

Analysis of Damage Effects of the Strong Wind and Storm Event from 13-15 March 2021 in Mongolia

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Abstract

Strong storms are the most common natural hazards in Mongolia and their frequencies, intensities, scope, damage and negative consequences of strong storms are likely to increase further due to the effects of climate change. The analysis of the disastrous characteristics and damage effects of the extremely strong wind and storm event from 13-15 March 2021 in the Mongolia's territory explores the following findings. Firstly, we have observed, that the loss of livestock is much higher with longer-duration strong winds and storms. Secondly, high wind speeds and longer- duration events are associated with noticeably negative impacts on herders and their livestock. Lastly, property damage demonstrates much escalation with instantaneous high wind speeds.

Keywords: Strong winds and storms, high wind speeds, phenomenon, damage effects

Introduction

In Mongolia, where characterized by an extreme continental climate and a substantial percentage of the population engaged in nomadic livestock husbandry, strong winds and storms are the most adverse and damaging natural phenomena. The rise in average annual air temperature, quantified at 2.25°C since 1940 in the country, surpassing the global average thrice-fold, shows a real impact of global warming. According to scientists' predictions of climate trends, there will be heightened temperatures during summers, diminished precipitation levels, milder winters, and escalated winter precipitation 1 [1]. These predictions reveal that natural phenomena, including droughts, dzud, floods, severe winds, and storms are likely to increase in the future. More than 10 types of meteorological phenomena occur in Mongolia2 [2], with winds and storms, flash floods, and lightning occurrences being the most frequent (*Figure1*).

The definition of a strong dust storm is atmospheric turbidity and significant degradation in visibility due to a huge amount of dust raised from the ground surface into the air by strong winds. Government resolution # 286 of 2015 defines a dust storm as having air turbidity and significant degradation invisibility within 1000m and lasting for more than 3 hours [3].

