has a role to keep track of health condition on each person.
Gobi-Altai	Erdene	-	There is a community group that consists of herders. They communicate each other by going to each gel directly.
Gobi-Altai	Biger	-	There is a community group that consists of herders. If sum mayor need to send information to herders, she uses this community group. In this Sum, mayor often go to each gel directly with this community group to communicate with herders. However usually she uses mobile phone to communicate with residents and herders. Community level of this Sum is quite good.

1-6) Infrastructure of the emergency alert for disaster

Table A5 Summary of the interview answers from mayors of each soum about their condition of the infrastructure of emergency alert for disaster at study area.

Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	If central government or Aimag government need to send information to local residents or herders, usually mayor send to each Bag mayor by mobile phone. In the case of central government, they use TV or radio to send alart or worning.
Omnogobi	Bayan- Ovoo	Mogoit	If important worning or alert from upper level government, Sum mayor send them to Bag mayors by mobile phone directly.
Gobi-Altai	Chandmani	-	When governement send information to herders, Sum mayor send them to each Bag. Bag mayor send information to herders directly by using mobile phones.
Gobi-Altai	Erdene	-	Modern times, Sum mayor communicate with Bag mayor through fixed phones. Fixed phones are set to some common hourse like community center, so they use them for communication. And also Bag mayor send information directly or through community groups that consists of herders.
Gobi-Altai	Biger	-	When Sum government need to send information to herders or local residents, Sum government use community group to send infromation. Nowadays, she use mobile phone to communicate with herders directly, but sometimes community group help with each herder conventionally.

1-7) Forage

Table A6 Summary of the interview answers from mayors of each soum about their forage condition at study area. Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	Nowadays, this Sum has lots of mining companies. Therefore, amount of forage is getting decreasing in whole. In exreme weather year, it is getting difficult to pass over winter without damage to livestock numbers. In this Sum, enviromental change occurs not only vegetation but also well points. Coal mining companies waste much water under the ground. Therefore this connect seriously to have reduces of forage productvity.
Omnogobi	Bayan- Ovoo	Mogoit	Basically forage productivity is quite low in rangeland of this Bag. However, there are good areas that have a good forage productivity in country side. However this "good" means "relatively good" with other rangeland in this Bag, so it does not so much forage. In Zud year, forage was completely lack in this area in whole, so Sum mayor strongly encouraged to central government to get forage from China. In the result, herders could get good forage from China. This was a great help for all of herders.
Gobi-Altai	Chandmani	-	Forage productivity depends on ecological zone in this Sum: desert zone, Gobi zone, and steppe zone. Almost all these areas don't have good forage productivity, so in case of zud or drought, local government gave fodders to herders. Or, herders need to go to countryside that is far from Sum center to run away from zud damage. This area has forages, however it takes long time to go to that area.

Table A6 (Continued) Summary of the interview answers from mayors of each soum about their forage condition at study area. Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Gobi-Altai	Erdene	-	Forage productivity depends on ecological zone: dersert zone, Gobi zone and steppe zone. Desert zone has little vegetation, so usually herders use Gobi zone or steppe zone. Herders usually move around Sum center, so this area does not have good forage productivity. Countryside has a good production, however it takes too much time to complete to move there. Therefore, herders rarely go to countryside to graze livestock animals.
Gobi-Altai	Biger	-	This sum has 3 types of ecological zone: desert zone, Gobi zone, and steppe zone. Forage production basically depends on these ecological zones, so herders spend summer time in steppe. They make fences near each gel to make forage for winter season. People move to Gobi area in winter season with winter forages that make in summer season.

2) Herder level

2-1) Economics

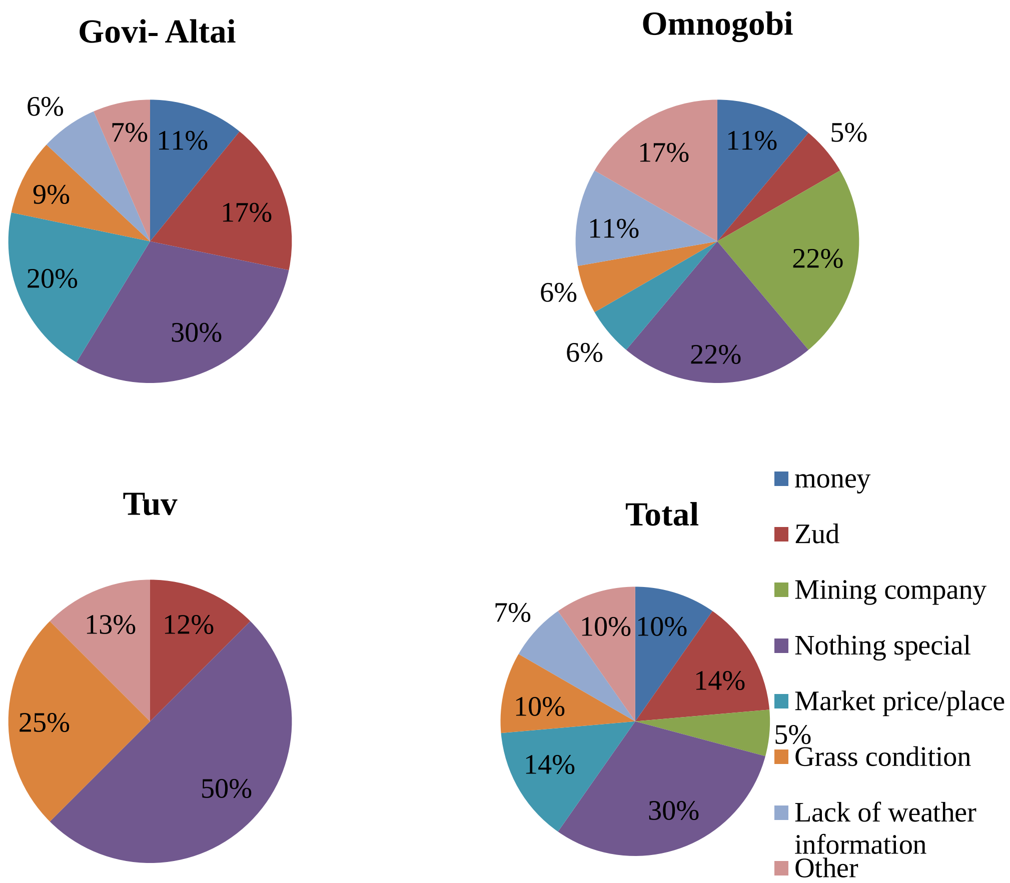


Fig.A2 Answers from local herders in each aimag of the study area for the question "what is the biggest misgiving in your life"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

2-2) Ratio of Small Animals

Table A7 Answers from each mayor in the study area for the question "what is the reason of your livestock composition in your family"?

Interviews were conducted by the open-discussion style.

Aimag name	Soum name	Answer
Tuv	Altanbulag	Cattle, Sheep; it's easy to manage in case of small number of animals.
Omnogobi	Bayan-Ovoo	Sheep, Goat; income from breeding livestock is expensive in each age.
Omnogobi	Bayan-Ovoo	Cattle; workers in mining company prefer beef rather than other meats.
Govi- Altai	Biger	Sheep, Goat; Growth rate of livestock is even faster than other big livestock animals.
Govi- Altai	Biger	Goat; Goat can adapt to new environment that has other kinds of plant species.
Majority	-	Goat, sheep; production of commodity for goat and sheep is more efficient than others. Before sales to the market as meat, goat and sheep can produce cashmere and wool in good price. Particularly cashmere is expensive. Market always needs goat and sheep meat, therefore elder goat and sheep are possible to sell out.

