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Advancing Understanding of Dzud Risk: a Livestock Mortality Model and Multi-Indicator Dzud Vulnerability Index (MDVI)

People in Need Mongolia, October 2018

MercyCorps

TAKH

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The model presented in this report was prepared by Frédéric Joly of TAKH (Association pour le cheval de Przewalski) in consultations with B. Nandintsetseg (Nagoya University, Japan; National University of Mongolia) and G. Amgalan (National Agency for Meteorology and Environment Monitoring of Mongolia, NAMEM). Laurel Hanson, Head of Programs at PIN Mongolia, contributed the report and provide final compilation and editing. Tina Puntsag, Communications Officer at PIN Mongolia, is credited for final branding. The photos presented in this report are credited to Frédéric Joly (TAKH).

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Table of Contents

List of Tables

List of Figures

1 Summary

Mongolia is regularly affected by a disaster in which socio-natural factors combine to create peaks of livestock mortality called dzud. The loss of livestock during dzud is the result of a combination of external climatic factors such as hazards, and internal factors such as overgrazing which makes forage resources difficult to access. The increasing incidence of dzud and its effect on Mongolian rural populations has led to a demand by development, humanitarian and Government of Mongolia actors for better predictive models of dzud and its risk.

This document presents a mathematical model developed under the LTT4R project. The model was developed for the consortium through consultations with Frédéric Joly of TAKH (Association pour le cheval de Przewalski), B. Nandintsetseg (Nagoya University, Japan; National University of Mongolia) and G. Amgalan (National Agency for Meteorology and Environment Monitoring of Mongolia, NAMEM). The report was compiled by Laurel Hanson, Head of Programs at People in Need (PIN). It is intended to advance discussions on dzud modelling and early warning and to inform development and humanitarian actors in Mongolia of dzud risk in time to adopt appropriate Disaster Risk Reduction (DRR) measures, including preparation and mitigation activities.

The model is based on anomalies and trends and although it was developed at the Aimag-level it is easily scalable and not site-specific. The following parameters are included:

1. Winter temperature anomaly (Δ_{WT})
2. Snowfall anomaly (Δ_{SF})
3. Anomaly of standing forage biomass estimated with help of remote sensing techniques (Δ_{SB})
4. Anomaly of pasture use (*i.e.* ratio forage demand to forage supply) (Δ_{PU})
5. Livestock zootechnical scores illustrating the trends of past mortality and female productivity as a proxy for body condition (ZS)

The model was calibrated using Aimag-level historical data from 1998 to 2014 and explains almost two thirds of livestock mortality in that period. From this, the team developed a Multi-Indicator Vulnerability Index (MDVI) based on the last 3 variables listed in Figure 1, expressed in the following equation:

$$MDVI_n = a + b\,ZS_{n-1} + c\,\Delta_{PU,n-1} + d\,ZS_{n-1}\,\Delta_{SB,n-1} + e\,ZS_{n-1}\,\Delta_{PU,n-1}$$

Үүнд: $a = 1.62$, $b = 0.46$, $c = 1.89$, $d = -0.32$, $e = -0.12$.

Figure 1: Multi-Indicator Dzud Vulnerability Index (MDVI)

The index uses the parameters of year n-1 to create vulnerability-based warnings; from it we established 4 classes of vulnerability, that correspond to the mean mortalities listed in the table below:

Index value	Mean mortality	Percentage of years with mortality >10%
0-1	1%	0%
1-2	3%	6%
2-3	6%	22%
>3	17%	59%
Total	**5%**	**15%**

Table 1: Vulnerability Thresholds for use with the MDVI

Our results demonstrate that the state of the pastoral system the year preceding a dzud event can inform about the system's vulnerability to hazards by the middle of autumn. The index that assesses it can be calculated to give enough time for appropriate action, because the required data can be obtained from trends for the livestock parameters, together with a the reference state we describe; and the forage parameters can be derived from remote sensing indices freely available almost in real time (Normalized Difference Vegetation Index - NDVI). Trends in livestock numbers, mortality and livestock female productivity can hence be collected in specific representative sample areas; and the forage parameters can be calculated from a model of biomass we established based on the European platform SPOT/VITO (biomass = 1802.3 NDVI 1.9963). This vulnerability assessment can help geographically prioritize and plan relief intervention(s) by identifying the areas the most at risk, to determine where to channel preparedness funds including the pre-positioning of relief materials such as livestock feed.

Currently, the Government of Mongolia is partnering with the Government of Japan and other actors to develop dzud risk awareness procedures. The current procedure uses vulnerability variables based on the ratio forage demand to forage supply, drought indices and winter weather predictions. The resulting dzud risk maps are produced through a spatialized procedure during winter and updated every 10 days according to weather predictions. Our findings could help refine risk maps by taking into account the livestock zootechnical scores that are for the moment absent of the procedure, and provide enhanced insights into predicted risk of livestock loss. These scores explain about 9% of livestock mortality, they could therefore significantly improve dzud risk maps.

Our results can therefore improve the current risk management system in Mongolia by refining the current protocol of risk map production, improving vulnerability assessments, and putting in place a tool of intervention prioritization. To do so, state scientists and technicians should integrate zootechnical scores into their risk assessment systems, which requires putting in place the appropriate data collection procedures. These procedures could be either based on current statistical office structures and protocols, or through a participative approach. For example, sentinel herders could send information about their livestock scores by sms, or through a smartphone application.

The work done on Household Economy Analysis (HEA) produced by the LTT4R consortium in consultations with the Food Economy Group (FEG) should be used in combination with this work. It complements the advances on geographical targeting procedures developed with the MDVI with an advanced understanding of how shocks and stressors affect herders among different wealth groups affected areas. The research presents HEA baselines conducted during October-November 2017, and an HEA outcome analysis (OA) desk-based exercise conducted in January 2018 for two livelihood zones in Sukhbaatar and Arkhanghai, Mongolia. The work describes the livelihood zones and creates wealth group rankings based on household assets including livestock numbers. The outcome analysis models how shocks and stressors such as the dzud affect different wealth groups in these livelihood zones. The report is available in English at http://bit.ly/2yS2fAa and in Mongolian at http://bit.ly/2yS2fAa.

2 Introduction

2.1 The Dzud in Mongolia

Mongolia has one of the harshest climates in the world, characterized by a very brief warm season lasting about 2 months, and a long winter with temperatures that can reach below -50°C. Approximately 46% of the country's 3 million population lives in remote rural areas, and many are nomadic pastoralists. One-third of the population of Mongolia depends on raising livestock for their livelihoods, including their entire cash income and approximately 30% of the herder's food source (FAO in PiN 2016).

The dzud is slow-onset disaster which produces a peak of livestock mortality. Initially associated with climate hazards only (a summer drought followed by a severe winter in which temperatures and/or snow make grazing inaccessible or unavailable for livestock), it is now increasingly understood that the dzud is the result of a combination of external climate-related factors and internal drivers related to the unbalance of animal numbers and forage resources (Begzsuren et al., 2004; Tachiiri et al., 2008; Fernández-Giménez, 2012; Thrift and Ichinkhorloo, 2015; Nandintsetseg et al., 2017). FAO has posited that the increased frequency is partly due to the El Niño–Southern Oscillation (ENSO), which brings colder temperatures to the region (FAO, 2016). The livestock loss of body condition and pasture degradation is also suspected to be involved by weakening livestock and make it vulnerable to winter hazards (Joly et al., 2017; Nandintsetseg et al., 2017).

Although herder households have traditionally well-developed mechanisms to survive the harsh environment, these have been exacerbated by political, social, economic and cultural factors, undermining coping capacity. The cyclical recurrence of the dzud phenomenon, a natural incidence specific to Mongolia, has also led to increased vulnerability.

Within this context, the LTT4R consortium and partners are working to increase the resilience of Mongolian pastoralists to shocks and stressors. The project is advancing early warning systems and indicators through the development of the MDVI, extending an SMS-based system to Mongolian herders for weather information, training local authorities and herders on tools such as Livestock in Emergency Guidelines and Standards and household dzud preparedness and mitigation, and performing other research components such as the aforementioned HEA. The MDVI and this report represent contributions to the wider community towards advancing understanding of dzud risk for better appropriate early action, preparedness and mitigation.

2.2 Current Early Warning Systems for the dzud in Mongolia

Pasture degradation, livestock loss of body condition and shortage of forage due to animal number increase are gradual processes and in this regard, dzuds can be seen as slow disaster. As a result a certain amount of parameters can be monitored to assess dzud risks. This report demonstrates that this can be measured in the autumn to give adequate time for humanitarian and development actors and the Government of Mongolia to take appropriate measures to reduce the effects of the dzud on Mongolian pastoralists.

In this framework, since the 2015/16 winter the Information and Research Institute of Meteorology, Hydrology and Environment (Mongolia) in collaboration with Nagoya University (Japan) has advanced understanding of areas at risk at the national level since the 2015/2016 winter (Nandintsetseg et al., 2018). To do so, they currently use a dzud risk map based on the ratio of forage demand and supply (based on standing forage biomass), current snow conditions, and weather predictions. This map is updated every 10 days and it provides 6 levels of risk that are available to the Mongolian administrations.

The risk map has been developed in the framework of a program called 4D (acronym for Disaster, Drought, Dust, and Dzud). The maps issued represents the current dzud risk maps being used by humanitarian, development and Government of Mongolia actors for early warning and geographic response targeting.

The current map is based on 7 parameters including both internal and external factors:
- Summer drought conditions
- Estimated winter-spring grazing ratio (ratio of forage demand and supply)
- Winter climate conditions
- Current air temperature anomaly
- Predicted air temperature anomaly
- Current snow depth/cover
- Predicted snowfall

2.3 Purpose of MDVI and Model

The work on the MDVI was spearheaded by PIN as the lead of the LTT4R consortium. Under LTT4R, the MDVI advances understanding of how to best plan and when to initiate actions for early warning, preparedness, mitigation and early action activities with a timely mechanism for the identification of geographical dzud risk. Indeed, although the exact ratio varies the United Nations Office for Disaster Risk Reduction (UNISDR) has demonstrated an approximately 4 to 1 and higher ratio of the effectiveness of investment in Disaster Risk Reduction (DRR) activities versus when investment is made in an emergency situation (UNISDR 2007; UNISDR 2017). The work done on the MDVI also advances Priority 7 of the Sendai Framework for Disaster Risk Reduction (SFDRR) (substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030) and Priorities 1 and 2 within the Mongolian context. Furthermore, the MDVI should be widely shared among humanitarian and development actors in Mongolia as well as the Government of Mongolia.