Dzud
Drought
Cold Wave
Cold Rain
Heat Wave
Wet Snow
Heavy Snow
Heavy Rain

Extreme Cold Hail
Gust Wind Lightning Flash Flood
Strong Wind and Storm

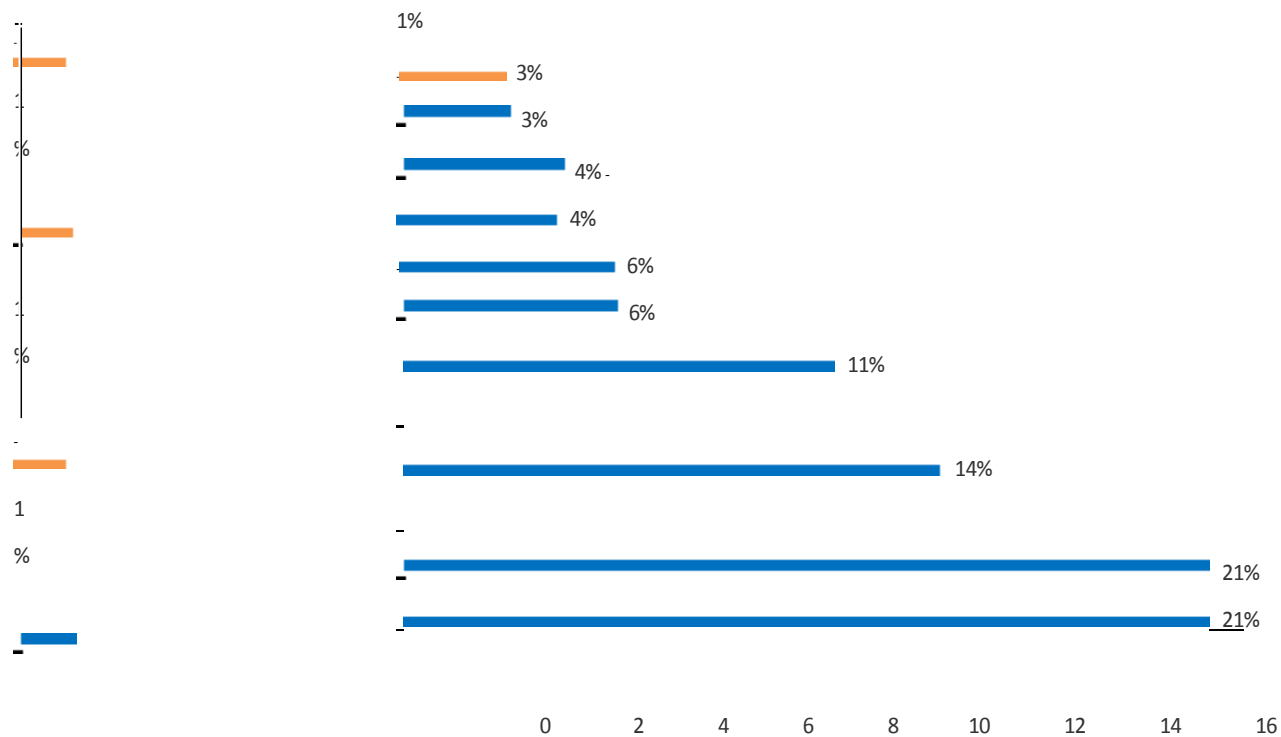


Figure 1. Percentage for annual average frequencies of hazardous events

¹ Gomboluudev, P. (2015). Climate Change and Future Trends in Mongolia”, Ulaanbaatar

² NEMA (2020) Disaster Data Book of Mongolia

Prolonged occurrences of strong winds and dust storms bring multiple risks and their consequences go beyond Mongolia's ecosystem, economy, society, health, and property to cause damage at the regional level.

The aims of study are to analyze in detail the features of the catastrophic phenomenon of an extremely strong wind and dust storm that covered a large part of the country on 13-15 March 2021 and to identify issues that are critical to the prevention and reduction of potential damage caused by further severe wind and storm events.

Materials and Methods

An exposure map of severe wind and storm events is drawn based on data from weather stations, observation points, and satellite images.

The study undertakes Pearson's correlation analysis to determine the correlation between the duration of wind speeds and the damage effects caused by the strong wind and storm events that occurred on 13-15 March 2021 by using the disaster loss and damage database of the National Emergency Management Agency.

Moreover, the study includes a comparative analysis of wind and storm conditions, using data from the disaster loss and damage database of the National Emergency Management Agency.

Results of the Study

One. Affected areas by Severe Wind and Storm Event from 13-15 March 2021

The Meteorological Organization disseminated a weather forecast predicting the catastrophic phenomenon 5 days in advance. They announced snowfall accompanied by wind speeds ranging from 18 to 20 m/s, occasionally reaching 28 m/s would occur on 13 March 2021 in the western provinces, on 14 March in the western and central provinces, and in the northern part of the Gobi regional provinces, followed by the eastern part of the territory on 15 March. During that period, a Yellow Level “Warning Alert” was informed on 11-12 March, as well as moving to a Red Level “Weather Precaution Alert” on 13-14 March [4].

Furthermore, the National Agency for Meteorology and Environmental Monitoring (NAMEM) formally submitted warning information regarding the weather catastrophic phenomenon to all related government agencies. Early warning information to prevent and mitigate the phenomenon was broadcasted to the public through various channels, including the “MongolSat Network” cable TV every 5 minutes, totaling 27 broadcasts, as well as through 24-hour early warning sign towers, about 10 TV stations, 30 social news websites, the Mongolia National Radio broadcast, and mass messages reaching 378860 local citizens [4].

During this hazardous event, the wind speed in Bayan-Ulgii, Uvs, and Khovd provinces was 16- 24 m/s, occasionally peaking at 34 m/s on 13 March. Additionally, it experienced 0.0--5.0 mm of snowfall with the wind speeds of 15 to 24m/s, occasionally reaching 28m/s, with heavy snowstorms lasted for 2-7 hours in Zavkhan and Govi-Altai provinces during the night of 13-14 March [5].

