Reponses to Reviewer #1

We greatly appreciate your comments and suggestions. We have make a careful plan to revise the manuscript according to what you have pointed out and believe that the quality of this manuscript will be improved as a result of the revision. We have included our detailed responses to each of your comments raised.

General comments:

Natural hazards that lead to disasters can cause tremendous impacts on societies, the environment, and economic wealth of the affected countries. Climate change will exacerbate existing challenges relating to livestock snow disaster risk. Adapting to climate change is a necessity for sensitive areas and those that are vulnerable to climate change such as the Qinghai-Tibetan Plateau. To investigate and better understand the risk of livestock snow disasters in the Qinghai-Tibetan Plateau is critical to towards sustainability of grassland animal husbandry and livelihood of the herdsmen. This topic fits well with the mission and scope of Natural Hazards and Earth System Sciences. However, there are still many flaws in the current manuscript.

Special comments:

1. There are many abbreviated symbols in the paper such as QTP, PRA, SDD, BRT etc. Because of too many abbreviations, readers often get confused. It is suggested that a separate symbol page should be set up in front of the manuscript.

RE: Thank you for your kind suggestion. As including a sperate symbol page in front of the manuscript is subjected to the decision of the editor, we will change all abbreviations to their full term throughout the manuscript to maximumly benefit the readers.

2. At present, there are many good quantitative methods for the study of snow disaster vulnerability and risk in alpine pastoral areas in particular on the Qinghai-Tibetan Plateau and Inner Mongolia Plateau. In the literature review in the "Introduction", the authors review this issue incompletely. The literature covered is also very limited. And main viewpoint may be biased. For example:

Page 2, lines 19-20, "The first type employs an ordinal risk assessment framework in which the risk index is derived by integrating several indices representing different components of risk";
Page 2, lines 12-13, "The other risk assessment approach is quantitative, often called the probabilistic risk assessment (PRA), in which risk is measured with a probability distribution of socioeconomic losses (consequences)";
Page 2, lines 24-32, "However, studies applying PRA to livestock snow disasters have been limited. Bai et al. (2011) published one of the first trials in applying the PRA framework to a livestock snow disaster risk assessment. In their study, winter season (November to April of the preceding year) average daily snow depth was used to describe snow hazard intensity. Physical

vulnerability, a function of livestock mortality rate in response to snow depth, was fitted using historical case data. Using annual average snow depth computed from satellite-retrieved data, return-period livestock mortality and mortality rates were derived as the final risk metrics. Based on their method, quantitative livestock snow disaster risks were mapped nationwide in China (Shi, 2011). The major flaw of this method was the mismatch between the event-based vulnerability function and annual measure of snow hazard. In another work focusing on Mongolia, a vulnerability function trained from a tree-based model was used, but still on an annual basis".

RE: Thank you for your kind suggestion. We did another round of careful literature search and review and found several important articles i.e. (Yeh *et al.*, 2014; Dong and Sherman, 2015; Miao *et al.*, 2016; Wei *et al.*, 2017). We have decided to add these references into the review section following your suggestion and suggestions from Reviewer #2 (comments 1 and 2).

References related to this comment:

Dong, S. and Sherman, R.: Enhancing the resilience of coupled human and natural systems of alpine rangelands on the Qinghai-Tibetan Plateau, Rangel. J., 37(1), i–iii, doi:10.1071/RJ14117, 2015.
Miao, L., Fraser, R., Sun, Z., Sneath, D., He, B. and Cui, X.: Climate impact on vegetation and animal husbandry on the Mongolian plateau: a comparative analysis, Nat. Hazards, 80(2), 727–739, doi:10.1007/s11069-015-1992-3, 2016.
Wei, Y., Wang, S., Fang, Y. and Nawaz, Z.: Integrated assessment on the vulnerability of animal husbandry to snow disasters under climate change in the Qinghai-Tibetan Plateau, Glob. Planet. Change, 157(March), 139–152, doi:10.1016/j.gloplacha.2017.08.017, 2017.
Yeh, E. T., Nyima, Y., Hopping, K. A. and Klein, J. A.: Tibetan Pastoralists' Vulnerability to Climate Change: A Political Ecology Analysis of Snowstorm Coping Capacity, Hum. Ecol., 42(1), 61–74, doi:10.1007/s10745-013-9625-5, 2014.