This work establishes vulnerability indicators for monitoring dzud risk that can provide geographically targeted advice and advance Early Warning Systems (EWS) in Mongolia. The overarching goal was to advance work towards the implementation of the Sendai Framework under LTT4R in Mongolia as funded by the European Union by understanding which parameters of the Mongolian pastoral system could be used to assess vulnerability in the months before a dzud event. The work draws from previous research in Durvuljin soum (Zavkhan Province) and in Bayan Khongor Province in Mongolia. These studies showed that certain zootechnical parameters present cyclical patterns which suggest that dzud events take place at specific moments when livestock is already vulnerable and cannot cope with winter hazards. Specifically, the livestock mortality and productivity of breeding-age females, respectively, increases and decreases prior to dzud events.

Additionally, the work assesses the usefulness of remote sensing to replace forage biomass field measurements to assess the ratio between forage supply and demand. This ratio has already been identified as a parameter correlated with livestock mortality during dzud (Nandintsetseg et al., 2017) and it is very important to have it well assessed and properly mapped properly to target intervention.

3 Methodology

This section provides a description of the sampling strategy and methods used for data collection. It also describes the limitations of the research.

3.1 General Approach and Scalability

To obtain a vulnerability index, the team built a mathematical model of animal mortality, taking into account both internal and external drivers. External drivers are climate related variables and internal variables are parameters related with livestock including numbers, forage and pasture condition. The model of animal mortality uses hazard variables and mortality of calendar year n (e.g. year 2010) and the internal elements associated to vulnerability from calendar year n-1 (e.g. year 2009). It is indeed necessary to assess vulnerability on year n-1 before winter to avoid mortality of year n as dzud mortality usually took place at the end of winter, justifying the use of this in modelling.

The research team used data at Aimag scale as initial trials at the Soum scale using zootechnical data showed surprisingly high level of dispersion, suggesting inconsistency in data gathering or processing. We therefore used data at the Aimag scale that was determined to be more consistent, buffering possible errors in the creation of the model. The team also used trends and anomalies to ensure the scalability of our results and ensure the validity of our model at nation scale, and avoid results that would have been site specific only. In the event that reliable data is produced at a smaller administrative scale (ex. Soum or Bagh level), the model can be scaled to that level.

The study period is 1998- 2014 as 1998 is the first year where remote sensing data was available, and 2014 is the last year when hazard data was available.

3.2 Parameters used to build the index

To build the model, the research team used the parameters described and summarized in the below table (the table also indicates the source of the data). The sources listed below are the National Statistics Office of Mongolia (NSOM), the National Agency for Hydrological, Meteorological and Environmental Monitoring of Mongolia (NAHMEM), the Normalized Difference Vegetation Index (NDVI) of the Moderate Resolution Imaging Spectroradiometer (MODIS) of the United States National Oceanic and Atmospheric Administration (NOAA) and of the European program (SPOT/VITO).

Parameter	Year Used	Source
Mortality (M)	N	NSOM
Winter temperature anomaly (Δ_{WT})	N	NAHMEM
Snowfall anomaly (Δ_{SF})	N	NAHMEM
Standing biomass anomaly (Δ_{SB})	N-1	NDVI (MODIS & SPOT/VITO) and NAHMEM
Pasture use anomaly (Δ_{PU})	N-1	NSOM
Zootechnical score (ZS)	N-1	NSOM

Table 2: Summary of Parameters Used to Build the Index

3.2.1 Mortality Rate

Mortality is the number of the animal losses on animal numbers obtained from the National Statistical Office of Mongolia (www.1212.mn) (NSOM). As animals are counted at the end of the year and as mortality usually occurs at the end of winter, the team calculated mortality as the ratio losses of year n divided by number of year n-1.

3.2.2 Winter Temperature and Snowfall Anomaly

The winter temperature and snowfall anomalies are the difference with the mean of the period 1981-2010 and illustrate the difficulty presented by winter conditions. The temperature anomaly is expressed in degrees Celsius and the snowfall in snow water equivalent expressed in millimetre (mm). Data is from 69 state stations and the mean per Aimag was used as all Aimags except Darkhan Uul had available data.

3.2.3 Forage biomass anomaly

The forage biomass anomaly describes the abundance/availability of forage, compared to the mean situation, over the study period. This parameter integrates both the effect of summer precipitation and pasture health. Pasture health is defined as the integrity of the biophysical processes ensuring the growth and renewal of vegetation and is not expressed in the amount of forage, which is too dependent on rainfall to be meaningful. It is expressed as the difference from the mean, divided by the mean to have pertinent comparisons between Aimags with a high grass density in the north, and those with a low density in the South.

The anomaly was assessed from the satellite vegetation index NDVI, which was used to establish a model of biomass from field plots studied in 2009. The NDVI of MODIS from US NOAA and SPOT/VITO from the European platform Copernicus were tested, and the team used the SPOT/VITO that returned a slightly better fit than MODIS. The model biomass was then used to calculate the mean standing biomass according to Aimag over the study period with help the Spatial Analyst extension of ArcGIS.

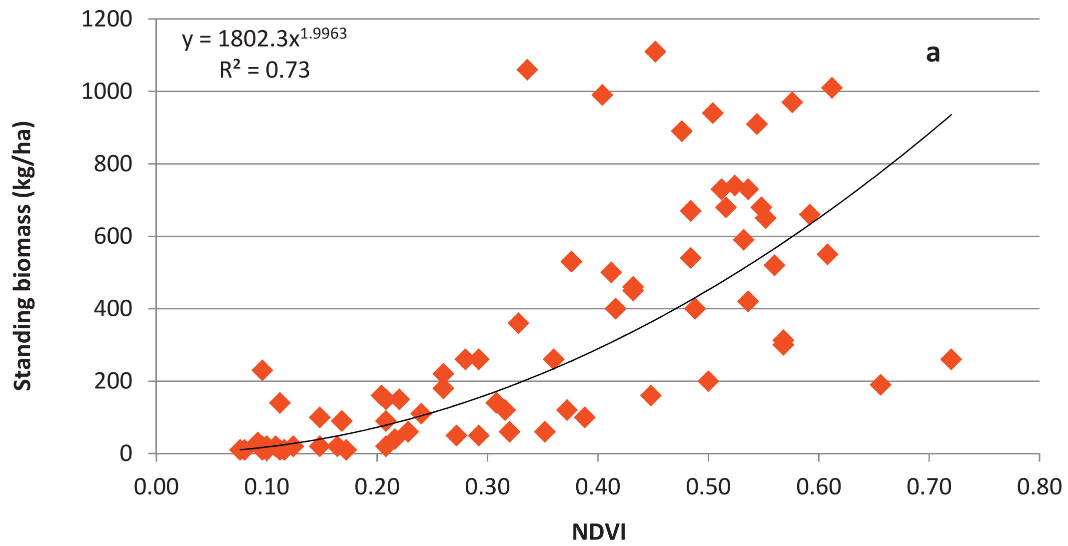

Figure 2a: Correlation between field biomass samples distributed over different Mongolian climate zones (end August 2009) and NDVI values provided by the SPOT/VITO (a) and MODIS (b) platforms (NDVI from the last dekad of August).

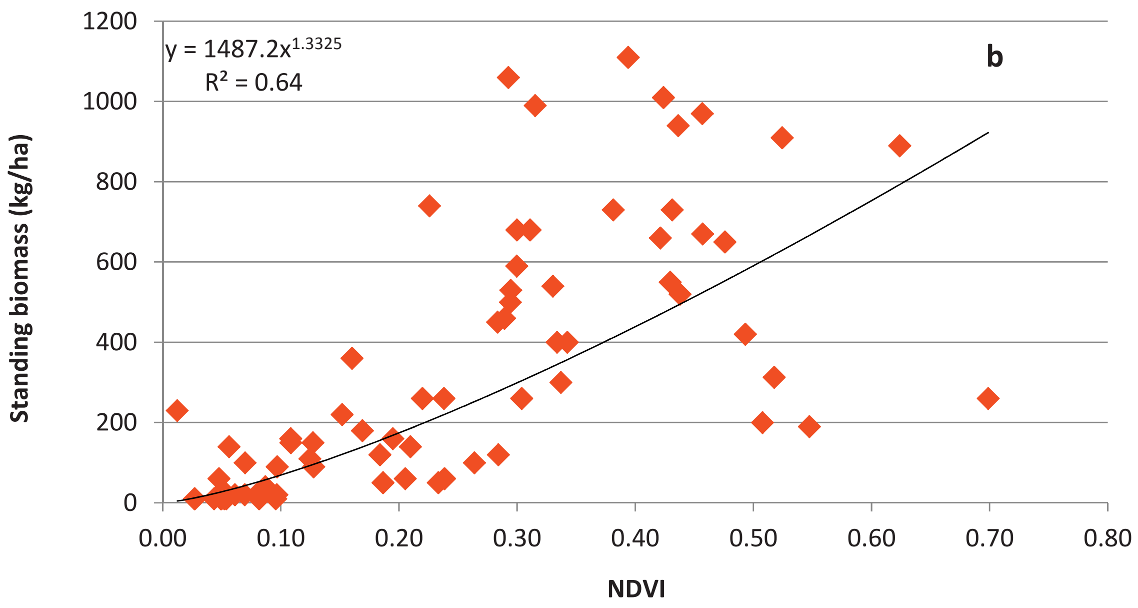

Figure 2b: Correlation between field biomass samples distributed over different Mongolian climate zones (end August 2009) and NDVI values provided by the SPOT/VITO (a) and MODIS (b) platforms (NDVI from the last dekad of August).

3.2.4 Pasture Use Anomaly

Pasture use is the ratio of forage demand to forage supply and illustrates the abundance of forage as compared with the number of animals. It was relevant to take into account the pasture use and forage anomaly because a given value of pasture use can describe 2 different situations. The first is a situation where both animals and forage are abundant, and the second is where they are both scarce. Mathematically, those situations can have identical values but they can be very distinct from the biological and systems viewpoint. It is indeed more favourable to have an abundance of both livestock and grass, because for a given amount of grass consumed, animals will have to less to walk to reach more food.

Forage supply was calculated from the livestock numbers given by NSOM, converted into sheep forage units (SFU). The coefficients are 1 goat = 0.9 SFU, 1 horse = 7 SFU, 1 cattle = 6 SFU and 1 camel = 5 SFU as given by NSOM. The team used the consumption for 1 year even though dzud mostly concern winter condition for two reasons. Firstly, the ratio other one year is illustrative of the forage conditions of the country (a yearly ratio above 0.5 illustrates very high risks of forage shortage). Second, using the anomaly makes it similar mathematically over winter months and one year.

The pasture use anomaly is expressed as the difference with the mean, divided by the mean over the study period.