The severe wind and storm conditions extended widely across Uvurkhangai, Bulgan, Umnugovi, and Dundgovi provinces where wind speeds ranged from 18 to 30 m/s, peaking at 34-40 m/s. Concurrently, wind speeds in Govi-Altai, Bayankhongor, Arkhangai, Tuv, Khentii, Dornod, Sukhbaatar, and Dornogovi provinces varied from 16 to 28 m/s, intensifying to 28-32 m/s on 14 March [5].

The following night of 14-15 March, the storm intensity was not down and the dust storm reached a catastrophic phenomenon level with speeds ranging from 16 to 28 m/s and occasionally peaking

at 34-35 m/s. The maximum wind speed reached 40 m/s in Saintsagaan and Erdenedalai soums of Dundgovi province. The geographical distribution of these strong wind and storm events is illustrated in *Figure 2*.

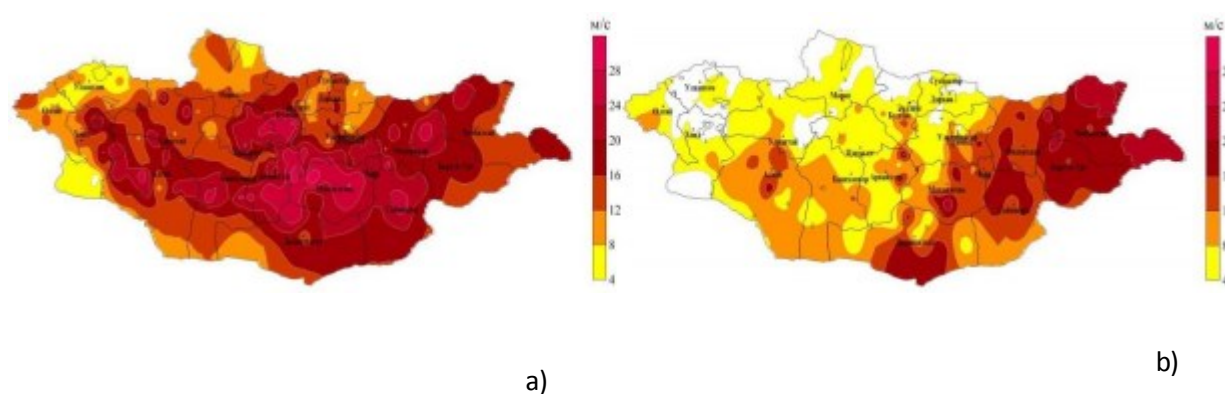


Figure 2 The Exposure Map of Provinces, by Distribution of the High WindSpeeds

a) A case of 14 March, b) A case of 15 March

The severe wind and storm events affected/covered nearly all provinces' territories on 14 March, extending to the Gobi and eastern regional provinces' territories on 15 March, as depicted in

Figure 2. Exposure Map of Provinces, by Distribution of the High Wind and Storm Speeds.

Two. Damage Effects ofthe Severe Wind and Storm Event from 13-15 March 2021

The Meteorological Organization delivered timely weather forecast information and warning alerts regarding hazardous events to the communities through a variety of communication channels. Nevertheless,a severe two-day catastrophic phenomenon in 2021 affected 16 provinces and their 151 soums, resulting in significant loss and damage to human lives, property, livestock, and the national economy. The extent of the caused damage is detailed in *Table 1*.

Table 1. Loss and damage caused by the severe windsandstorms from 14-15 March 2021 by the numbers

Elements	Affected provinces	Affected soums	Lost people	Lost people who	Human death	Damaged houses, roof	Destroyed Ger, traditional	Damaged fences and sheds	Collapsed electric lines and poles	livestock lost and gone down in the	Perished livestock	Lost livestock that rescued and found	Missing livestock
#	16	151	706	696	10	283	531	2235	128	2309954	140347	2102564	67664

Considering the impacts on the population, a total of 706 individuals were reported disappeared and lost across 61 soums in 12 provinces during the severe winds and storms. Among them, 696 individuals were eventually found alive, while tragically, 10 individuals lost their lives.