2-3) Location

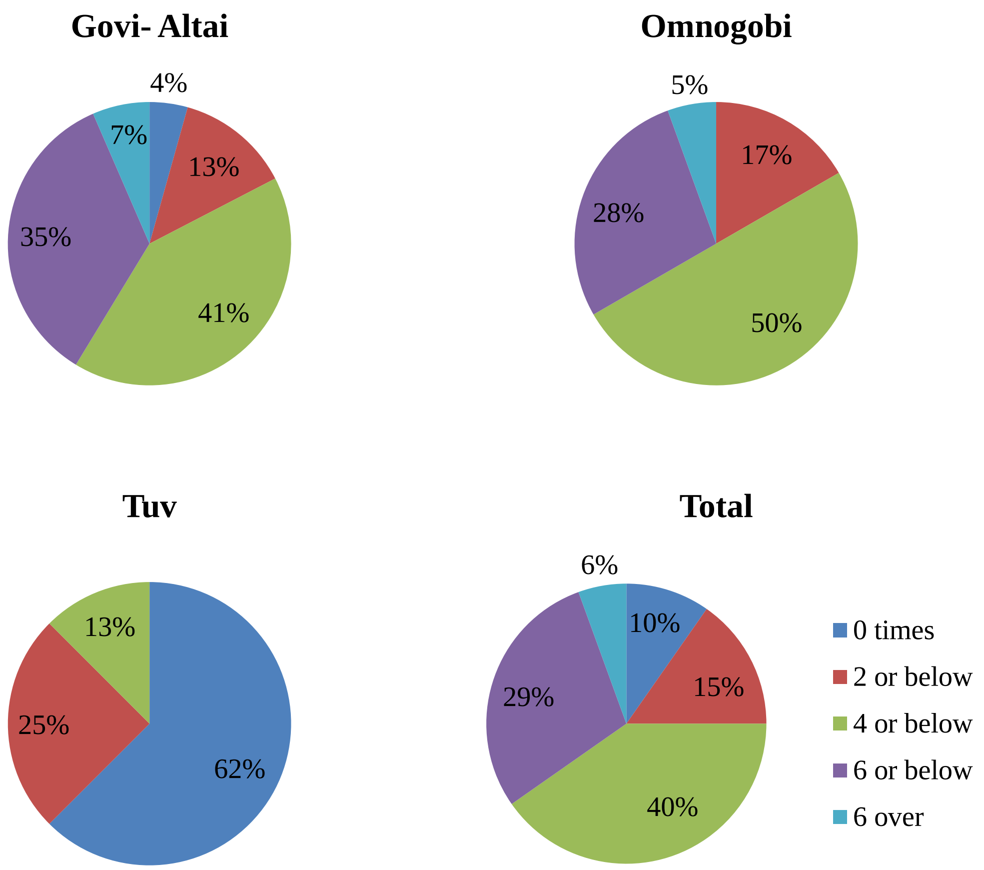


Fig.A3 Answers from local herders in each aimag of the study area for the question "how many times do you move during a year"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

2-4) Transportation

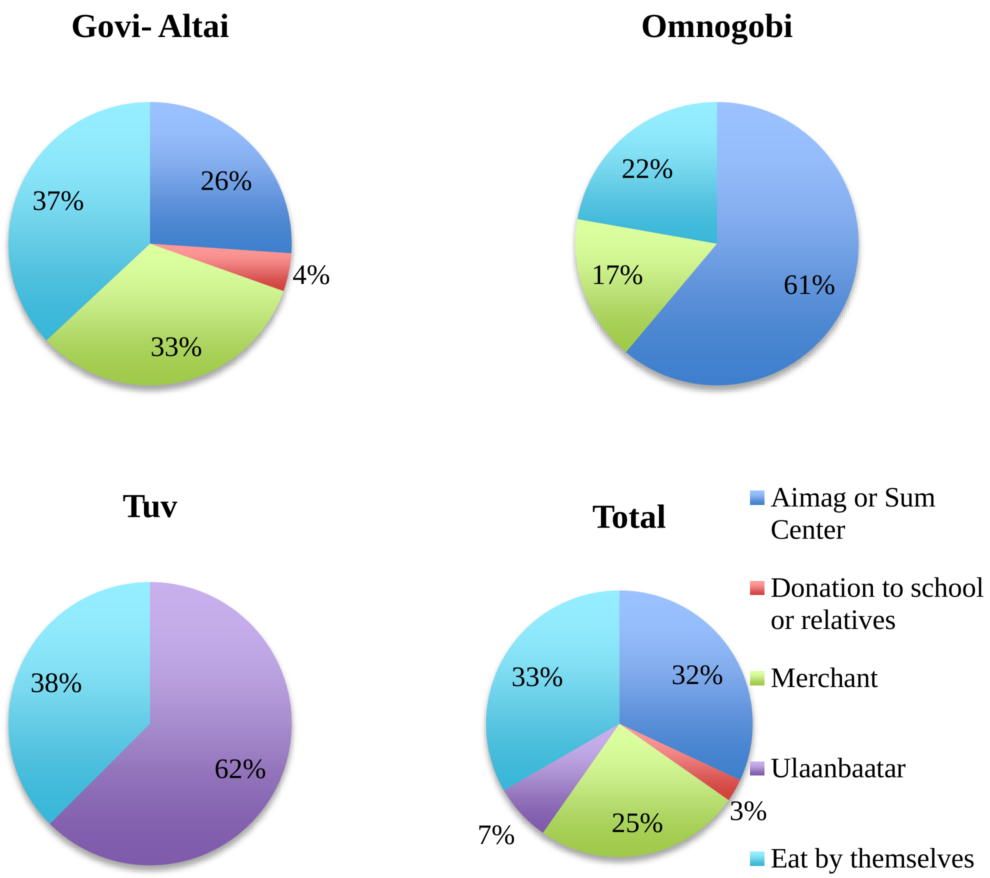


Fig.A4 Answers from local herders in each aimag of the study area for the question "where do you sell your livestock animals"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

2-5) Community

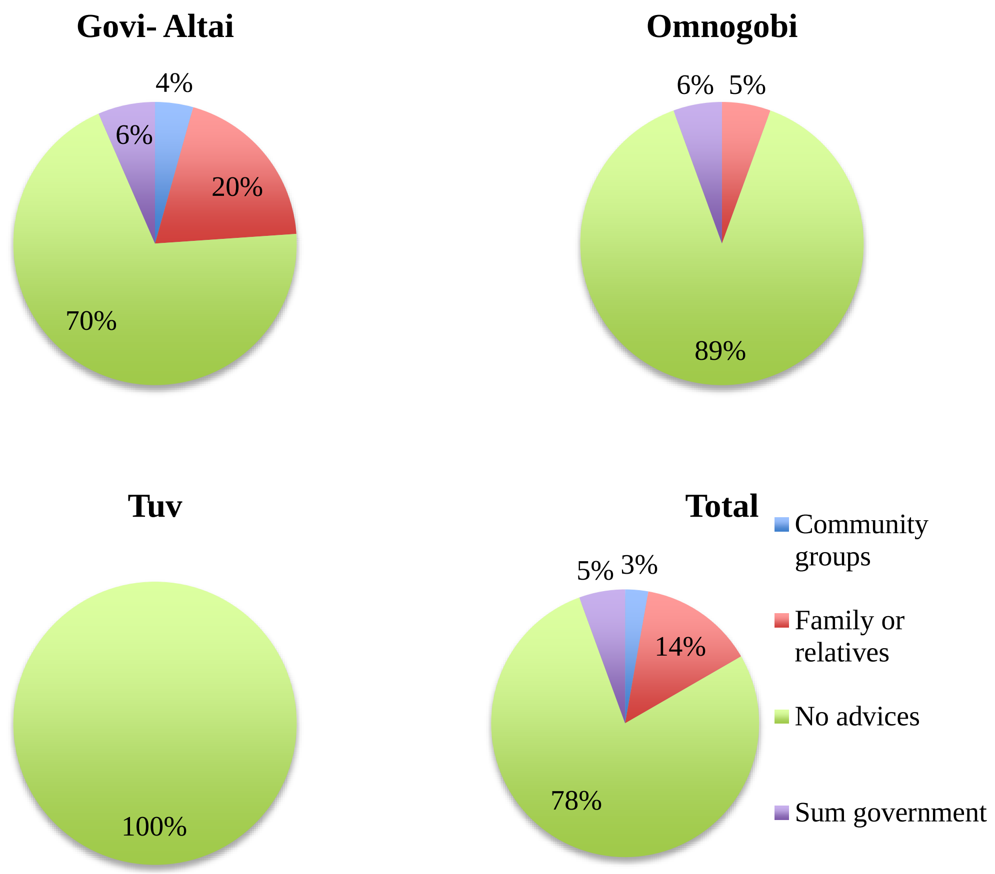


Fig.A5 Answers from local herders in each aimag of the study area for the question "who is the first for you to ask for help? Relatives? Neighbors? Or community"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