3.2.5 Zootechnical Score

The zootechnical score is a proxy (i.e. an indicator) for the body condition of livestock and therefore its ability to cross winter without mortality. It is based on the trends of mortality rate and female productivity (assessed from ratio young per breeding age female available from NSOM). It is the sum of both fecundity and mortality scores.

If productivity decreases for two solid years the fecundity score it is equal to one and it is equal to zero in all other situations. If mortality increases two solid years and it is equal to one and it is equal to zero in all other situations. For year n, the value of the score is therefore based on the trends between n-2 and n-1, and between n-1 and n.

3.3 Statistical Analysis

The team analysed the obtained dataset with the help of the open access software R in two steps. We first established a livestock mortality model with the help of the function “geeglm” of the package “geepack”[1]. This function was chosen as it can handle times-series and what is called “clustered data”, i.e. data embedded within different units, in our case Aimags. In this way, the team obtained a mathematical expression we used to produce our indicator of vulnerability, by replacing the hazard value by their means over the study period. The team only used the parameters that appeared to influence mortality as illustrated by the p-values of the associated coefficients in the model (significance threshold set at 0.05).

The research team then made categories of this index, aiming at providing meaningful intervals of mortality and sufficient data points in each category (please see the details in the table below). The team then made a statistical categorical Kruskal Wallis test between vulnerability classes and mortality to cross-validate the index.

[1]geeglm is the combination of the terms gee and glm, gee standing for ‘General Estimator Equation solver’ and glm standing for ‘Generalized Linear Model’.

4 Findings

The geeglm confirmed that all the selected parameters have an influence on mortality, by impacting livestock alone or in interaction with each other (see below for the full geeglm report). The validity of the geeglm was confirmed by a normality test on the residuals of the model (Shapiro-Wilk Test W= 0.7 p-value <2e-16).

The significance of the hazard and non-hazard parameters confirmed the hypothesis that internal factors contribute to make livestock vulnerable to hazards, which ultimately cause dzud. Unsurprisingly the value of the geeglm estimates indicate that the highest mortalities are associated with a high snow height and low temperature, a scarce forage, a high pasture use and poor body condition as assessed by the zootechnical score.

By plotting the predicted and real mortality values to obtain the familiar R2 value of an ordinary regression (polynomial), we note that the model explains almost two-thirds of the mortality variability, as shown below.

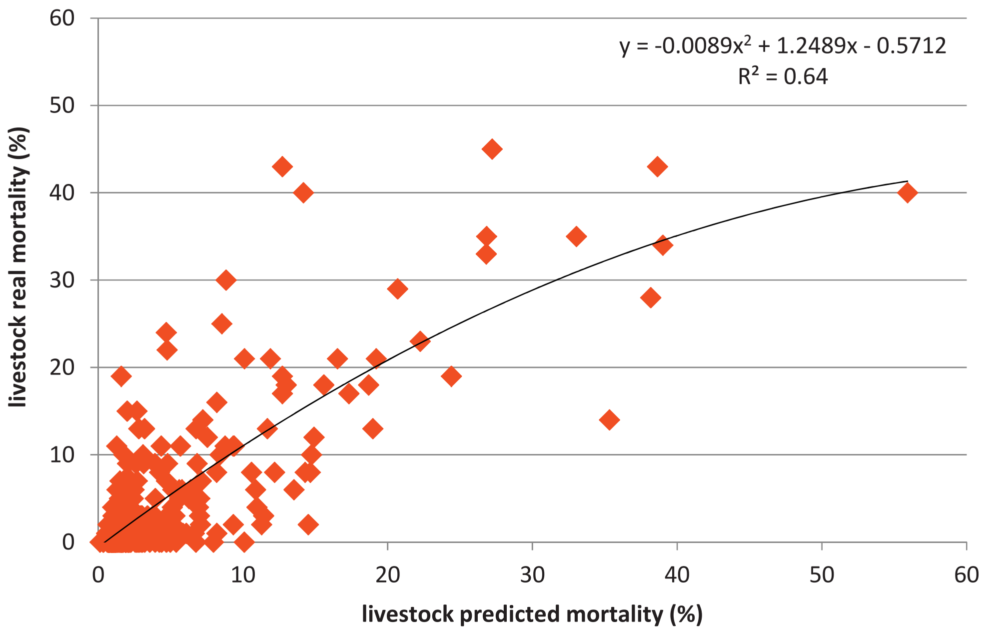

Figure 3: Real mortality and mortality predicted by the model

4.1 Geeglm Report

The following section contains the full results of the Geeglm report.

```
> gee.fit <- geeglm(Loss_rate_Y_100~Snowfall11_3_anomaly_Y*Forage_anomaly_Y_minus_1*Zootechnical_index_Y_minus_1+Temp11_2_anomaly_Y*Pasture_Use_Y_minus_1_anomaly*Zootechnical_index_Y_minus_1, id=Aimag_code, waves= Year, data=Mortality_Mongolia_geepack, family=poisson, corstr="exch")
> summary(gee.fit)

Call:
geeglm(formula = Loss_rate_Y_100 ~ Snowfall11_3_anomaly_Y * Forage_anomaly_Y_minus_1 *
   Zootechnical_index_Y_minus_1 + Temp11_2_anomaly_Y * Pasture_Use_Y_minus_1_anomaly *
   Zootechnical_index_Y_minus_1, family = poisson, data = Mortality_Mongolia_geepack,
   id = Aimag_code, waves = Year, corstr = "exch")

 Coefficients:
                                                        Estimate Std.err  Wald Pr(>|W|)
(Intercept)                                               0.5930  0.0949 39.01  4.2e-10 ***
Snowfall11_3_anomaly_Y                                    0.0373  0.0125  8.91  0.00284 **
Forage_anomaly_Y_minus_1                                  0.4032  0.3945  1.04  0.30667
Zootechnical_index_Y_minus_1                              0.5446  0.0667 66.76  3.3e-16 ***
Temp11_2_anomaly_Y                                       -0.1663  0.0442 14.16  0.00017 ***
Pasture_Use_Y_minus_1_anomaly                             1.8854  0.3483 29.30  6.2e-08 ***
Snowfall11_3_anomaly_Y:Forage_anomaly_Y_minus_1          -0.0806  0.0455  3.14  0.07617 .
Snowfall11_3_anomaly_Y:Zootechnical_index_Y_minus_1      -0.0517  0.0104 24.82  6.3e-07 ***
Forage_anomaly_Y_minus_1:Zootechnical_index_Y_minus_1     0.4428  0.3317  1.78  0.18191
Temp11_2_anomaly_Y:Pasture_Use_Y_minus_1_anomaly         -0.0647  0.1559  0.17  0.67800
Zootechnical_index_Y_minus_1:Temp11_2_anomaly_Y          -0.1420  0.0376 14.29  0.00016 ***
Zootechnical_index_Y_minus_1:Pasture_Use_Y_minus_1_anomaly  0.2090  0.2647  0.62  0.42973
Snowfall11_3_anomaly_Y:Forage_anomaly_Y_minus_1:Zootechnical_index_Y_minus_1  -0.1138  0.0368  9.56
0.00198 **
Zootechnical_index_Y_minus_1:Temp11_2_anomaly_Y:Pasture_Use_Y_minus_1_anomaly  0.3115  0.0979 10.13
0.00146 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Estimated Scale Parameters:
            Estimate Std.err
(Intercept)     4.53   0.474

Correlation: Structure = exchangeable  Link = identity

Estimated Correlation Parameters:
      Estimate Std.err
alpha   0.0124  0.0152
Number of clusters:   21   Maximum cluster size: 16
```

5 Vulnerability Indicator (MDVI) Proposition

Through replacing the hazard variables in the mathematical mortality model by their mean values, the index is expressed according to equation 1:

$$ЭБОҮИ_n = a + b\,ZS_{n-1} + c\,\Delta_{PU,n-1} + d\,ZS_{n-1}\,\Delta_{SB,n-1} + e\,ZS_{n-1}\,\Delta_{PU,n-1}$$

Figure 4: MDVI Equation

With MDVIn the vulnerability index of year n, and ZS_{n-1}, $\Delta PU_{,n-1}$, $\Delta_{SB,n-1}$ the zootechnical score, the pasture use and standing biomass anomalies of year n-1. The values of the coefficients in Eq. 1 are:

a = 1.62
b = 0.46
c = 1.89
d = -0.32
e =-0.12

Table 3: Coeffficient Values for MDVI Equation

Low values of MDVI indicate that when livestock body condition is good and forage resource abundant, both in terms of relative abundance compared to livestock consumption and by comparison with other years, mortality is low. As a result, livestock is resistant and has access to enough forage. Conversely, high values indicate poor body condition associated with adverse forage conditions, due to a combination of high livestock demand and grass scarcity due to pasture degradation and/or drought. As a result livestock is weak, and has little forage at disposal.

The mortality according to the values of the proposed index is plotted in Figure 5. The R2 of a regression between the values of the index and the past mortality is 0.33, which is about half of the mortality of the model. It is in line with previous studies that established that vulnerability and hazard contribute in equal part to dzud mortality.

Four index classes provide a statistically significant typology (Kruskal-Wallis chi-squared test=90, df=3, p-value <2e-16) that are interesting using for their mean value and % of occurrence of mortality higher than 10%.

With indices below 1 our dataset returned no case of mortality above 10% and mean mortality is just 1%, which indicates that mortality risk is extremely low. It is low even in harsh winter conditions as illustrated by the mortality which is below 3% in Tuv and Bulgan in 2004, or UvurKhangai 2013 (snowfall above 15 mm and temperature anomaly negative). This illustrates how livestock in good condition with a favourable forage environment can face harsh snowy winter.

Between 1 and 2 the mean mortality is 3 with 6% of case with mortality above 10%. These values respectively increase, respectively, to 6 and 22 when the index is between 2 and 3. Above three, overall mean mortality is high and peaks of mortality occurred more than half of the time in our dataset. A high index is hence not automatically associated to a dzud as this event requires climate hazards to occur. Phrased simply, this vulnerability index should be seen as an assessment of dzud probability and not a dzud predictor. There are indeed numerous cases when index is in the >3 but no dzud took place (Bayan-Olgii in 2008 or in Gobi-Altai and Gobi-Sumber in 2008).