3. Page 3, lines 13-15, "*Worldwide, the QTP suffers from some of the highest livestock snow disasters due to its large area of snow cover area, longlasting snow cover days, and nomadic grazing. This region is also a hot spot in climate change. Quantitative risk assessments for the present day will likely be a significant source of information for disaster risk reduction*". The above sentence should be moved to before line 5 on the second page.
Delete lines 15-16 of the second page, *"In addition, the framework can be adapted for livestock mortality in snow disasters in the context of future climate change analysis, and therefore support climate adaptation planning for local government and herding communities".*

RE: These places will be revised according to your suggestion.

4. In the "Materials and Methods" section, the Qinghai-Tibet Plateau as case area, it is necessary to have a more comprehensive description of the geographical, environmental, social, and economic backgrounds of the QTP, especially the role of livestock in livelihood for local people.

RE: Per your suggestion, we have decided to add a sub-section exclusively introduce the QTP, including its geographical, environmental social and economic backgrounds, with emphasis on the role of livestock in livelihood for local people.

5. We know the positive intervention of humans on the grassland ecosystem and that the

grassland carrying capacity could be elevated with a reduction of harmful human activities (adverse effect), an increase of disaster prevention capacity. For example, the proportion of fenced pasture area to the total usable grassland (to show the capacity of grassland biomass to regenerate), the warm shed area per unit of livestock (to illustrate the capacity of livestock to prevent freezing disasters) and the proportion of sown grassland area to the total usable grassland (to descript the capacity of balancing forage supply and demand), accessibility of traffic and information (to depict the capacity of disaster response or prevention), if the above key factors are missing, in other words, if the authors do not emphasize the socio-system intervention for livestock snow disaster assessment, it will be very difficult to objectively assess the risk of snowstorms in livestock.

6. Page 4, line 10, "*prevention capacity as measured by gross domestic production (GDP) of the underlying county*", GDP as prevention capacity is not a scientific proxy, indeed, local fiscal revenue and the intensity of infrastructure construction in animal husbandry (including alpine grassland) are the key to reducing vulnerability and risk of livestock snow disaster.

7. Similarly, page 8-9, in "2.4 Loss modelling", as one of loss index, GDP at county level is not consistent with the risk topic of livestock snow disaster. It is suggested that the added value of animal husbandry at county level should be adopted.

RE: Above comments (5, 6, and 7) are related to each other and are responded together.

We totally agree that it needs a thorough understanding of vulnerability to snow disaster before a good risk assessment carries out. You have offered important insights into local herders' coping capacity to snow disasters, and the factors that you mentioned (fenced pasture area, warm shed area, sown grassland, and accessibility) are critical in deciding vulnerability to snow disaster. These variables are valuable, but mostly only available for certain regions and can only be obtained from interview/survey. Per your suggestion, we checked again the statistical yearbooks, including the provincial statistical yearbooks of Qinghai and Tibet which date back to 1989, and the National County (City) Socioeconomic Statistical Yearbook (2000~), but found no indicators such as fenced pastures, warm shed areas, and sown grassland area.

So we kept the strategy of using a proxy variable to indicate prevention capacity. Following your suggestion, we collected data on "fiscal revenue" (*Fiscal_Rev*) and "added value in animal husbandry" (*Value_Add*), which could be the first-best choices to denote prevention capacity. In addition, we also considered Fiscal Expenditure (*Fiscal_Exp*); and GDP per capita (*GDP_PC*). All the values were turned to 2015 Yuan. These variables were slightly-to-moderately correlated with GDP. The Pearson correlation coefficients between *Value_Add*, *Fiscal_Rev*, *Fiscal_Exp*, *GDP_PC* and *GDP* are: 0.336, 0.760, 0.420 and 0.223, respectively.

We re-ran our generalized additive model (GAM) as shown in Eq (1) by replacing GDP with each of the four variables, and performed model diagnostics to check goodness-of-fit as well as response curves. Summary statistics of model runs are provided as below:

Table 1 Generalized additive model results by using different socioeconomic factors indicating prevention capacity

$\ln LR = s(Duration) + s(Wind) + s(P) +$	R-sq.(adj)	Deviance explained	GCV	N(sample)	Significance level of the socioeconomic factor

$s(GDP)$	0.554	62.1%	2.5105	79	At 0.01 level
$s(Value\_Add)$	0.563	62.5%	2.5508	73	At 0.01 level
$s(Fiscal\_Rev)$	0.516	58.4%	2.8392	73	Not significant
$s(Fiscal\_Exp)$	0.524	58.4%	2.7301	73	At 0.01 level
$s(GDP\_PC)$	0.506	57.2%	2.8561	74	Not significant

As shown in the table, variable *Fiscal_Rev* cannot improve the prediction of ln*LR* (natural logarithm of mortality rate). *Value_Add* is capable of deriving competing results. The response curves of the variables are also similar: ln*LR* showed downward slope with each of the three variables, indicating decreasing loss rate in response to enhanced prevention capacity.