Table 2. The number and percentage of people affected by the severe strong windsandstorms on 14 and 15 March 2021 (by province)

Provinces	Affected soums		Lost /missing people		Missing people who were rescued/ found alive		Number of death
	#	%	#	%	#	%	
Arkhangai	2	3.3	4	0.6	3	0.4	1
Bayankhongor	4	6.6	11	1.5	11	1.6	
Bulgan	3	4.9	7	0.9	7	1.0	
Govisumber	3	4.9	33	4.7	33	4.7	
Dornogovi	7	11.5	60	8.4	60	8.6	
Dornod	1	1.6	3	0.4	3	0.4	
Dundgovi	15	24.6	468	66.3	459	65.9	9
Zavkhan	2	3.3	2	0.3	2	0.3	
Uvurkhangai	8	13.1	23	3.2	23	3.3	
Umnugovi	9	14.7	85	12.0	85	12.2	
Sukhbaatar	1	1.6	1	0.1	1	0.1	
Tuv	6	9.8	9	1.3	9	1.3	

Total: 12	61	100	706	100	696	100	10
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Table 2 indicates a significant impact on citizens in Dundgovi province, with approximately 66.3% of all individuals reported lost/missing during the strong winds and storms, and 90% of those who lost their lives. The Govi regional provinces were also notably affected, accounting for 12% of the missing individuals in Umnugovi province, 8.4% in Dornogovi province, and 4.7% in Govisumber province.

Following the wind and storm disaster, 531 Gers, traditional dwellings and 2,235 fences and sheds collapsed across 154 soums in 16 provinces. Additionally, the roofs of 283 houses were torn off, and 128 electric pillar poles supporting 220V overhead power lines fell in seven provinces. Consequently, temporary disruptions in electricity occurred in 34 soums across ten provinces.

Table 3. The number and percentage of properties affected by the severe strong winds and storms on 14 and 15 March 2021 (by province)

Provinces	Destroyed dwellings/Ger		Buildings with damaged roof		Damaged fences and sheds		Collapsed electric poles and lines	
	#	%	#	%	#	%	#	%
Arkhangai	51	9.6	40	14.1	384	17.2	10	7.8
Bayankhongor	11	2.1	6	2.1	176	7.8		
Bulgan	2	0.4	22	7.8			73	57.03
Govi-Altai	22	4.1	35	12.4	221	9.9	36	28.1
Govisumber	5	0.9	2	0.7	1	0.04		
Dornogovi	70	13.2						
Dornod	11	2.1	10	3.5	22	0.9	2	1.6
Dundgovi	93	17.5	69	24.4	587	26.3		
Zavkhan	9	1.7	1	0.3			1	0.7
Uvurkhangai	32	6.0	7	2.5	436	19.5		
Umnugovi			1	0.3				
Sukhbaatar	8	1.5	11	3.9	36	1.6		
Tuv	65	12.2	43	15.2	237	10.6	5	3.9
Uvs	86	16.2	11	3.9	106	4.7	1	0.8
Khovd	16	3.0	2	0.7	26	1.2		
Khentii	50	9.4	23	8.1	3	0.1		
Total: 16	531	100	283	100	2235	100	128	100

During the severe winds and storms, 2.3 million heads of livestock went down the storms, with reports in 22 soums across seven provinces. 140,347 heads of livestock, accounting for approximately 6% of the total, perished as a result of the event.