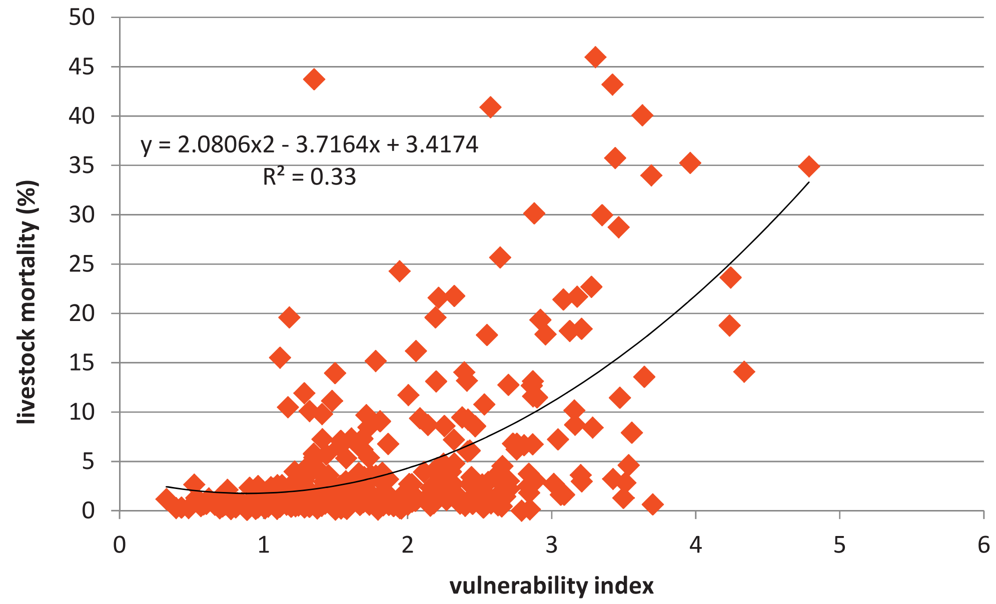

Figure 5: Real mortality according to the proposed vulnerability index (MDVI)

Index value	Mean mortality	Proportion of years with mortality >10%	Number of case in the dataset
0-1	1%	0%	34
1-2	3%	6%	175
2-3	6%	22%	93
>3	17%	59%	34
Total	**5%**	**15%**	**336**

Table 4: Mortality structure according to the proposed vulnerability index

5.1 Current vulnerability and trend

Vulnerability assessed in the year 2017 as assessed by this indicator is high, as showed in Table 5 and Figure 6 below. Data for 2018 was not available at the time of report writing, however the table shows a diverse situation regarding the historical record in 2017. This vulnerability is expected to increase as long as livestock numbers rise, which have increased regularly since 2010.

Aimag	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	1.13	1.69	1.94	2.63	2.81	1.15	1.3	1.57	1.33	1.36	2.34	3.35	1.86	1.31	1.35	1.49	2.54	2.67	2.4	3.07
Bayankhongor	1.57	2.14	2.92	3.42	2.66	0.6	1.2	1.17	2.27	1.42	3.04	4.24	2.47	0.85	1.06	1.34	2.51	3.28	2.15	4.85
Bayan-Ulgii	1.72	1.53	1.61	2.2	2.84	1.34	1.87	0.92	2.55	1.75	3.56	2.87	2.27	1.54	0.82	0.96	2.05	2.44	1.93	3.54
Bulgan	1.27	2.32	2.86	2.7	2.22	1.	1.05	1.09	1.24	1.48	2.54	2.47	2.32	1.73	1.74	1.87	2.67	2.48	2.62	2.89
Darkhan-Uul	1.3	1.3	2.12	2.44	4.14	0.78	1.41	1.37	1.1	1.29	1.94	2.18	2.11	1.89	1.47	1.95	2.99	2.09	2.34	3.1
Dornod	0.7	1.98	2.26	3.06	1.45	1.24	2.68	1.67	1.32	2.47	2.09	3.18	2.4	1.39	1.22	1.43	1.89	1.96	4.67	3.18
Dornogovi	0.62	2.76	1.18	2.66	1.98	1.16	1.85	3.64	2.03	1.02	0.89	2.25	1.95	1.38	0.69	1.9	4.56	4.14	2.92	2.49
Dundgovi	0.96	4.79	1.35	1.24	2.48	0.69	2.45	2.26	2.53	2.01	2.16	2.57	0.77	0.48	0.39	0.88	3.49	2.58	2.69	1.77
Govi-Altai	2.56	1.82	1.41	3.63	2.04	0.43	1.24	1.28	2.63	3.21	3.53	3.69	1.29	0.75	1.07	1.15	1.77	1.58	1.63	5.28
Govisumber	0.52	2.38	1.35	1.87	1.79	0.94	1.54	3.7	2.79	3.2	2.21	1.81	2.85	1.03	1.09	2.	5.69	2.77	5.55	3.14
Khentii	1.1	2.03	2.41	2.63	1.73	1.27	1.47	1.53	2.01	2.9	1.57	1.48	1.59	2.04	1.31	1.95	2.59	2.39	3.51	3.48
Khovd	1.82	1.28	1.71	3.12	2.84	0.57	1.39	1.11	2.65	2.44	3.51	2.19	1.29	1.23	1.11	1.15	1.95	1.69	2.16	4.41
Khuvsgul	1.44	2.42	2.64	2.19	2.11	1.44	1.29	1.22	1.45	1.67	2.84	2.55	2.05	1.65	1.8	1.49	2.06	2.14	2.08	2.74
Orkhon	0.98	1.57	1.41	3.01	4.34	1.02	1.11	1.59	1.37	1.58	1.99	2.01	1.93	1.33	1.24	1.57	1.16	1.03	1.26	1.56
Selenge	1.05	1.13	1.73	2.28	2.53	1.04	1.24	1.19	1.09	1.5	2.18	2.73	2.54	2.36	1.9	1.96	2.73	2.53	2.78	3.14
Sukhbaatar	0.53	1.63	1.11	3.5	1.71	1.66	2.76	3.09	1.33	3.28	1.38	1.7	2.16	1.18	0.78	1.19	2.74	2.31	4.02	2.28
Tuv	1.36	2.42	2.32	2.52	2.87	0.9	1.34	1.17	1.3	1.78	2.16	2.06	1.46	1.81	1.46	1.73	3.2	2.71	3.68	2.84
Ulaanbaatar	1.32	1.71	1.17	1.3	2.89	1.3	1.63	1.54	1.4	1.6	2.05	3.21	2.45	2.58	1.32	1.91	2.05	2.03	3.04	3.33
Umnugovi	1.42	3.16	2.7	4.23	3.16	0.33	1.2	2.21	1.69	0.66	1.39	3.96	2.16	1.16	0.73	1.67	2.11	2.98	2.32	4.
Uvs	1.49	1.78	1.69	1.5	2.21	0.58	1.44	1.02	1.99	3.28	3.47	3.47	1.87	1.43	1.17	1.23	2.53	3.97	1.92	4.39
Uvurkhangai	1.23	3.08	2.39	1.28	2.43	0.72	1.67	1.57	1.22	1.3	3.43	3.3	1.06	0.81	0.74	1.01	2.96	2.56	2.36	3.05
Zavkhan	2.3	2.96	2.88	2.43	2.32	0.73	1.4	1.08	1.83	2.7	2.87	3.44	1.36	1.11	1.24	0.97	2.36	2.09	2.07	3.82
Weighed mean[1]	1.36	2.28	2.12	2.54	2.39	0.96	1.56	1.54	1.74	2.	2.54	2.83	1.79	1.36	1.19	1.41	2.59	2.53	2.65	3.34

Table 5: Past values of the vulnerability index according to Aimag

1: Average weighed by livestock numbers in SFU

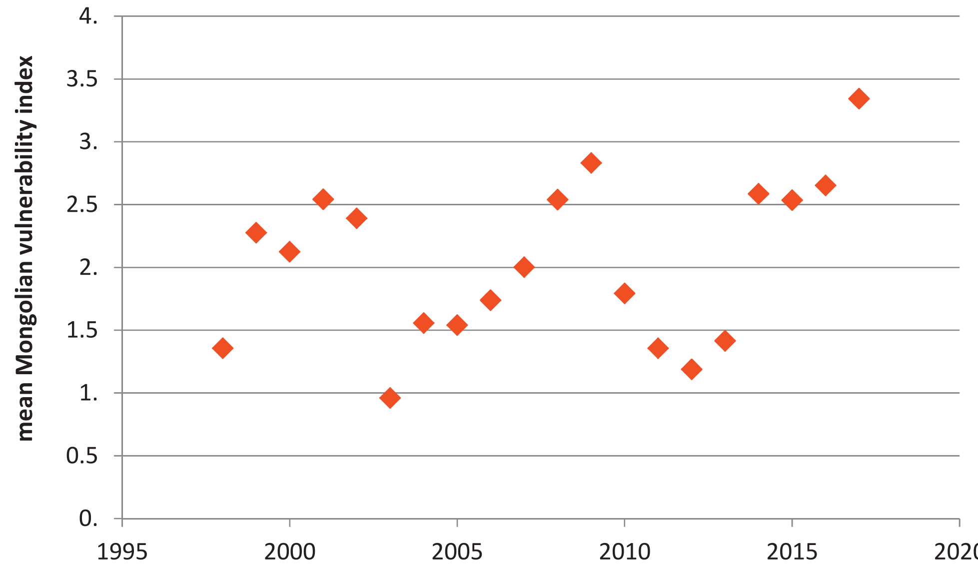

Figure 6: Weighed average of the vulnerability index at the country scale (weighed by livestock numbers in SFU per Aimag)

5.2 Conclusions and Lessons Learnt

Our results confirm that the state of Mongolian pastoral systems can inform about their vulnerability to winter hazards. This state of vulnerability can be quantified with the help of an index based on values of slow changing variables describing the state of the systems before winter. As a consequence, such an index has the potential to help state and non-state relief agencies to plan preparedness and intervention activities to help the communities in the areas identified by the MDVI as the most likely to be impacted in case of harsh winter.

The information compiled in the MDVI can be used to help humanitarian and development actors and the Government of Mongolia to geographically focus their interventions on areas with the highest vulnerability index. For example, fodder or concentrates can be pre-stocked in vulnerable areas or winter preparation activities such as training and assistance on building improved winter shelters or destocking can be concentrated in geographic areas pre-identified by the index.

As mentioned in the Summary section, the work done on Household Economy Analysis (HEA) produced by the LTT4R consortium in consultations with the Food Economy Group (FEG) should be used in combination with this work. It complements the advances on geographical targeting procedures developed with the MDVI with an advanced understanding of how shocks and stressors affect herders among different wealth groups affected areas. The research presents HEA baselines conducted during October-November 2017, and an HEA outcome analysis (OA) desk-based exercise conducted in January 2018 for two livelihood zones in Sukhbaatar and Arkhanghai, Mongolia. The work describes the livelihood zones and creates wealth group rankings based on household assets including livestock numbers. The outcome analysis models how shocks and stressors such as the dzud affect different wealth groups in these livelihood zones. The report is available in English at http://bit.ly/2yS2fAa and in Mongolian at http://bit.ly/2yS2fAa.