2-6) Infrastructure of the emergency alert for disaster

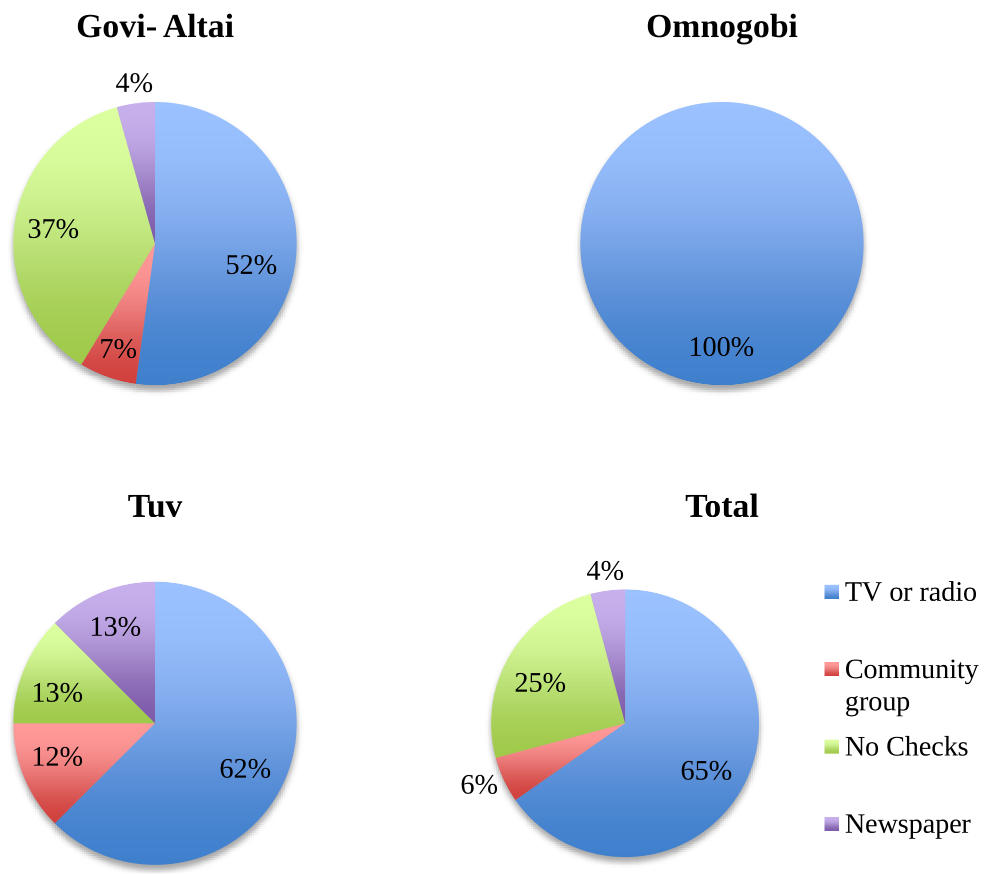


Fig. A6 Answers from local herders in each aimag of the study area for the question "how do you get weather forecast"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

2-7) Forage

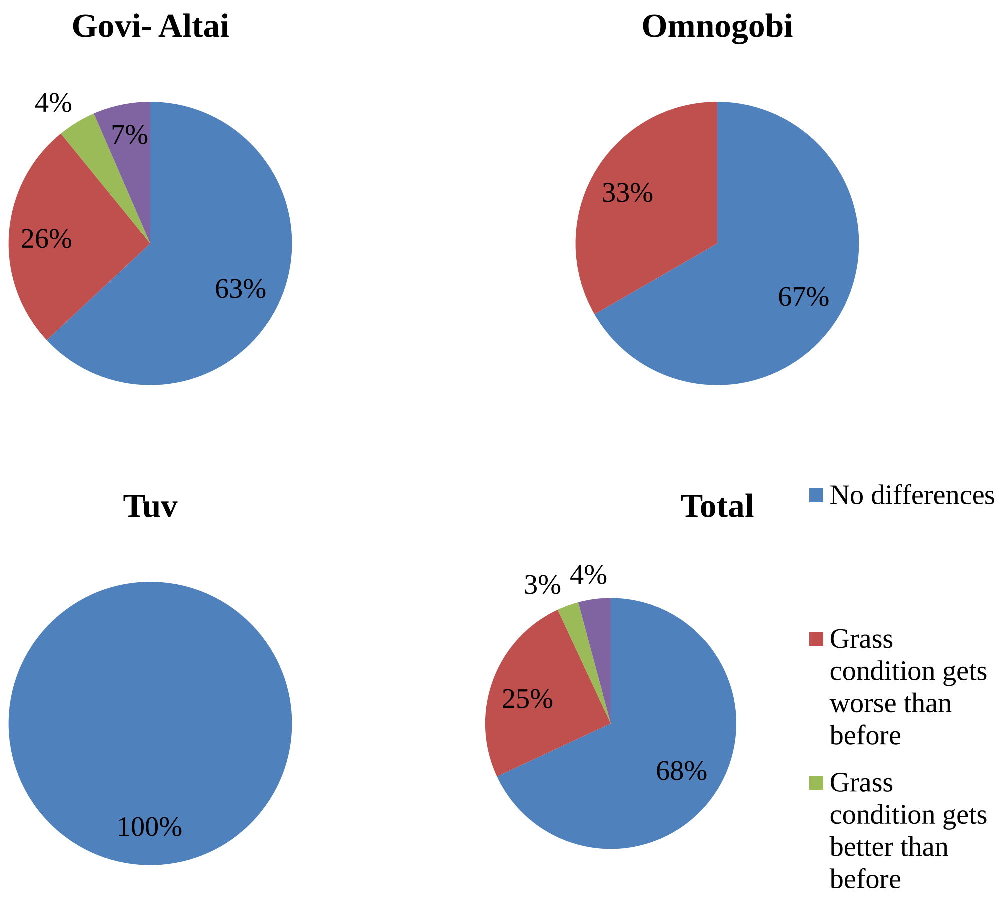


Fig. A7 Answers from local herders in each aimag of the study area for the question "Do you feel any changes in comparison with the past"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

A-2.2 Awareness

1) Local-governmental level

Table A8 Answers from each mayor in the study area for the question

"does your soum have any emergency reliefs for heavy snow or extreme cold weather"?

Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	No. Herders in this sum usually move to other rangeland, however it is possible to get pastures during summer for winter season, they cut out grasses. However, sometimes we can't get lots of pastures due to drought. In this case, mining company helps herders.
Omnogobi	Bayan- Ovoo	Mogoit	Yes, but we just communicate with each herder. Basically herders in this sum cut out pastures during summer for winter season.
Gobi-Altai	Chandmani	-	No. Herders in this sum move to other rangeland traditionally before winter. They do not only move but also prepare fodder by making fences or buying from market.
Gobi-Altai	Erdene	-	Yes, but we just communicate with Bag mayors. Herders usually move to other rangeland that have good pastures. Sometimes, we have a lack of prepared pastures, we make contract with national park managers to take pasture.
Gobi-Altai	Biger	-	Yes, but we just communicate with some herders or communities. Herders usually move to warm area in this sum during winter. In case of extreme cold or snow season, they need to move next to Aimag: Bayankhongor. However in this case, they need to spend quite long time. They do not want to move far awary, therefore many of them suffer from zud.

2) Herder level

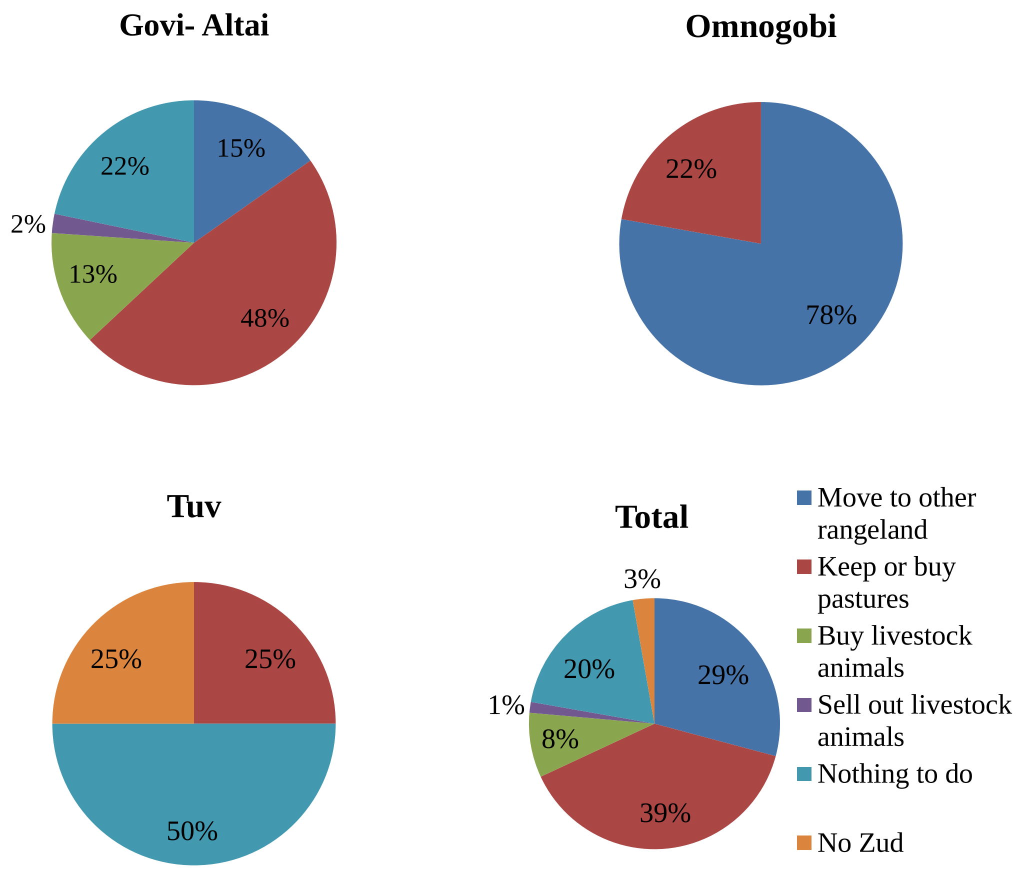


Fig. A8 Answers from local herders in each aimag of the study area for the question "how do you adapt to zud in general"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

2.3 Preparedness

1) Local-governmental level

Table A9 Answers from each mayor in the study area for the question "how will you indicate to herders if you can get information about zud prediction in early winter"?

Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	I want to give news to herders about weather or information that relates zud.
Omnogobi	Bayan- Ovoo	Mogoit	I want to give information to herders about the area that has lots of pastures, warm condition, or no snows. Or we want to give market information around this sum for herders to sell out their livestock animals earlier than usual.
Gobi-Altai	Chandmani	-	We want to develop a 100 ton container for keeping grasses. We already have a container, however we could not adapt to zud.
Gobi-Altai	Erdene	-	We'd like to get rid of mining companies from this sum. Mining companies waste much water and run on grassland hevily, therefore land degradation gets serious. We'd like to give this pasture condition for mining companies that means there are no areas to use for mining.
Gobi-Altai	Biger	-	We want to make a decision for adaptation to zud with giving information to herders about weather information, pasture conditions, market information within or around this sum. By based on all of those information, we'd like to judge a best adaptation strategy for herders.

Table A10 Answers from each mayor in the study area for the question

"If you take action to implement that you answered, what type of information should we transport"?

Interviews were conducted by the open-discussion style.

Aimag Name	Sum Name	Bag Name	Answer
Omnogobi	Bayan- Ovoo	-	We are interested in the difference of mining companies about not only basic information of companies but also how is the condition to help herders.
Omnogobi	Bayan- Ovoo	Mogoit	We need any kinds of zud information. Particularly, weather information, rangeland information, and market information.
Gobi-Altai	Chandmani	-	If it's possible, we are interested in the priod of current zud.
Gobi-Altai	Erdene	-	Basically zud information. However, we are interested in where liciesed mining search points or mining activity points locate.
Gobi-Altai	Biger	-	We need past Zud impact information, pasture potential, pasture prevention, and market information around sum by using maps.

2) Herder level

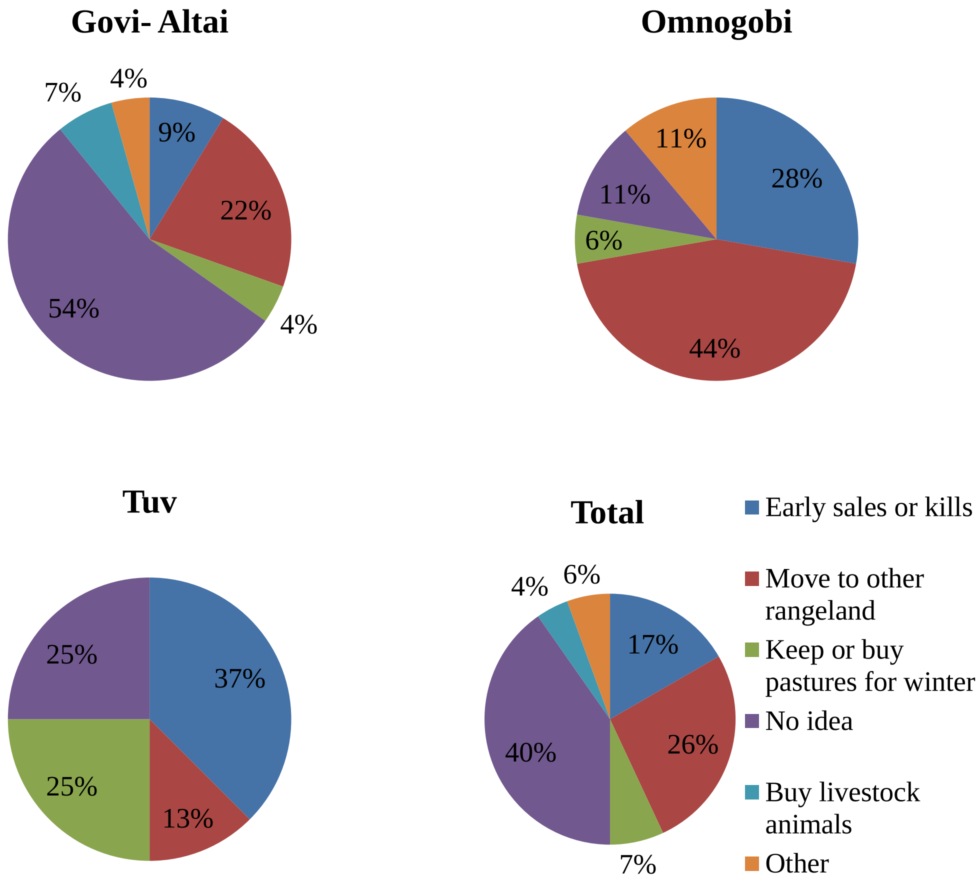


Fig. A9 Answers from local herders in each aimag of the study area for the question "How will you act if you can get information about zud prediction in winter"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

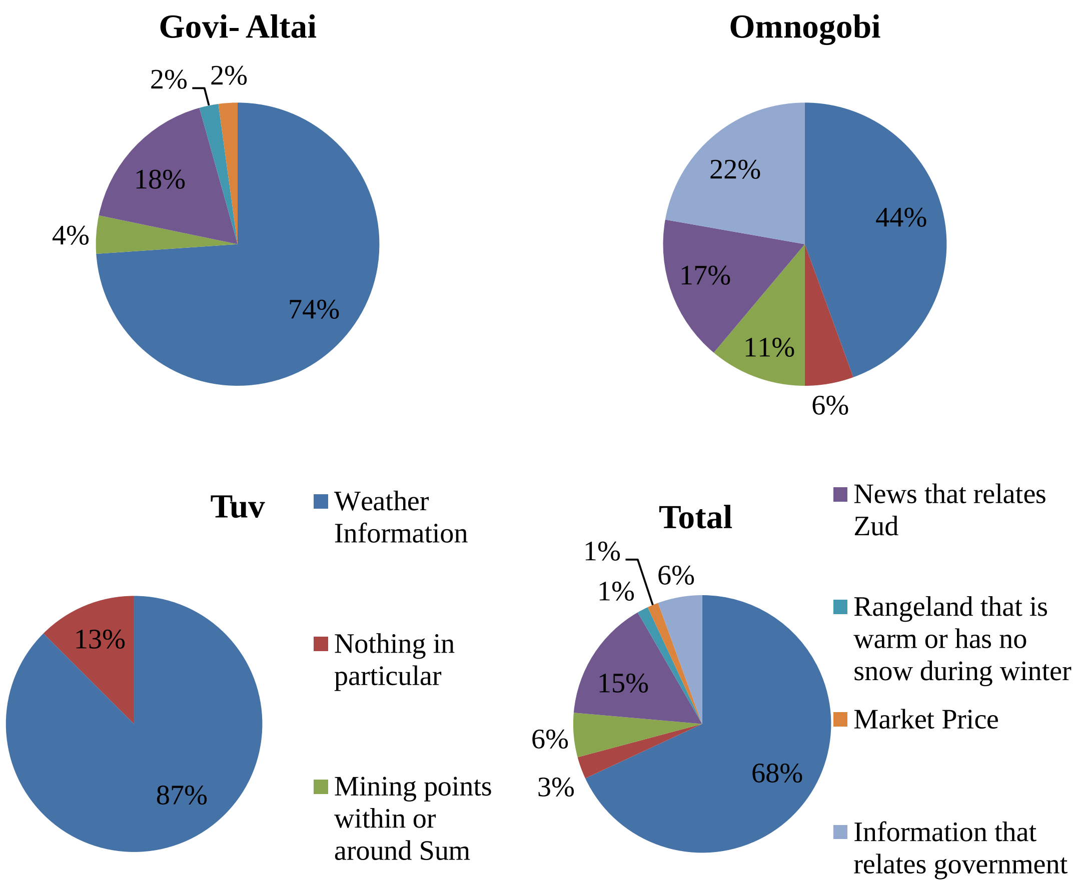


Fig. A10 Answers from local herders in each aimag of the study area for the question "If you take action to implement that you chose, what type of information should we transport"?