Table 4. The number and percentage of livestock affected by the severe strong windsandstorms on 14 and 15 March 2021 (by province)

	Livestock lost/gone down in the storms		Perished livestock		Lost livestock that were found		Missing livestock	
	#	%	#	%	#	%	#	%
Arkhangai	338	0.01	68	0.04	270	0.01		
Dundgovi	2177788	94.3	137205	97.8	1972919	93.8	67664	100
Zavkhan	600	0.03			600	0.03		
Sukhbaatar			10	0.01				
Tuv	125864	5.4	2100	1.5	123776	5.9		
Uvs	2364	0.1	964	0.7	2000	0.09		
Khovd	3000	0.1			3000	0.14		
Total: 7	2309954	100	140347	100	2102564	100	67664	100

94.3% of the total livestock lost and went down in the storm and 97.8% of perished livestock due to the storm were concentrated in Dundgovi province. A severe dust storm commenced in Dundgovi province at 10:07 AM on 14 March 2021, with wind speeds ranging from 24 to 28 m/s,

occasionally reaching 34 to 40 m/s. The storm lasted 14 hours until 01:45 AM on 15 March 2021, resulting in a disastrous situation in the province³.

Analysis of correlations between windspeeds and damage effects

The analysis of damage effects resulting from the disaster was conducted concerning the wind speeds across affected provinces. At the first place, to improve the data quality of wind speed and damage, a quality check was performed using the Z-Score method, and the value's correlation was calculated by cutting the outliers.

$$Z_i = \frac{Y_i - Y^-}{s} \quad (1)$$

Z-Score is a numerical measurement method identifying outliers, which are values that significantly deviate from the mean of the dataset. Specifically, any data point with an absolute value of Z-Score greater than 3 is considered as an outlier and subsequently cut from the dataset.

By using this method, we prepared the wind speed and damage data of affected 154 soums across 16 provinces to calculate the correlation.

The damage in affected soums was categorized into four distinct groups: damaged and destroyed properties, affected population, perished livestock, and lost livestock. Damage data in each category and the high wind speeds were estimated to make their correlation value.

Wind speeds are evaluated using two parameters: average high speed and instantaneous high speed, and their correlations with four categories of damage were examined using Pearson correlation analysis. The results of this analysis are presented in Table 5.

$$r = \frac{N \sum xy - (\sum x)(\sum y)}{\sqrt{[N \sum x^2 - (\sum x)^2][N \sum y^2 - (\sum y)^2]}} \quad (2)$$

Pearson's correlation coefficient "r" ranges from +1 to -1, with values closer to +1 or -1 indicating stronger correlations. A value of 0 suggests no linear correlation between the two variables. A value greater than 0 indicates a positive correlation, conversely, a value less than 0 indicates a negative correlation.

Table 5. Correlations between the wind speed and damage effects

Wind speed	Damaged & destroyed properties	Affected population	Perished livestock	Lost livestock
Average high speed	0.31	0.34	0.39	0.78
Instantaneous high speed	0.31	0.42	0.35	0.78

According to the findings presented in Table 5, the wind speeds exhibit certain correlations with damage effects of some categories, including damaged and destroyed properties, affected population, and lost livestock, however; there is a high correlation with the number of perished livestock.

Figure 3 visually illustrates the correlations between instantaneous high wind speed and the number of affected populations, as well as the depiction of the correlations between average high wind speed and the numbers of damaged and destroyed properties, perished livestock, and lost livestock.

Given the strong correlations observed between windspeeds and the numbers of lost and perished livestock, it is crucial to receive weather forecasts carefully for herders and ensure forecasting windspeeds and preparation for a hazardous event, such as grazing livestock animals not far from homes, getting fencing readiness, and preparing some people for assistance accordingly. Additionally, it is observed that the number of damaged and destroyed properties is comparatively high in densely populated areas of soums regardless of the wind speed variations.