6 Recommendations and Implications:

This section summarizes the recommendations of the research team as well as the implications of the MDVI.

6.1 Vulnerability assessment

To make the use of this index operational the data required to compute it should be available as early as possible, if possible by mid-autumn or the beginning of the cold season. The team used statistical data from NSOM that provides data obtained from census conducted annually in December. As mentioned above, the index can be used to prioritize areas of intervention and therefore to advance the work of the humanitarian and development communities as well as the Government of Mongolia, this data should be provided by October.

As the team worked with trends and anomalies, these sites would simply have to provide trends compared to the previous years, and use the reference data provided in this report per Aimag, which would make it possible to compute values of the current year. For example, regarding pasture use, if both the increase/percentage of livestock numbers and standing biomass can be obtained, the pasture use and the pasture anomaly can be easily calculated and up-dated. This rationale is also valid for the zootechnical score, precisely because this score is based on trend. So sentinel herders gathering the required trend could help compute the index by October, and all the biomass related parameters can be easily obtained from remote sensing data that are made available almost in real time by the US and European platforms.

This network of sentinels could be state-based but it could also rely on a participatory approach. Trends could therefore be collected through a sms platform or a dedicated smartphone application, and participating herders could receive an incentive, for example by being listed on the first recipients in case of feed distribution during hazard condition. However safety measured should be identified and put in place to avoid herders to give an account of the situation which is worse than real, and make their zone listed as a priority.

There is potential progresses that could be done to integrate this effort with the current dzud risk map provided by the state. These maps could indeed add the zootechnical score we studied which may significantly improve their risk assessment, as this score explained a non-negligible 9% of mortality (as determined through an ordinary linear regression between prediction of a geeglm model with only the zootechnical score and mortality). The vulnerability map could also be made available through the state warning systems).

6.2 Future improvements

There are finally a number of modifications that can be made to improve the precisions of the geeglm model used. First, Aimags used could be clustered into relevant ecological or geographical zones; each cluster would be associated to a model which would certainly increase the predictive power of the latter. The smallest Aimags of Orkhon, Darkhan Uul and Govi Sumber could also be merged into their bigger neighbour to avoid altering the results of the model (such merging has been made by the author Tachiiri et al. (2008) who studied the dzuds of the years 2000s).

It would besides be interesting to add other type of parameters likely to impact livestock resistance to climate hazards in the model, such as the veterinary condition. The occurrence of outbreaks such as the foot-and-mouth disease could be quantified and introduced in the mortality model or used to refine the zootechnical scores.

It would be also worth investigating the relevance of non-continuous models able to take into account both threshold effects, like regression trees, and spatial temporal-autocorrelation. Besides that, establishment of mathematical models requires dataset large enough and in our case we used data ranging from 1998 to 2014. During such time the situation of herders changed, as herders are now better prepared to dzud than they were after the collapse of the socialist regime. The hay preparation has most likely improved since then and herders have better selling and slaughtering practices of the weak animals before winter. In addition, humanitarian and development actors as well as the Government of Mongolia undertook several early action/preparedness activities.

It is hypothesized that these factors explain why the high vulnerability of 2017 did not result in a massive dzud during the winter 2017/2018. It can also be conjectured that herders will continue to learn how better prepare for winter condition which may require adjusting the model, by taking only into account in the model establishment only years above a certain date. In order to do so, it is advocated that the humanitarian and development communities move towards a better model focused on resilience, preparedness and early action in order to help herders and their communities.

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8 Annex 1: Livestock Loss Rates from 1998-2017

Loss rates	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	0.01	0.01	0.06	0.24	0.04	0.07	0.01	0.01	0.01	0.01	0.01	0.02	0.30	0.03	0.02	0.06	0.02	0.02	0.03	0.03
Bayankhongor	0.02	0.03	0.09	0.19	0.43	0.02	0.01	0.01	0.01	0.01	0.03	0.07	0.24	0.01	0.01	0.02	0.02	0.02	0.03	0.01
Bayan-Ulgii	0.12	0.02	0.06	0.07	0.13	0.02	0.02	0.07	0.01	0.02	0.04	0.08	0.12	0.01	0.07	0.01	0.00	0.00	0.02	0.01
Bulgan	0.01	0.01	0.07	0.13	0.03	0.22	0.01	0.01	0.00	0.01	0.00	0.01	0.09	0.03	0.01	0.01	0.01	0.02	0.02	0.02
Darkhan-Uul	0.02	0.02	0.03	0.09	0.01	0.08	0.01	0.00	0.00	0.00	0.00	0.01	0.13	0.01	0.01	0.01	0.01	0.01	0.01	0.06
Dornod	0.01	0.01	0.02	0.09	0.02	0.04	0.01	0.01	0.01	0.00	0.01	0.09	0.22	0.00	0.01	0.04	0.01	0.01	0.01	0.01
Dornogovi	0.02	0.01	0.07	0.20	0.05	0.02	0.01	0.03	0.14	0.01	0.02	0.00	0.05	0.00	0.01	0.01	0.00	0.01	0.07	0.00
Dundgovi	0.01	0.02	0.35	0.05	0.02	0.02	0.00	0.01	0.03	0.00	0.03	0.02	0.41	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Govi-Altai	0.05	0.03	0.04	0.07	0.40	0.01	0.00	0.01	0.00	0.01	0.03	0.05	0.34	0.04	0.02	0.02	0.02	0.01	0.01	0.00
Govisumber	0.01	0.03	0.09	0.44	0.01	0.00	0.00	0.00	0.01	0.00	0.04	0.04	0.09	0.00	0.00	0.01	0.01	0.01	0.04	0.01
Khentii	0.01	0.03	0.03	0.13	0.03	0.05	0.01	0.02	0.03	0.01	0.11	0.05	0.11	0.01	0.02	0.01	0.01	0.01	0.01	0.02
Khovd	0.05	0.02	0.03	0.10	0.18	0.02	0.00	0.01	0.00	0.00	0.03	0.03	0.20	0.03	0.01	0.01	0.01	0.01	0.02	0.01
Khuvsgul	0.02	0.02	0.06	0.26	0.02	0.04	0.01	0.02	0.01	0.01	0.01	0.04	0.18	0.01	0.01	0.03	0.01	0.01	0.01	0.04
Orkhon	0.02	0.01	0.02	0.10	0.03	0.14	0.02	0.01	0.01	0.00	0.00	0.01	0.12	0.00	0.01	0.01	0.00	0.01	0.00	0.04
Selenge	0.02	0.02	0.03	0.08	0.01	0.11	0.01	0.01	0.00	0.00	0.00	0.01	0.07	0.01	0.01	0.00	0.00	0.01	0.00	0.04
Sukhbaatar	0.03	0.01	0.03	0.16	0.01	0.02	0.04	0.06	0.02	0.02	0.23	0.01	0.03	0.02	0.01	0.01	0.00	0.01	0.06	0.00
Tuv	0.01	0.05	0.09	0.22	0.03	0.13	0.02	0.01	0.01	0.01	0.04	0.01	0.16	0.01	0.01	0.01	0.01	0.01	0.03	0.02
Ulaanbaatar	0.02	0.10	0.03	0.10	0.02	0.03	0.01	0.01	0.01	0.00	0.01	0.01	0.18	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Umnugovi	0.02	0.03	0.09	0.13	0.19	0.10	0.01	0.03	0.04	0.01	0.01	0.02	0.35	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Uvs	0.02	0.02	0.15	0.07	0.14	0.02	0.01	0.06	0.02	0.02	0.08	0.11	0.29	0.02	0.03	0.02	0.01	0.01	0.07	0.01
Uvurkhangai	0.01	0.01	0.21	0.14	0.12	0.03	0.00	0.02	0.01	0.00	0.04	0.03	0.46	0.01	0.00	0.01	0.00	0.02	0.01	0.01
Zavkhan	0.02	0.04	0.18	0.30	0.06	0.05	0.01	0.04	0.01	0.01	0.02	0.07	0.36	0.02	0.01	0.03	0.01	0.01	0.04	0.01

9 Annex 2: Temperature anomalies (°C) for the period from 1999-2014

Temperature anomalies	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Arkhangai	2.75	-0.39	-1.62	0.86	-0.10	0.54	-2.70	-0.17	3.05	-0.66	0.91	-3.36	-1.06	-3.23	-2.33	1.49
Bayanhongor	3.36	-0.34	-0.36	0.31	-0.13	-0.29	-2.70	0.09	2.49	-1.30	1.88	-2.17	-1.00	-1.70	-1.24	0.74
Bayan-Ulgii	2.76	0.74	0.16	0.49	0.84	0.71	-3.70	0.59	3.74	-1.19	2.08	-0.95	-0.36	-2.56	0.23	0.98
Bulgan	3.52	-0.62	-2.79	1.06	-3.65	-0.45	-3.02	-0.32	3.21	-0.29	2.31	-3.29	-1.32	-4.27	-4.08	0.92
Dornod	1.00	-0.57	-4.62	1.93	-1.51	-0.52	-2.21	-1.01	1.93	-0.11	0.08	-3.68	-1.55	-3.47	-3.73	2.12
Dornogobi	1.64	-1.15	-1.13	2.80	-1.46	1.38	-0.57	0.55	2.77	0.37	1.84	-2.33	0.03	-2.52	-1.15	3.23
Dundgobi	3.11	0.07	-0.28	0.36	-0.58	-0.30	-1.93	1.37	3.70	0.02	1.94	-3.27	-0.56	-2.13	-2.14	1.66
Gobi-Altai	2.89	0.06	0.05	-1.76	-0.47	-0.49	-3.20	-0.11	2.08	-2.66	1.05	-2.34	-2.60	-2.01	0.11	0.25
Gobi-sumber	0.12	0.17	-3.95	1.80	-0.83	0.37	-0.65	1.67	3.60	1.47	1.85	-3.50	1.02	-2.93	-2.95	2.95
Khentii	0.45	-0.24	-5.37	1.66	-3.59	-0.79	-3.11	0.24	2.09	-0.29	1.28	-4.59	-0.37	-3.12	-3.49	1.61
Khovd	3.82	1.46	-0.02	-1.62	0.20	0.42	-3.83	0.64	3.07	-0.42	0.47	-4.34	-1.25	-2.46	0.28	-0.59
Khuvsgul	2.93	-0.97	-1.84	1.03	-1.73	2.13	-3.13	0.72	4.28	-0.52	1.83	-2.82	-0.38	-3.29	-3.38	1.70
Orkhon	1.91	-0.32	-2.90	1.81	-0.57	0.11	-2.32	-1.25	3.06	-0.55	0.23	-4.02	-1.35	-2.40	-3.07	0.71
Selenge	2.01	-0.35	-4.29	1.65	-2.63	-1.60	-3.97	-0.94	3.23	-0.22	1.38	-3.31	-1.54	-3.27	-4.27	1.08
Sukhbaatar	0.85	-0.12	-4.03	2.26	-0.93	0.53	-0.92	0.66	2.27	0.84	0.76	-2.29	-0.98	-2.04	-2.54	2.33
Tuv	0.57	-0.28	-3.75	1.23	-1.61	-0.67	-2.04	0.38	3.41	-0.21	0.83	-3.49	-0.41	-3.72	-3.77	1.10
Ulaanbaatar	-0.16	-0.67	-4.30	0.34	-1.97	-0.56	-1.68	0.60	3.32	-0.07	0.92	-2.88	-0.22	-3.33	-2.36	1.13
Umnugobi	2.56	-0.34	0.18	1.64	-0.72	0.13	-2.48	-0.39	2.60	-1.33	1.11	-2.25	-1.35	-1.50	-1.12	1.44
Uvs	3.83	0.83	0.02	-0.62	0.69	1.51	-4.57	1.03	3.71	-1.45	1.00	-5.05	-0.21	-3.49	-0.06	-0.34
Uvurkhangai	2.59	-0.91	-1.06	0.72	0.44	0.22	-2.47	-0.01	3.38	-0.95	1.27	-2.81	-1.77	-2.25	-2.15	1.09
Zavkhan	3.37	-0.25	-1.36	0.47	0.47	0.84	-3.64	-0.11	2.57	-2.48	0.38	-3.55	-1.54	-3.63	-0.57	-0.57