(Gobi-Altai:N=48, Omnogobi: N=18, Tuv:N=8)

Appendix B: Questionnaire sheet and the result on posteriori survey of SMS communication tool to dzud

B-1 Questionnaire sheet

Each Question was designed as follows. Each item was also located from A to N, which was shown in each title of the questions.

0） Basic Information

① Please let me ask you about your age.（ years old）

② Please let me ask you about the current location where you live now.（Myangai / Urt / Ih bulag / Buudai / Huremt / soum center / outside of Biger soum）

③ Please let me ask you about the number of you family.（ people）

④ Are you a nomadic herder? (Yes / No)

⑤ How many heads of livestock do you have? （ heads）

⑥ Have you ever damaged by dzud? （Yes / No）

１）Participation of the test

① Do you usually get information of weekly weather forecasts and forage distributions through your mobile phone? （Yes / No）

→If the answer is Yes, please go to 2.2.1. In case of No, please go to 2.2.2.

Questions for users who had been provided information

1) Were you join the workshop in 5 August 2013 or 19 August 2014?（Yes / No）

[If the answer is Yes] Who told you about the workshop? （ ）

[If the answer is Yes] Please tell us the reason why you joined the workshop.（ ）

２）About media of information providing

① Was mobile phone the best as the media to get information about weather forecast and forage distributions? （Yes / No）

３）About the style of information providing

① Were you able to understand the meaning of the text on the information you got through mobile phone? （Yes/No）

[If the answer is Yes] How did you understand the meaning of the text ? （ ）

[If the answer is No] Did you ask to your relatives, friends or government officers to understand the meaning of the text? (Yes / No)

[If the answer is No] Did you spend over 1 day to understand the meaning of the text? （Yes / No）

② Do you understand the limitation of SMS that each message has only 160 characters? （Yes / No）

４）Intelligibility of information

① Do you usually listen to the radio or watch TV? （Yes / No）

② Do you usually check weather forecasts on TV or radio? （Yes / No）

③ Do you usually ask new policies or guidelines of your soum through your relatives, neighbors, or friends? （Yes / No）

④ Do you feel something different between every winter and winter on dzud? （Yes／No）

⑤ Have you ever heard about the news that governments had provided emergency fodders during dzud? （Yes / No）

⑥ Do you feel something different between the information you had ever got and current information you get every week through mobile phone? （Yes／No）

⑦ Do you usually store pasutures for the winter/spring? （Yes／No）

⑧ Do you know where there are lots of pastures in your soum? （Yes / No）

５）Actions after users get information through mobile phone

① Did you store pastures for winter/spring after you checked information on mobile phone?（Yes / No）

② Did you slaughter the weaken livestock after you checked information on mobile phone?（Yes / No）

③ Have you habitually learned to check weather forecast or forage distribution?

④ Have you habitually learned to prepare something earlier than usual to cope with dzud since you got information on mobile phone?（Yes / No）

⑤ Have you changed your seasonal migration sites where you usually do not use since you got information on mobile phone?（Yes / No）

⑥ Have you learned to build fences for pasture storage or ponds, or to cultivate plants?（Yes / No）

⑦ Please tell us any change since you got information on mobile phone if you have.
( )

６）Accuracy of weather forecast

① Do you trust weather forecast you get on mobile phone better than on TV?（Yes/No）

② Do you trust temperature forecast you get on mobile phone better than on TV?（Yes/No）

③ Do you trust precipitation forecast you get on mobile phone better than on TV?（Yes/No）

④ Do you trust wind forecast you get on mobile phone better than on TV?（Yes/No）

⑤ Do you trust those forecasts you get on mobile phone better than the message came from NDI since December 2014? (Yes / No)

７）Effect to grazing

① Did you refer the information you got on mobile phone for decision to migrate seasonal campsite last year? （Yes/No）

② Did you refer the information you got on mobile phone to find out pastureland for preparation of winter/spring fodders? （Yes/No）

③ Did you refer the information you got on mobile phone to avoid overgrazing?
（Yes / No）

８）Communication

① Do you often communicate with people who are not family or relatives? （Yes / No）

② Is there any group, which are not good relationship with the group that you belong?
（Yes / No）

③ Have you got emergency fodders from soum or government during dzud?（Yes / No）

④ Have you communicate with people who usually have no communication with you by using information providing system on mobile phone? （Yes / No）

９）Satisfaction to the system

① Is the amount of information enough for you to support your herding or lifestyle? (Enough / Not enough)

② Do you satisfy the number of monitoring points for forage distribution on the information from the system?（Yes / No）

③ Do you satisfy the frequency of information providing (once a week) ?（Yes / No）

<u>Questions for users who had never been provided information on mobile phone</u>

③ Do you know that people in your soum can get weather forecasts and forage distribution through mobile phone?（Yes / No）

１）Literacy Level

① Do you usually listen to the radio or watch TV? （Yes / No）

② Do you usually check weather forecasts on TV or radio? （Yes / No）

③ Do you usually ask new policies or guidelines of your soum through your relatives, neighbors, or friends? （Yes / No）

④ Do you feel something different between every winter and winter on dzud? （Yes／No）

⑤ Have you ever heard about the news that governments had provided emergency fodders during dzud? （Yes / No）

⑥ Do you feel something different between the information you had ever got and current information you get every week through mobile phone? （Yes／No）

⑦ Do you usually store pasutures for the winter/spring? （Yes／No）

⑧ Do you know where there are lots of pastures in your soum? （Yes / No）

２）Preparation to cope with dzud

① Did you learn to store pastures for winter/spring after you had dzud ?（Yes / No）

② Did you learn to slaughter the weaken livestock after you had dzud?（Yes / No）

③ Did you habitually learn to prepare something earlier than usual to cope with dzud after you had dzud?（Yes / No）

④ Did you change your seasonal migration sites where you usually do not use after you had dzud?（Yes / No）

⑤ Did you learn to build fences for pasture storage or ponds, or to cultivate plants after you had dzud?（Yes / No）

⑥ Please tell us any change for preparation to cope with dzud after you had dzud if you have.（ ）

３）Accuracy of weather forecast on TV and radio

⑥ Do you trust weather forecast you get on mobile phone better than on TV?（Yes/No）

⑦ Do you trust temperature forecast you get on mobile phone better than on TV?（Yes/No）

⑧ Do you trust precipitation forecast you get on mobile phone better than on TV?（Yes/No）

⑨　Do you trust wind forecast you get on mobile phone better than on TV?（Yes/No）

４）Communication

①　Do you often communicate with people who are not family or relatives?　（Yes / No）

②　Is there any group, which are not good relationship with the group that you belong?
（Yes / No）

③　Have you got emergency fodders from soum or government during dzud?（Yes / No）

2. Results

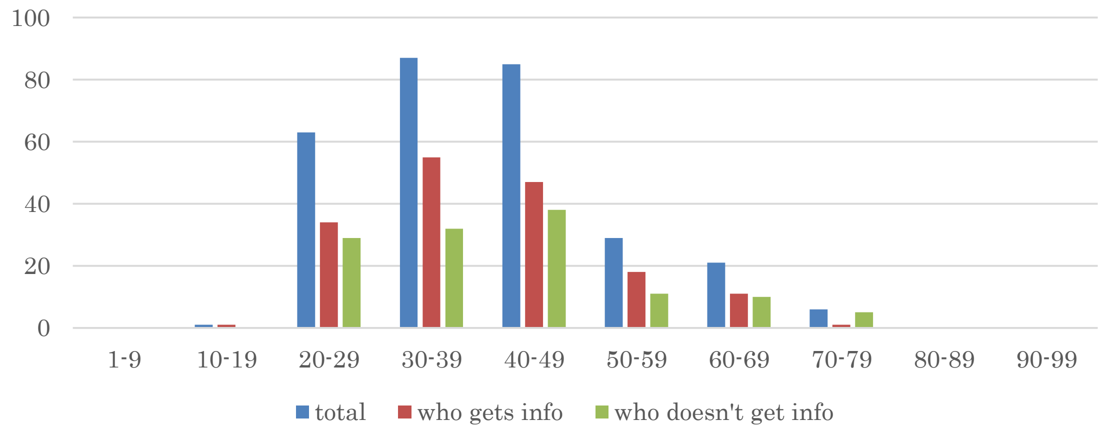


Fig. B1 Histgram of the interviwee's ages in Biger soum, Gobi-Altai Aimag

Blue: total answers (N=292), Red: who gets information on cell-phone (N=167),

Green: who don't get information on cell-phone (N=125)