Given above analysis, together with your suggestion, we have decided to use value added of animal husbandry in our vulnerability function, and update all our results throughout the manuscript.

8. Page 7, lines 3-6, the authors stated that "*Historical snow disaster event data with the time of each event for each meteorological station were used to train the BRT model. These data were obtained from two sources. Records for 1980–2007 were obtained from W. Wang et al. (2013) while records from 2008–2015 were obtained from the China Meteorological Science Data Sharing Service System (CMSDS, http://data.cma.gov.cn)*." However, are the identification criteria of the two snowstorm records sources consistent?

RE: This comment is high related to Reviewer #2's comment (Page 7 Lines 4-6: Are there no bias between the two data?). According to (Wang *et al.*, 2013), the data for period of 1980-2007 were obtained from the yearbooks of meteorological disasters. Therefore, these data were originally recorded by provincial meteorological administrations officially, and published as a collection in yearbooks. The data for 2008-2015 were directly obtained from China Meteorological Administration in digital format. Therefore, they are both from official records from meteorological administration, the standards in identifying snow disasters are the same according to local Meteorological Administration officials.

In the revision, we have decided to add the information to clarify the potenail bias between two data is very limited. "*Records for 1980–2007 were a collection of snow disaster records published in 6 provincial meteorological yearbooks neighboring the Plateau (Wang et al., 2013b). Records from 2008–2015 were obtained from the China Meteorological Science Data Sharing Service System (CMSDS, http://data.cma.gov.cn). Records in both datasets are official observations by the meteorological administrations and are consistent with each other in terms of observation standards*."

9. Page 8, in "2.3 Exposure", the herd size as a critical proxy of exposure, although the spatial distribution of livestock size can reflect the extent of snowstorm exposure of livestock, it is well known that the Qinghai-Tibetan Plateau has a vast area with obvious spatial differences, and the distribution density of livestock (the number of livestock per unit area) may be more scientifically and accurately describe the spatial feature of snowstorm exposure.

RE: Thank you for your suggestion. We have changed our term from “herd size” to “herd density” where exposure is discussed. In the exposure map we derived (Fig. A2), the unit has already been (Sheep unit/ha). Accordingly, we will update the risk metrics map in terms of mortality (Fig.7) to show the loss measured with sheep units/km^2.

10. Page 9, lines 1-4, I don’t understand that *“County level GDP values were assigned to each grid within its boundary. We used constant GDP values for 2015 for two reasons. First, the results can be directly treated as a stationary time series for estimating the probability distribution, as the influence of prevention capacity improvement has been removed. Second, it meets the goal of risk assessment, to estimate the likelihood of potential loss in the near future*”. The GDP of each county changes with time. Dynamic GDP should be used instead of static GDP to predict the probability of loss, which is not consistent with reality.

RE: Thanks for your comment. In our vulnerability function, GDP (has been changed to value added in animal husbandry per your comment) was used as an indicator of prevention capacity. Therefore, whether to use historical dynamic value or a static present value essentially depends on our purpose of analysis.

1) If we are modeling actual historical losses for model calibration and verification purposes, historical dynamic value should be used (for such discussion, please refer to the response to reviewer#2’s comment regarding Page 19 Lines 15-16 and Page 19 Lines 27-28).

2) If we are assessing livestock risk (the probability of potential loss) for the next couple of years, then using present-day prevention capacity would be a better choice than using historical prevention capacity. Then, our risk assessment effort tries to answer “if historical events occur in nowadays prevention capacity, how would the probability distribution of the loss will be”. Correspondingly, the risk metrics would be meaningful for prevention planning and insurance implications because we are considering the near future given today’s situation.

Technically, to fit a probability distribution from samples of loss requires that the sample data must be at least stationary in its mean and variance, so as to remove any technical, environment, or prevention capacity change effect. This is the reason in many risk assessment research, historical loss must be “detrended” before it was fit (Maddala, 1977; Lobell and Burke, 2010; Ye *et al.*, 2015). In our case, as GDP (or value added in animal husbandry) keeps growing along the time, modeled losses based on historical dynamic GDP (or value added in animal husbandry will contain obvious trend and therefore cannot be used directly to fit any probability distribution.