10 Annex 3: Snowfall anomalies (mm of snow water equivalent) for the period from 1999 to 2014

Snowfall anomalies	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Arkhangai	-3.80	4.57	8.10	5.44	9.70	2.30	-2.33	-3.23	-2.83	3.17	-2.03	10.20	8.47	0.00	5.04	2.27
Bayanhongor	-8.52	1.98	-6.44	9.08	16.32	-1.26	-0.28	-6.52	1.14	1.14	-6.76	0.42	1.78	-2.30	-0.28	-2.44
Bayan-Ulgii	3.07	-5.63	0.30	4.07	1.87	0.64	5.84	-3.06	-4.83	7.74	-0.96	21.60	7.70	-1.30	4.10	5.24
Bulgan	-4.38	3.07	7.02	1.82	10.97	14.97	-0.78	1.27	0.22	3.52	3.27	5.82	20.22	1.82	11.82	10.47
Dornod	6.45	-3.08	16.07	0.60	9.72	12.97	2.47	-0.38	3.72	-0.55	7.92	14.12	9.50	6.15	20.37	0.17
Dornogobi	-2.63	-1.58	-0.86	-4.41	2.82	-5.28	-2.33	-3.83	0.04	-2.76	-0.71	6.14	-1.08	6.12	2.24	-7.16
Dundgobi	-4.58	-1.13	-3.53	4.77	3.57	4.32	0.77	-5.08	2.22	3.92	-2.53	8.52	2.62	0.07	3.87	-2.13
Gobi-Altai	-5.50	-3.10	-2.40	22.30	17.70	-1.10	-0.53	-3.87	-3.53	2.57	1.00	7.30	1.27	0.67	3.40	1.10
Gobi-sumber	2.71	-1.50	2.21	-5.00	-0.19	2.41	-1.20	-8.70	4.81	-7.90	-3.60	16.51	-8.90	-1.90	0.51	-7.10
Khentii	8.31	-4.26	16.49	6.16	10.76	14.51	9.59	-3.01	19.51	-4.79	9.31	16.21	3.49	7.44	9.21	-0.21
Khovd	-6.42	-4.48	0.75	6.69	3.22	1.99	0.72	-0.61	-6.52	2.59	0.55	23.45	6.75	-7.52	1.42	-2.45
Khuvsgul	-3.45	4.77	5.50	8.15	9.90	0.45	6.87	-6.40	-3.55	-3.60	-2.25	2.95	6.10	3.97	8.10	4.00
Orkhon	-4.11	16.99	1.99	3.39	3.99	31.99	-0.71	9.99	15.19	2.39	4.99	12.19	15.09	-6.11	25.79	8.39
Selenge	-4.88	-6.38	10.37	1.62	3.79	26.74	7.74	-6.28	3.87	-2.96	-3.63	3.69	5.32	-6.41	9.22	-0.83
Sukhbaatar	2.23	-7.61	11.16	-5.17	0.13	5.90	-1.44	-4.47	1.23	-3.41	7.50	-2.51	6.13	3.06	9.86	2.83
Tuv	-0.36	-0.34	7.34	6.77	6.02	21.59	3.32	-3.89	5.77	-2.61	-0.09	11.59	3.89	0.94	9.87	-0.29
Ulaanbaatar	8.39	1.59	9.94	6.89	4.59	24.44	9.69	-1.56	12.04	-4.51	-0.61	5.44	4.54	3.49	10.24	-2.51
Umnugobi	-6.30	-3.62	-5.28	-1.22	10.98	1.32	3.40	-4.88	9.86	5.26	-1.10	2.74	9.28	3.42	2.48	-4.50
Uvs	-3.00	1.28	7.63	12.38	0.11	-1.45	5.91	-3.15	-2.35	3.33	0.08	10.21	6.26	-4.75	6.78	2.08
Uvurkhangai	-4.45	1.65	-1.62	3.22	3.98	5.18	-0.82	-4.52	0.88	13.65	-3.45	7.85	15.15	3.75	15.58	0.85
Zavkhan	-4.21	-2.29	12.47	4.73	7.85	-4.59	-0.89	-1.77	-7.81	-2.07	2.71	15.03	13.25	-3.13	9.73	4.67

11 Annex 4: Fecundity Scores for the Period of 1998 to 2017

Fecundity score	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0
Bayankhongor	0	1	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0	1	1	0
Bayan-Ulgii	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1
Bulgan	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Darkhan-Uul	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1
Dornod	0	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
Dornogovi	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
Dundgovi	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Govi-Altai	1	0	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Govisumber	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1
Khentii	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
Khovd	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Khuvsgul	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Orkhon	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Selenge	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Sukhbaatar	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Tuv	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Ulaanbaatar	0	1	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	1
Umnugovi	0	1	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1
Uvs	0	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Uvurkhangai	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Zavkhan	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0

12 Annex 5: Mortality Scores for the Period of 1998-2017

Mortality score	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Bayankhongor	0	0	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0
Bayan-Ulgii	1	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Bulgan	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Darkhan-Uul	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Dornod	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0
Dornogovi	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
Dundgovi	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
Govi-Altai	1	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Govisumber	0	0	1	1	0	0	0	1	1	0	0	1	1	0	0	1	0	0	0	0
Khentii	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Khovd	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Khuvsgul	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Orkhon	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Selenge	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Sukhbaatar	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
Tuv	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ulaanbaatar	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	1
Umnugovi	0	1	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Uvs	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0
Uvurkhangai	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zavkhan	1	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0

13 Annex 6: Zootechnical Scores for the Period from 1998 to 2017

Zootechnical score	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	0	0	0	2	0	0	0	0	0	0	0	2	2	0	0	0	0	1	0	0
Bayankhongor	0	1	2	2	2	0	0	0	2	0	0	2	2	0	0	0	0	1	2	0
Bayan-Ulgii	1	0	0	1	1	0	0	0	0	0	2	2	2	0	0	0	0	0	0	1
Bulgan	0	1	2	2	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0
Darkhan-Uul	0	0	2	2	0	0	0	0	0	0	0	0	2	0	0	1	1	0	0	1
Dornod	0	1	2	2	0	0	0	0	0	0	0	2	2	0	0	1	0	0	0	1
Dornogovi	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
Dundgovi	0	1	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	1
Govi-Altai	2	0	0	2	2	0	0	0	1	1	2	1	1	0	0	0	0	0	0	0
Govisumber	0	0	2	2	0	0	0	2	2	0	0	1	1	0	0	1	0	0	1	1
Khentii	0	1	2	2	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2	2
Khovd	1	0	0	2	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1
Khuvsgul	0	1	1	2	0	0	0	0	0	0	2	2	2	0	0	0	0	0	0	0
Orkhon	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0
Selenge	0	0	1	2	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0
Sukhbaatar	0	0	0	2	0	0	1	2	0	0	1	0	0	0	0	0	0	0	1	0
Tuv	0	1	2	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Ulaanbaatar	0	1	0	0	0	0	0	1	0	0	1	2	2	0	0	1	0	0	1	2
Umnugovi	0	2	2	2	2	0	0	0	2	0	0	0	2	0	0	0	0	0	1	1
Uvs	0	1	1	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0	1	0
Uvurkhangai	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Zavkhan	2	2	2	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	2	0