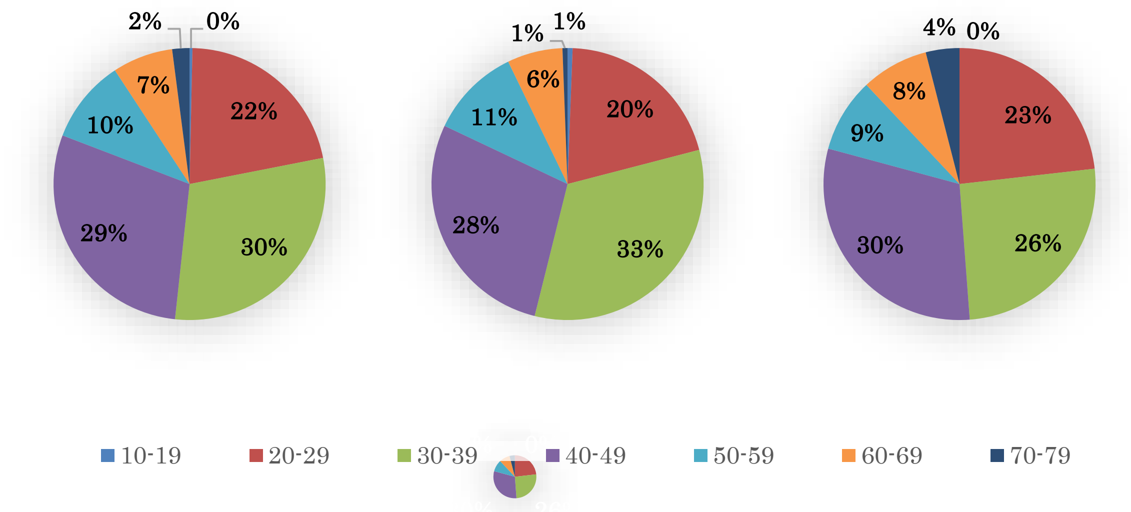


Fig. B2 Pie chart of the interviewee's age in Biger soum, Gobi-Altai Aimag

Left: total answers (N=292), Middle: who gets information on cell-phone (N=167),

Right: who don't get information on cell-phone (N=125)

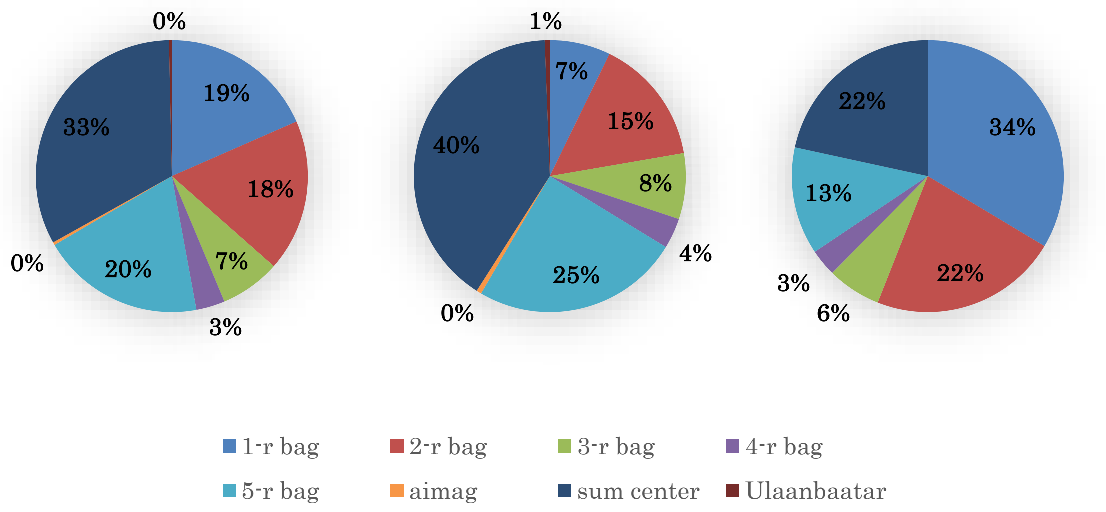


Fig. B3 Pie chart of the interviewee's address in Biger soum, Gobi-Altai Aimag

Left: total answers (N=293), Middle: who gets information on cell-phone (N=167),

Right: who don't get information on cell-phone (N=126)

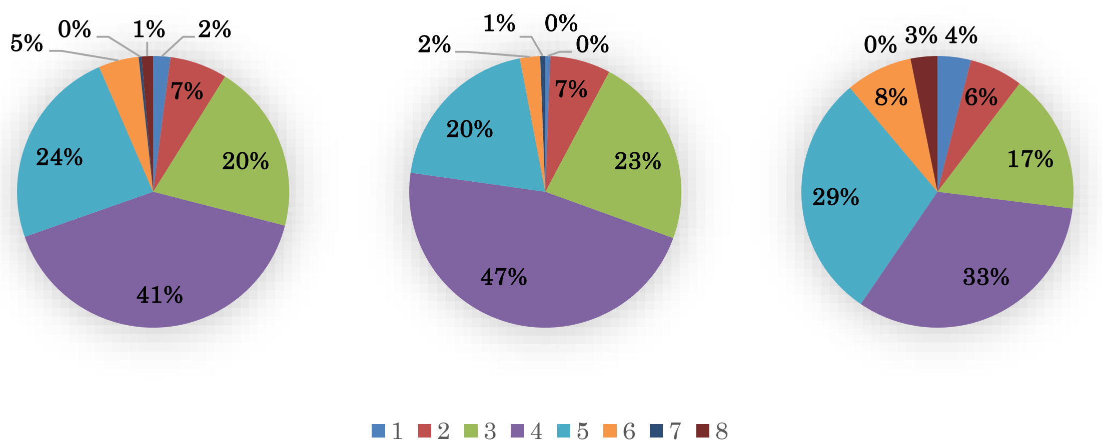


Fig. B4 Pie chart of the family members of interviewees in Biger soum, Gobi-Altai Aimag

Left: total answers (N=293), Middle: who gets information on cell-phone (N=167),

Right: who don't get information on cell-phone (N=126)

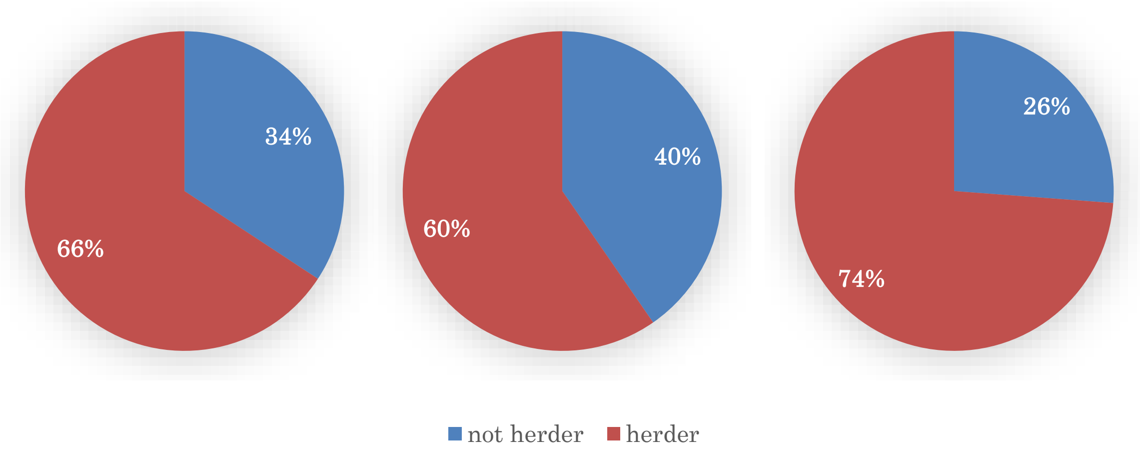


Fig. B5 Pie chart of interviewee's occupation (herders/not herders) in Biger soum, Gobi-Altai Aimag

Left: total answers (N=292), Middle: who gets information on cell-phone (N=166),

Right: who don't get information on cell-phone (N=126)