In order to better explain the difference, we modeled annual winter losses (from September ~ June of the next year) using both historical (dynamic) and static (2015) value added of animal husbandry, and the time series are shown below (Figure 1).

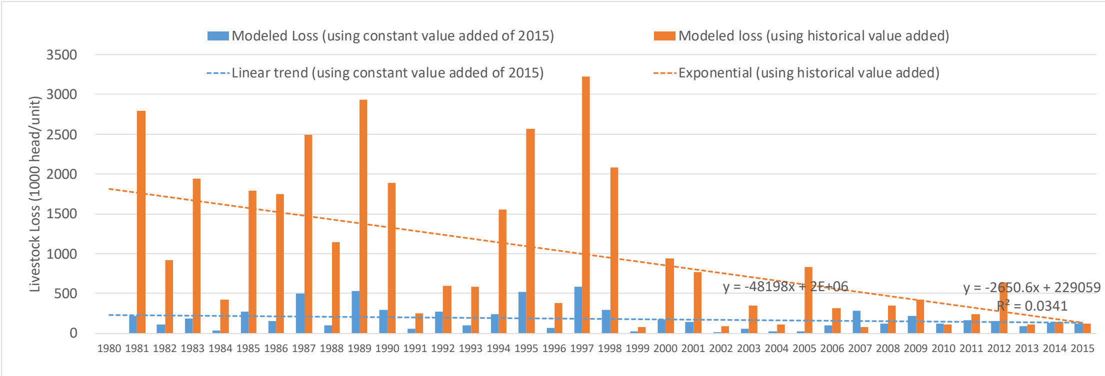

Figure 1 Modeled total livestock loss over the Tibetan Plateau. The blue time series was losses modeled using constant *Value_Add* of year 2015, assuming present-day prevention capacity (static). The orange time series was losses modeled using *Value_Add* of historical values (dynamic), assuming historical prevention capacity. All the losses are for a specific snow disaster season from September to the next June rather than a civil year.

Loss modeled using historical value added of animal husbandry (*Value_Add,* the orange time series in Figure 1) obvious contained trends. It showed an obvious downward trend. Fitting a probability distribution would over-estimate the size of risk. Using a static present value of one recent year, it technically meets the requirement of a stationary time series (the blue trend line is flat in Figure 1). Then losses derived from our event-based model are derived with the prevention level of historical period. Their difference demonstrates the effect of improved prevention capacity (which might echoes the Comment #1, and provides meaningful discussion for your Comment #11).

In the revision, more explanation about the difference of the modeled losses using static and dynamic socioeconomic data will be provided.

11. The discussion part only deals with the content of spatial pattern (4.1Spatial patterns of livestock snow disaster risk in the QTP). As an important part of risk change, the characteristics of dynamic and temporal variation cannot be absent. Moreover, the authors do not pay attention to the causal relationship between risk and its influencing factors.

RE: Thank you for your comment. We have prepared to add a subsection in the result section show temporal changes of livestock mortality derived from our model, and enrich our discussion by comparing it to historical losses observed.

The discussion over the causal relationship between risk and its influencing factors can be partly be done by comparing the dynamics of the modeled loss with historical prevention capacity and static present-day prevention capacity, as shown in Figure 1. We will also added discussion about the role of improved prevention capacity in section 4.3 Risk-informed implications. –

12. In "4.3 Risk-informed implications" *Page 20, line 22, "Our results imply that the present level of preparedness in local regions are far from sufficient";*
Page 21, line 5, "Due to the difficulty in improving prevention capacity, insurance schemes are needed to provide relief";
From the perspective of above mentioned sentences, this is not the inspiration of the article

analysis, but the main existing problems.

RE: Thank you for your comment. We plan to revise the discussion section by 1) better emphasizing the advantage of event-based probabilistic risk assessment, particularly its capability of providing quantitative measure of preparedness capacity using return-period values, and 2) discussing the contribution of enhanced prevention capacity as suggested by your comment #11.

13. The language of the manuscript is rather deficient and requires the re-editing of native speakers.

RE: We will send the paper for professional proof-reading service before re-submission.

References

Dong, S. and Sherman, R. (2015) 'Enhancing the resilience of coupled human and natural systems of alpine rangelands on the Qinghai-Tibetan Plateau', *Rangeland Journal*, pp. i–iii. doi: 10.1071/RJ14117.

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