14 Annex 7: Standing Forage Biomass (Tons) for the Period from 1998 to 2017

Standing forage biomass (tons)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	3.78E+07	2.96E+07	2.44E+07	2.20E+07	1.22E+07	2.61E+07	2.43E+07	2.25E+07	2.89E+07	3.19E+07	2.24E+07	2.33E+07	3.61E+07	3.38E+07	3.69E+07	3.82E+07	2.62E+07	3.17E+07	3.37E+07	2.87E+07
Bayankhongor	1.32E+07	1.20E+07	9.58E+06	5.61E+06	5.27E+06	1.19E+07	8.07E+06	9.30E+06	9.92E+06	1.08E+07	6.14E+06	5.83E+06	9.08E+06	1.58E+07	1.55E+07	1.46E+07	9.83E+06	9.50E+06	1.72E+07	7.23E+06
Bayan-Ulgii	8.16E+06	7.22E+06	6.30E+06	5.76E+06	4.19E+06	7.01E+06	5.33E+06	9.24E+06	4.29E+06	6.48E+06	4.32E+06	4.96E+06	6.01E+06	5.85E+06	1.05E+07	1.07E+07	6.70E+06	6.28E+06	8.36E+06	5.61E+06
Bulgan	4.20E+07	3.28E+07	2.92E+07	2.81E+07	2.04E+07	3.03E+07	3.03E+07	3.30E+07	3.44E+07	3.47E+07	3.02E+07	3.34E+07	3.99E+07	3.62E+07	3.92E+07	4.06E+07	3.37E+07	3.78E+07	3.80E+07	3.35E+07
Darkhan-Uul	2.25E+06	2.39E+06	2.47E+06	2.04E+06	7.08E+05	2.19E+06	1.36E+06	1.53E+06	2.13E+06	2.30E+06	2.27E+06	2.21E+06	2.64E+06	2.02E+06	2.62E+06	2.65E+06	1.99E+06	2.29E+06	2.28E+06	1.98E+06
Dornod	9.04E+07	5.50E+07	6.11E+07	3.88E+07	5.21E+07	6.12E+07	3.20E+07	5.14E+07	6.82E+07	4.43E+07	5.54E+07	5.11E+07	6.20E+07	6.81E+07	8.04E+07	9.06E+07	6.45E+07	7.02E+07	3.52E+07	6.53E+07
Dornogovi	1.42E+07	4.58E+06	8.90E+06	4.96E+06	3.87E+06	6.81E+06	4.96E+06	2.51E+06	5.82E+06	6.06E+06	7.55E+06	3.96E+06	4.56E+06	6.92E+06	1.30E+07	6.54E+06	3.28E+06	3.85E+06	6.82E+06	6.63E+06
Dundgovi	1.23E+07	3.16E+06	9.22E+06	5.31E+06	3.04E+06	9.10E+06	3.57E+06	3.91E+06	5.49E+06	4.59E+06	3.96E+06	3.50E+06	5.26E+06	8.71E+06	1.21E+07	8.32E+06	3.14E+06	4.74E+06	5.93E+06	1.00E+07
Govi-Altai	6.21E+06	5.83E+06	6.70E+06	3.24E+06	4.40E+06	8.93E+06	4.97E+06	5.71E+06	4.38E+06	3.96E+06	4.19E+06	3.03E+06	5.96E+06	7.56E+06	6.84E+06	7.57E+06	6.26E+06	7.72E+06	8.99E+06	3.41E+06
Govisumber	2.42E+06	7.65E+05	1.64E+06	7.83E+05	4.37E+05	1.01E+06	7.93E+05	5.67E+05	8.51E+05	5.35E+05	6.22E+05	9.47E+05	5.51E+05	1.33E+06	1.52E+06	1.33E+06	5.34E+05	1.20E+06	7.07E+05	1.36E+06
Khentii	5.28E+07	4.14E+07	4.24E+07	3.39E+07	3.14E+07	4.14E+07	3.69E+07	3.84E+07	4.14E+07	2.59E+07	4.09E+07	4.42E+07	4.09E+07	3.57E+07	5.74E+07	5.42E+07	4.03E+07	4.78E+07	4.55E+07	5.04E+07
Khovd	6.93E+06	7.69E+06	5.72E+06	3.88E+06	3.79E+06	9.94E+06	5.70E+06	7.49E+06	4.06E+06	4.83E+06	4.48E+06	4.69E+06	5.58E+06	6.26E+06	7.74E+06	8.36E+06	6.26E+06	7.87E+06	7.22E+06	4.36E+06
Khuvsgul	7.11E+07	5.72E+07	4.77E+07	5.51E+07	3.45E+07	4.94E+07	5.66E+07	6.25E+07	6.13E+07	6.08E+07	5.77E+07	6.63E+07	7.34E+07	6.03E+07	5.96E+07	7.01E+07	6.03E+07	6.23E+07	7.31E+07	6.00E+07
Orkhon	6.80E+05	5.52E+05	5.87E+05	4.06E+05	1.93E+05	4.41E+05	4.44E+05	3.56E+05	4.94E+05	5.21E+05	5.15E+05	5.04E+05	6.27E+05	5.54E+05	6.30E+05	6.58E+05	5.01E+05	5.54E+05	5.41E+05	4.46E+05
Selenge	3.45E+07	3.50E+07	3.27E+07	3.06E+07	1.72E+07	3.07E+07	2.56E+07	2.79E+07	3.51E+07	3.44E+07	3.32E+07	3.40E+07	3.87E+07	3.06E+07	3.87E+07	3.91E+07	3.27E+07	3.58E+07	3.61E+07	3.13E+07
Sukhbaatar	4.92E+07	2.35E+07	3.27E+07	1.47E+07	2.07E+07	2.24E+07	1.65E+07	1.72E+07	2.53E+07	1.14E+07	2.83E+07	1.92E+07	1.75E+07	3.13E+07	4.77E+07	3.77E+07	2.08E+07	2.66E+07	1.79E+07	3.13E+07
Tuv	4.51E+07	3.21E+07	3.58E+07	2.70E+07	1.41E+07	3.39E+07	2.56E+07	3.20E+07	3.47E+07	3.10E+07	3.48E+07	3.38E+07	3.73E+07	3.39E+07	4.49E+07	4.37E+07	2.97E+07	3.73E+07	3.25E+07	3.70E+07
Ulaanbaatar	2.53E+06	2.28E+06	2.27E+06	1.94E+06	9.70E+05	2.00E+06	1.61E+06	2.40E+06	2.34E+06	2.16E+06	2.28E+06	1.77E+06	2.04E+06	1.35E+06	2.64E+06	2.56E+06	2.31E+06	2.53E+06	2.17E+06	2.18E+06
Umnugovi	5.74E+06	3.90E+06	4.23E+06	1.95E+06	2.22E+06	8.04E+06	3.70E+06	2.29E+06	5.37E+06	7.22E+06	4.77E+06	1.94E+06	3.91E+06	4.36E+06	7.18E+06	4.24E+06	3.88E+06	3.14E+06	5.20E+06	3.39E+06
Uvs	1.28E+07	1.29E+07	1.07E+07	8.47E+06	5.59E+06	1.79E+07	1.03E+07	1.42E+07	9.35E+06	6.51E+06	7.81E+06	7.32E+06	1.21E+07	9.65E+06	1.27E+07	1.35E+07	8.34E+06	5.90E+06	1.41E+07	6.20E+06
Uvurkhangai	1.84E+07	9.75E+06	1.12E+07	9.49E+06	4.64E+06	1.43E+07	8.00E+06	8.96E+06	1.24E+07	1.41E+07	6.31E+06	6.87E+06	1.05E+07	1.57E+07	2.06E+07	1.93E+07	1.06E+07	1.17E+07	1.46E+07	1.29E+07
Zavkhan	2.67E+07	1.99E+07	1.59E+07	1.51E+07	8.90E+06	2.50E+07	1.67E+07	2.28E+07	1.74E+07	1.43E+07	1.64E+07	1.47E+07	2.86E+07	2.09E+07	2.18E+07	2.97E+07	1.61E+07	1.96E+07	2.95E+07	1.34E+07

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15 Annex 8: Standing Forage Biomass Anomaly for the period from 1998-2017

Standing forage biomass anomaly	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	0.34	0.05	-0.13	-0.22	-0.57	-0.07	-0.14	-0.20	0.03	0.13	-0.20	-0.17	0.28	0.20	0.31	0.36	-0.07	0.13	0.20	0.02
Bayankhongor	0.30	0.18	-0.06	-0.45	-0.48	0.17	-0.21	-0.08	-0.02	0.06	-0.40	-0.43	-0.11	0.56	0.53	0.43	-0.03	-0.07	0.70	-0.29
Bayan-Ulgii	0.23	0.09	-0.05	-0.13	-0.37	0.06	-0.20	0.39	-0.35	-0.03	-0.35	-0.25	-0.10	-0.12	0.58	0.61	0.01	-0.06	0.26	-0.16
Bulgan	0.26	-0.02	-0.13	-0.16	-0.39	-0.09	-0.09	-0.01	0.03	0.04	-0.10	0.00	0.19	0.08	0.17	0.21	0.01	0.13	0.14	0.00
Darkhan-Uul	0.06	0.13	0.17	-0.03	-0.67	0.04	-0.35	-0.27	0.01	0.09	0.08	0.05	0.25	-0.04	0.24	0.26	-0.06	0.09	0.08	-0.06
Dornod	0.50	-0.09	0.02	-0.35	-0.13	0.02	-0.47	-0.15	0.13	-0.26	-0.08	-0.15	0.03	0.13	0.34	0.51	0.07	0.17	-0.41	0.09
Dornogovi	1.16	-0.30	0.35	-0.24	-0.41	0.04	-0.25	-0.62	-0.12	-0.08	0.15	-0.40	-0.31	0.05	0.98	0.00	-0.50	-0.41	0.04	0.01
Dundgovi	0.94	-0.50	0.45	-0.16	-0.52	0.43	-0.44	-0.38	-0.13	-0.28	-0.38	-0.45	-0.17	0.37	0.91	0.31	-0.51	-0.25	-0.07	0.58
Govi-Altai	0.11	0.04	0.20	-0.42	-0.21	0.60	-0.11	0.02	-0.22	-0.29	-0.25	-0.46	0.07	0.35	0.22	0.35	0.12	0.38	0.61	-0.39
Govisumber	1.41	-0.24	0.63	-0.22	-0.57	0.00	-0.21	-0.44	-0.15	-0.47	-0.38	-0.06	-0.45	0.33	0.51	0.32	-0.47	0.19	-0.30	0.36
Khentii	0.28	0.01	0.03	-0.18	-0.24	0.01	-0.10	-0.07	0.01	-0.37	-0.01	0.07	-0.01	-0.13	0.39	0.31	-0.02	0.16	0.10	0.22
Khovd	0.14	0.27	-0.06	-0.36	-0.38	0.64	-0.06	0.23	-0.33	-0.20	-0.26	-0.23	-0.08	0.03	0.28	0.38	0.03	0.30	0.19	-0.28
Khuvsgul	0.21	-0.03	-0.19	-0.07	-0.42	-0.16	-0.04	0.06	0.04	0.03	-0.02	0.12	0.24	0.02	0.01	0.19	0.02	0.06	0.24	0.02
Orkhon	0.33	0.08	0.15	-0.20	-0.62	-0.14	-0.13	-0.30	-0.03	0.02	0.01	-0.01	0.23	0.09	0.23	0.29	-0.02	0.09	0.06	-0.13
Selenge	0.07	0.08	0.01	-0.05	-0.47	-0.05	-0.21	-0.14	0.08	0.06	0.03	0.05	0.19	-0.05	0.20	0.21	0.01	0.11	0.12	-0.03
Sukhbaatar	0.90	-0.10	0.26	-0.43	-0.20	-0.14	-0.36	-0.34	-0.03	-0.56	0.09	-0.26	-0.33	0.21	0.84	0.45	-0.20	0.02	-0.31	0.20
Tuv	0.34	-0.05	0.06	-0.20	-0.58	0.00	-0.24	-0.05	0.03	-0.08	0.03	0.00	0.10	0.00	0.33	0.30	-0.12	0.11	-0.04	0.10
Ulaanbaatar	0.22	0.10	0.10	-0.06	-0.53	-0.03	-0.22	0.16	0.13	0.04	0.10	-0.14	-0.01	-0.35	0.28	0.24	0.11	0.22	0.05	0.05
Umnugovi	0.29	-0.12	-0.05	-0.56	-0.50	0.81	-0.17	-0.49	0.21	0.62	0.07	-0.56	-0.12	-0.02	0.62	-0.04	-0.13	-0.29	0.17	-0.24
Uvs	0.19	0.21	0.00	-0.21	-0.48	0.66	-0.04	0.32	-0.13	-0.39	-0.27	-0.32	0.12	-0.10	0.18	0.25	-0.22	-0.45	0.31	-0.42
Uvurkhangai	0.54	-0.18	-0.06	-0.20	-0.61	0.20	-0.33	-0.25	0.04	0.19	-0.47	-0.42	-0.12	0.32	0.73	0.62	-0.11	-0.02	0.22	0.08
Zavkhan	0.36	0.01	-0.19	-0.23	-0.55	0.27	-0.15	0.16	-0.12	-0.27	-0.17	-0.26	0.46	0.06	0.11	0.51	-0.18	0.00	0.50	-0.32