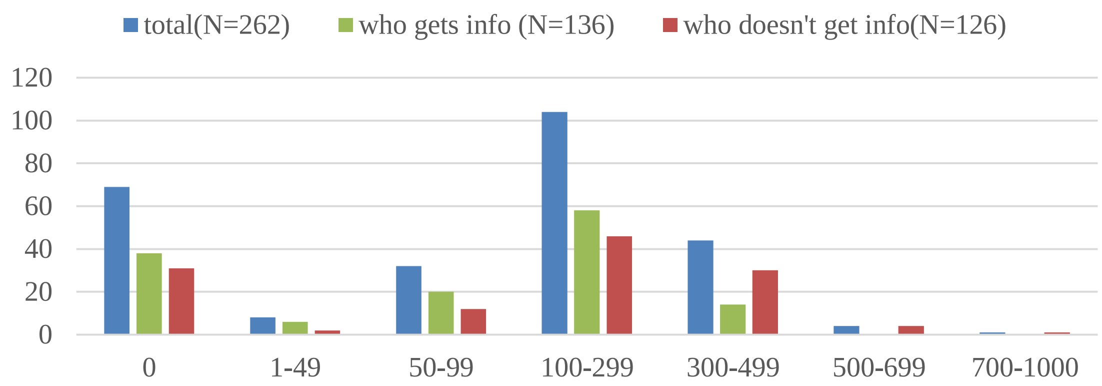


Fig. B6 Histogram of the interviewee's livestock population

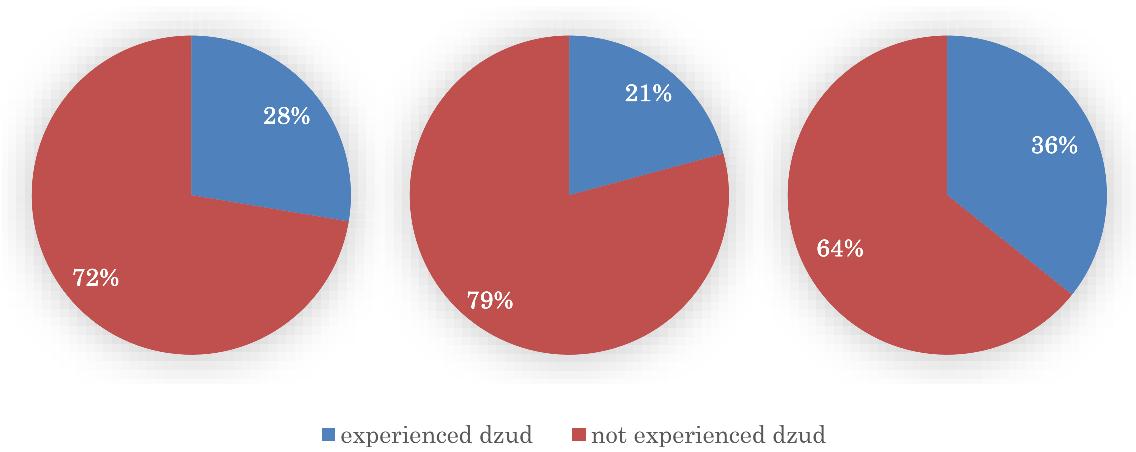


Fig. B7 Pie chart of the interviewee's dzud experience

Left: total answers (N=275), Middle: who gets information on cell-phone (N=149), Right: who don't get information on cell-phone (N=126)

Table B1 Answers from local herders in the study area for the question "were you join the workshop in 5 August 2013 or 19 August 2014"?

Participation	All interviewees	Only who gets information
Not joined workshop	206	95
Joined workshop	85	70
Total	291	165

Table B2 Answers from local herders in the study area for the question "who told you about the workshop"?

(focused on answers who joined workshop) (N=95)

Friend	1
Governmental office	58
Neighbors	3
Neighbors, governmental office	1
Relatives	1
Relatives, neighbors	1
Social workers	4
No one didn't tell about WS (got information about workshop by own selves)	26

Table B3 Answers from local herders in the study area for the question "did you learn something new from this workshop"?

(focused on answers who joined workshop) (N=83)

There was not something new to learn	1
There was something new to learn	82

Table B4 Answers from local herders in the study area for the question "was mobile phone the best as the media to get information about weather forecast and forage distributions"? (focused on answers who get information through mobile phone) (N=167)

Mobile phone is not the best as the media to get information about weather forecast and forage distributions	9
	15
Mobile phone is the best as the media to get information about weather forecast and forage distributions	8

Table B5 Answers from local herders in the study area for the question

“were you able to understand the meaning of the text on the information you got through mobile phone”?

(focused on answers who get information through mobile phone) (N=167)

Understand the meaning of the text on the information, which was sent through mobile phone, was not possible.	22
Understand the meaning of the text on the information, which was sent through mobile phone, was possible.	145

Table B6 Answers from local herders in the study area for the question

“did you ask to your relatives, friends or government officers to understand the meaning of the text”?

(focused on answers who did not understand the meaning of the information) (N=20)

I did not ask to your relatives, friends or government officers to understand the meaning of the text.	6
I asked to your relatives, friends or government officers to understand the meaning of the text.	16

Table B7 Answers from local herders in the study area for the question

“did you spend over 1 day to understand the meaning of the text”?

(focused on answers who did not understand the meaning of the information) (N=20)

I did not spend over 1 day to understand the meaning of the text.	18
I spent over 1 day to understand the meaning of the text.	4

Table B8 Answers from local herders in the study area for the question

“do you usually check weather forecasts on TV or radio”? (N=293)

	Interviewees who don't get info	Interviewees who get info
I usually listen to the radio or watch TV.	126	166
I don't usually listen to the radio or watch TV.	0	0

Table B9 Answers from local herders in the study area for the question

“do you usually ask new policies or guidelines of your soum through your relatives, neighbors, or friends”?

(Multiple answers allowed. Options; A:Relatives, B:Friends, C:Neighbors, D:Social workers) (N=289)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio(%)	Answers	Ratio
Friends	41	23%	22	10%	63	16%
Government office	0	0%	13	6%	13	3%
Neighbors	38	21%	60	29%	98	26%

Relatives	63	36%	41	20%	104	27%
Social workers	31	17%	65	32%	96	25%

Table B10 Answers from local herders in the study area for the question
"have you ever heard about the news that governments had provided emergency fodders during dzud"? (N=293)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	**Ratio**	**Answers**	**Ratio**	**Answers**	**Ratio**
I have never heard about the news that governments had provided emergency fodders during dzud?	60	48%	115	71%	175	61%
I have heard about the news that governments had provided emergency fodders during dzud?	66	52%	47	29%	113	39%

Table B11 Answers from local herders in the study area for the question
"do you feel something different between the information you had ever got and current information you get every week through mobile phone"? (N=293)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	**Ratio**	**Answers**	**Ratio**	**Answers**	**Ratio**
I don't feel something different between the information I had ever got and current information I get every week through mobile phone.	122	97%	13	8%	135	46%
I feel something different between the information I had ever got and current information I get every week through mobile phone.	4	3%	154	92%	158	54%

Table B12 Answers from local herders in the study area for the question
"do you usually store pasutures for the winter/spring"? (N=285)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	**Ratio**	**Answers**	**Ratio**	**Answers**	**Ratio**

I don't usually store pasutures for the winter/spring.	37	29%	59	37%	96	34%
I usually store pasutures for the winter/spring.	89	71%	100	63%	189	66%

Table B13 Answers from local herders in the study area for the question "do you usually store pasutures for the winter/spring"? (Multiple answers allowed. Options; A: Local house holders, B: Individually go to places, C: TV, D: Mobile phone, E: Others) (N=293)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	**Ratio**	**Answers**	**Ratio**	**Answers**	**Ratio**
Friends	1	1%	1	0%	2	1%
Government office	0	0%	24	11%	24	6%
Individually go to places	3	2%	3	1%	6	2%
Local house holders	102	59%	89	39%	191	48%
Mobile phone	1	1%	86	38%	87	22%
Neighbors	61	35%	13	6%	74	19%
TV	0	0%	10	4%	10	3%
Social workers	4	2%	0	0%	4	1%

Table B14 Answers from local herders in the study area for the question "did you store pastures for winter/spring after you checked information on mobile phone"? (for interviewees who get info) / Did you learn to store pastures for winter/spring after you had dzud ? (for interviewees who don't get info) (N=287)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	**Ratio**	**Answers**	**Ratio**	**Answers**	**Ratio**
I didn't store pastures for winter/spring after I checked information on mobile phone / after experienced dzud.	125	99%	70	43%	195	68%
I stored pastures for winter/spring after I checked information on mobile phone / after experienced dzud.	1	1%	91	57%	92	32%

Table B15 Answers from local herders in the study area for the question

"did you store pastures for winter/spring after you checked information on mobile phone"?

(for interviewees who get info) / Did you learn to slaughter the weaken livestock after you had dzud? (for interviewees who don't get info) (N=286)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
I didn't slaughter the weaken livestock after I checked information on mobile phone / after experienced dzud.	125	99%	78	49%	203	71%
I slaughtered the weaken livestock after I checked information on mobile phone / after experienced dzud.	1	1%	82	51%	83	29%

Table B16 Answers from local herders in the study area for the question

"have you habitually learned to check weather forecast or forage distribution"?

(focused on answers who got information through mobile phone) (N=162)

	Answers	Ratio
I didn't habitually learn to check weather forecast or forage distribution	66	41%
I habitually learned to check weather forecast or forage distribution.	96	59%

Table B17 Answers from local herders in the study area for the question "have you habitually learned to prepare something earlier than usual to cope with dzud since you got information on mobile phone"? (for interviewees who get info) / Did you habitually learn to prepare something earlier than usual to cope with dzud after you had dzud? (for interviewees who don't get info) (N=288)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
I didn't habitually learn to prepare something earlier than usual to cope with dzud since I got information on mobile phone / after experienced dzud.	126	100%	79	49%	205	71%
I habitually learned to prepare something earlier than usual to cope with dzud since I got information on mobile phone / after experienced dzud.	0	0%	83	51%	83	29%

Table B18 Answers from local herders in the study area for the question "have you changed your seasonal migration sites where you usually do not use since you got information on mobile phone"? (for interviewees who get info) / Did you change your seasonal migration sites where you usually do not use after you had dzud? (for interviewees who don't get info) (N=288)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
I didn't change your seasonal migration sites where I usually do not use since I got information on mobile phone / after experienced dzud.	125	99%	78	48%	203	70%
I changed your seasonal migration sites where I usually do not use since I got information on mobile phone / after experienced dzud.	1	1%	84	52%	85	30%

Table B19 Answers from local herders in the study area for the question

"have you learned to build fences for pasture storage or ponds, or to cultivate plants"?

(for interviewees who get info) / Did you learn to build fences for pasture storage or ponds, or to cultivate plants after you had dzud? (for interviewees who don't get info) (N=289)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
I didn't learn to build fences for pasture storage or ponds, or to cultivate plants / after experienced dzud.	124	98%	68	42%	192	66%
I learned to build fences for pasture storage or ponds, or to cultivate plants / after experienced dzud.	2	2%	95	58%	97	34%

Table B20 Answers from local herders in the study area for the question

"do you trust weather forecast you get on mobile phone better than on TV"? (N=292)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
I don't trust weather forecast I get on mobile phone better than on TV?	122	97%	15	9%	137	47%
I trust weather forecast I get on mobile phone better than on TV?	4	3%	151	91%	155	53%

Table B21 Answers from local herders in the study area for the question

"do you trust temperature forecast you get on mobile phone better than on TV"? (N=292)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
I don't trust temperature forecast I get on mobile phone better than on TV.	122	97%	21	13%	143	49%
I trust temperature forecast I get on mobile phone better than on TV.	4	3%	145	87%	149	51%

Table B22 Answers from local herders in the study area for the question "do you trust precipitation forecast you get on mobile phone better than on TV"? (N=292)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
I don't trust precipitation forecast I get on mobile phone better than on TV.	122	97%	10	6%	132	45%
I trust precipitation forecast I get on mobile phone better than on TV.	4	3%	156	94%	160	55%

Table B23 Answers from local herders in the study area for the question "do you trust wind forecast you get on mobile phone better than on TV"? (N=292)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
I don't trust wind forecast I get on mobile phone better than on TV.	122	97%	10	6%	132	45%
I trust wind forecast I get on mobile phone better than on TV.	4	3%	156	94%	160	55%

Table B24 Answers from local herders in the study area for the question "do you trust those forecasts you get on mobile phone better than the message came from NDI since December 2014"? (focused on answers who did not understand the meaning of the information) (N=165)

	Answers	Ratio
I don't trust those forecasts I get on mobile phone better than the message came from NDI since December 2014.	16	10%
I trust those forecasts I get on mobile phone better than the message came from NDI since December 2014.	149	90%

Table B25 Answers from local herders in the study area for the question

“did you refer the information you got on mobile phone for decision to migrate seasonal campsite last year”?

(focused on answers who did not understand the meaning of the information) (N=156)

	Answers	Ratio
I didn't refer the information I got on mobile phone for decision to migrate seasonal campsite last year.	95	61%
I referred the information I got on mobile phone for decision to migrate seasonal campsite last year.	61	39%

Table B26 Answers from local herders in the study area for the question

“did you refer the information you got on mobile phone to find out pastureland for preparation of winter/spring fodders”? (focused on answers who did not understand the meaning of the information) (N=157)

	Answers	Ratio
I didn't refer the information I got on mobile phone to find out pastureland for preparation of winter/spring fodders.	117	75%
I refered the information I got on mobile phone to find out pastureland for preparation of winter/spring fodders.	40	25%

Table B27 Answers from local herders in the study area for the question

“did you refer the information you got on mobile phone to avoid overgrazing”?

(focused on answers who did not understand the meaning of the information) (N=156)

	Answers	Ratio
I didn't refer the information I got on mobile phone to avoid overgrazing.	74	47%
I referred the information I got on mobile phone to avoid overgrazing.	84	53%

Table B28 Answers from local herders in the study area for the question

“How do you communicate with people who are not family or relatives”? (Open-ended style) (N=280)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
To meet and talk with people directly	72	44%	65	31%	137	36%
To meet and talk with people by using mobile phone	89	54%	148	69%	237	63%
No communications	4	2%	0	0%	4	1%

Table B29 Answers from local herders in the study area for the question "is there any group, which are not good relationship with the group that you belong"? (N=280)

	Interviewees who don't get info		Interviewees who get info		Total	
	Answers	Ratio	Answers	Ratio	Answers	Ratio
There is no groups, which are not good relationship with the group that you belong.	45	36%	79	48%	124	43%
There is some groups, which are not good relationship with the group that you belong.	81	64%	86	52%	167	57%

Table B30 Answers from local herders in the study area for the question "Have you communicate with people who usually have no communication with you by using information providing system on mobile phone"? (focused on answers who did not understand the meaning of the information) (N=167)

	Answers	Ratio
I have never communicated with people who usually have no communication by using information providing system on mobile phone.	26	16%
I have communicated with people who usually have no communication by using information providing system on mobile phone.	141	84%

Table B31 Answers from local herders in the study area for the question "is the amount of information enough for you to support your herding or lifestyle"?

(focused on answers who did not understand the meaning of the information) (N=166)

	Answers	Ratio
The amount of information is not enough for me to support your herding or lifestyle?	9	5%
The amount of information is enough for me to support your herding or lifestyle?	157	95%

Table B32 Answers from local herders in the study area for the question "do you satisfy the number of monitoring points for forage distribution on the information from the system"? (focused on answers who did not understand the meaning of the information) (N=163)

	Answers	Ratio
I don't satisfy the number of monitoring points for forage distribution on the information from the system.	55	34%
I satisfy the number of monitoring points for forage distribution on the information from the system.	108	66%

Table B32 Answers from local herders in the study area for the question "do you satisfy the frequency of information providing (once a week)"?

(focused on answers who did not understand the meaning of the information) (N=167)

	Answers	Ratio
I don't satisfy the frequency of information providing (once a week)	6	4%
I satisfy the frequency of information providing (once a week)	161	96%

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Table B32 Answers from local herders in the study area for the question “do you satisfy the frequency of information providing (once a week)”?

Abbreviations

ACMR	All China Data Center
AIC	Akaike's Information Criterion
ALOS/RPISM	Panchromatic Remote-sensing Instrument for Stereo Mapping scene on the Advanced Land Observing Satellite.
ASTER/VNIR	Visible and Near Infrared sensor on Advanced Spaceborne Thermal Emission and Reflection Radiometer satellite
CI	Climate Index
CRL	Change Rate of Livestock Population
DEM	Digital Elevation Model
DTA	Distance to the Aimag Centre
ECMWF	The European Centre for Medium-Range Weather Forecasts
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GIS	Geoinformation Systems
GLEWS	Global Livestock Early Warning System
GPS	Ground Positioning System
GWR	Geographically Weighted Regression
IGBP	The International Geosphere-Biosphere Programme
IM	Inner Mongolia
LEZ	Landscape Ecological Zoning
LFS	Total Number of Livestock per unit Forage in Summer
LFW	Total Number of Livestock per unit Forage in Winter
M	Mongolia
MNT	Mongolian Tuglik
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	The National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NEMA	National Emergency Management Agency
NOAA	National Oceanic and Atmospheric Administration
NPO	Non-Profit Organization
NSO	National Statistical Office, Mongolia
OLS	Ordinary Least Squares
PDSI	Palmer Drought Severity Index (
PHYGROW	hytomass Growth Model
PSL	Population of Small Livestock
SMS	Short Mail Message
SU	Sheep Unit
UCAR	University Corporation for Atmospheric Research
VIF	Variance Inflation Factor
WWF	World Wildlife Fund
XML	Extensible Markup Language

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Requirements for Ph.D Degree

Original Article (2)

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