(with 1998-2013 ref period to fit the analysis period)

16 Annex 9: Pasture Use for the Period from 1998 to 2017

Pasture Use	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	0.08	0.11	0.12	0.10	0.17	0.08	0.09	0.10	0.09	0.09	0.15	0.15	0.07	0.09	0.09	0.10	0.16	0.14	0.15	0.19
Bayankhongor	0.17	0.19	0.22	0.24	0.16	0.08	0.14	0.14	0.15	0.16	0.31	0.33	0.16	0.11	0.13	0.15	0.26	0.30	0.18	0.48
Bayan-Ulgii	0.15	0.17	0.18	0.19	0.24	0.15	0.20	0.11	0.27	0.19	0.26	0.20	0.14	0.17	0.10	0.12	0.22	0.26	0.21	0.32
Bulgan	0.05	0.06	0.07	0.06	0.08	0.04	0.04	0.04	0.05	0.05	0.07	0.07	0.05	0.06	0.06	0.06	0.09	0.08	0.09	0.10
Darkhan-Uul	0.09	0.09	0.09	0.10	0.25	0.06	0.10	0.09	0.08	0.09	0.13	0.14	0.09	0.12	0.10	0.10	0.16	0.13	0.15	0.17
Dornod	0.01	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.06	0.04
Dornogovi	0.08	0.27	0.13	0.17	0.20	0.13	0.19	0.35	0.11	0.12	0.10	0.23	0.20	0.15	0.09	0.20	0.44	0.40	0.21	0.25
Dundgovi	0.18	0.66	0.12	0.22	0.39	0.14	0.39	0.36	0.26	0.33	0.35	0.41	0.15	0.11	0.09	0.17	0.54	0.41	0.36	0.25
Govi-Altai	0.26	0.28	0.22	0.38	0.15	0.09	0.20	0.21	0.32	0.40	0.38	0.46	0.14	0.14	0.18	0.19	0.27	0.25	0.25	0.73
Govisumber	0.06	0.20	0.07	0.07	0.16	0.09	0.14	0.22	0.16	0.26	0.19	0.12	0.19	0.10	0.10	0.14	0.45	0.23	0.41	0.24
Khentii	0.03	0.05	0.04	0.05	0.05	0.04	0.04	0.05	0.05	0.08	0.05	0.04	0.05	0.06	0.04	0.05	0.07	0.07	0.08	0.08
Khovd	0.23	0.22	0.28	0.33	0.28	0.12	0.23	0.20	0.41	0.38	0.40	0.35	0.22	0.21	0.20	0.20	0.31	0.28	0.34	0.61
Khuvsgul	0.04	0.06	0.06	0.04	0.06	0.04	0.04	0.04	0.04	0.05	0.06	0.05	0.04	0.05	0.05	0.04	0.06	0.06	0.06	0.08
Orkhon	0.24	0.35	0.32	0.43	0.87	0.24	0.26	0.35	0.31	0.35	0.43	0.43	0.26	0.30	0.29	0.27	0.27	0.25	0.29	0.35
Selenge	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.03	0.04	0.04	0.03	0.04	0.03	0.03	0.05	0.04	0.05	0.05
Sukhbaatar	0.03	0.08	0.06	0.11	0.08	0.08	0.10	0.10	0.07	0.15	0.05	0.08	0.10	0.06	0.04	0.06	0.13	0.11	0.16	0.11
Tuv	0.06	0.08	0.06	0.06	0.12	0.04	0.06	0.05	0.06	0.08	0.07	0.09	0.06	0.08	0.06	0.07	0.13	0.11	0.13	0.12
Ulaanbaatar	0.15	0.14	0.13	0.14	0.29	0.14	0.17	0.13	0.15	0.17	0.17	0.24	0.16	0.26	0.15	0.16	0.21	0.21	0.27	0.26
Umnugovi	0.25	0.37	0.30	0.50	0.33	0.09	0.22	0.36	0.16	0.14	0.24	0.62	0.20	0.21	0.15	0.29	0.35	0.48	0.32	0.57
Uvs	0.15	0.14	0.12	0.15	0.21	0.07	0.14	0.11	0.19	0.30	0.23	0.23	0.10	0.14	0.12	0.12	0.23	0.35	0.15	0.39
Uvurkhangai	0.17	0.32	0.19	0.17	0.30	0.11	0.22	0.20	0.17	0.17	0.41	0.40	0.15	0.12	0.11	0.14	0.31	0.31	0.29	0.37
Zavkhan	0.10	0.13	0.11	0.09	0.14	0.05	0.09	0.07	0.11	0.16	0.14	0.15	0.05	0.07	0.08	0.07	0.14	0.13	0.09	0.22

17 Annex 10: Pasture Use Anomaly for the Period of 1998-2017

Pasture Use Anomaly	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arkhangai	-0.26	0.04	0.18	-0.02	0.63	-0.25	-0.17	-0.03	-0.15	-0.14	0.38	0.44	-0.30	-0.16	-0.14	-0.07	0.49	0.37	0.42	0.77
Bayankhongor	-0.02	0.07	0.22	0.37	-0.10	-0.54	-0.22	-0.24	-0.17	-0.10	0.76	0.88	-0.07	-0.41	-0.29	-0.14	0.48	0.67	0.04	1.72
Bayan-Ulgii	-0.16	-0.05	0.00	0.05	0.37	-0.14	0.13	-0.37	0.50	0.07	0.49	0.11	-0.19	-0.04	-0.42	-0.35	0.23	0.44	0.17	0.81
Bulgan	-0.18	0.14	0.16	0.05	0.32	-0.33	-0.30	-0.28	-0.20	-0.07	0.25	0.23	-0.05	0.06	0.07	0.14	0.56	0.46	0.54	0.68
Darkhan-Uul	-0.17	-0.17	-0.18	-0.07	1.34	-0.44	-0.11	-0.13	-0.27	-0.17	0.17	0.30	-0.16	0.14	-0.08	-0.02	0.51	0.25	0.39	0.57
Dornod	-0.48	-0.07	-0.16	0.19	-0.09	-0.20	0.56	0.03	-0.16	0.45	0.25	0.34	-0.07	-0.12	-0.21	-0.27	0.15	0.18	1.62	0.65
Dornogovi	-0.53	0.61	-0.23	-0.02	0.20	-0.24	0.13	1.08	-0.35	-0.31	-0.39	0.34	0.18	-0.13	-0.49	0.15	1.56	1.34	0.26	0.47
Dundgovi	-0.35	1.45	-0.54	-0.20	0.46	-0.49	0.45	0.34	-0.05	0.21	0.29	0.51	-0.45	-0.60	-0.65	-0.39	0.99	0.51	0.34	-0.07
Govi-Altai	0.06	0.11	-0.11	0.51	-0.38	-0.63	-0.20	-0.17	0.28	0.59	0.52	0.84	-0.43	-0.46	-0.29	-0.24	0.08	-0.02	0.01	1.95
Govisumber	-0.58	0.41	-0.48	-0.49	0.10	-0.35	-0.04	0.55	0.10	0.84	0.31	-0.16	0.36	-0.31	-0.28	0.02	2.16	0.62	1.93	0.67
Khentii	-0.27	-0.02	-0.06	0.00	0.06	-0.18	-0.07	-0.04	-0.04	0.68	-0.02	-0.07	-0.01	0.23	-0.16	-0.01	0.52	0.41	0.64	0.67
Khovd	-0.12	-0.18	0.05	0.22	0.05	-0.56	-0.12	-0.27	0.55	0.44	0.50	0.31	-0.17	-0.21	-0.26	-0.25	0.18	0.04	0.29	1.28
Khuvsgul	-0.09	0.19	0.29	-0.23	0.27	-0.09	-0.17	-0.21	-0.09	0.03	0.18	0.06	-0.20	0.02	0.10	-0.06	0.24	0.28	0.25	0.60
Orkhon	-0.34	-0.02	-0.11	0.22	1.44	-0.31	-0.27	-0.01	-0.13	-0.02	0.20	0.21	-0.28	-0.15	-0.20	-0.23	-0.24	-0.31	-0.19	-0.03
Selenge	-0.30	-0.26	-0.19	-0.17	0.49	-0.30	-0.20	-0.22	-0.28	-0.06	0.30	0.38	0.08	0.40	0.15	0.18	0.59	0.49	0.62	0.81
Sukhbaatar	-0.57	0.01	-0.26	0.42	0.05	0.02	0.32	0.21	-0.15	0.88	-0.38	0.05	0.29	-0.23	-0.44	-0.22	0.60	0.37	1.05	0.35
Tuv	-0.13	0.19	-0.10	-0.08	0.67	-0.38	-0.15	-0.24	-0.17	0.09	0.06	0.24	-0.08	0.11	-0.08	0.06	0.84	0.58	0.91	0.65
Ulaanbaatar	-0.16	-0.19	-0.24	-0.17	0.68	-0.17	0.01	-0.27	-0.11	-0.01	0.01	0.36	-0.05	0.51	-0.15	-0.05	0.23	0.22	0.56	0.51
Umnugovi	-0.10	0.34	0.09	0.83	0.19	-0.68	-0.22	0.32	-0.43	-0.50	-0.12	1.25	-0.27	-0.24	-0.47	0.03	0.26	0.72	0.17	1.05
Uvs	-0.07	-0.13	-0.22	-0.06	0.32	-0.55	-0.09	-0.32	0.20	0.89	0.47	0.45	-0.35	-0.10	-0.24	-0.21	0.48	1.25	-0.03	1.47
Uvurkhangai	-0.20	0.54	-0.11	-0.18	0.43	-0.48	0.03	-0.03	-0.21	-0.17	0.96	0.90	-0.29	-0.43	-0.46	-0.32	0.48	0.50	0.40	0.76
Zavkhan	0.00	0.27	0.14	-0.15	0.38	-0.47	-0.11	-0.29	0.12	0.58	0.42	0.46	-0.54	-0.27	-0.20	-0.34	0.40	0.25	-0.09	1.17