³ Emergency Management Department, Dundgovi province (2021)

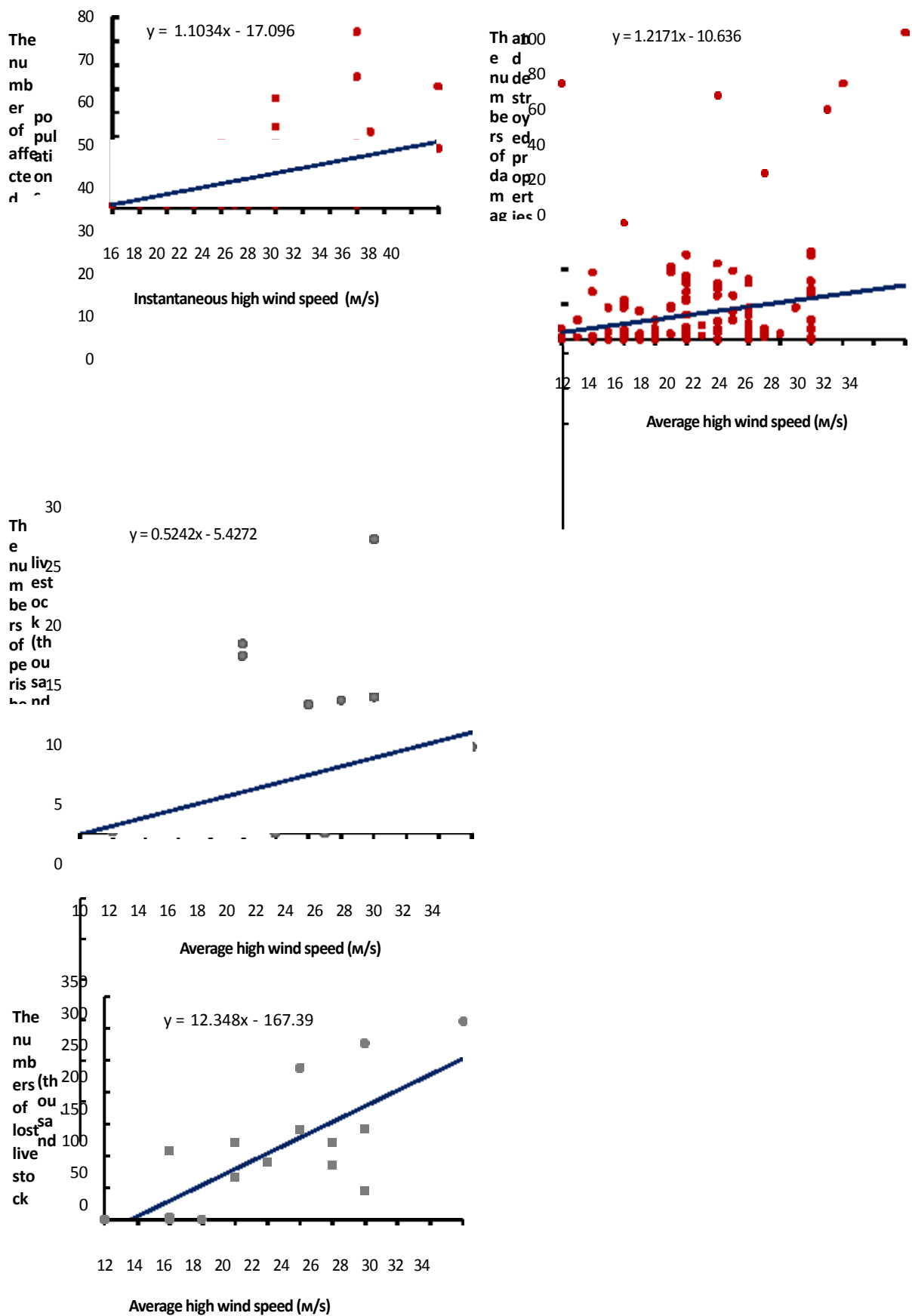


Figure 3. Correlations between the wind speed and damage effects

Besides wind speed, the duration of winds and storms is a crucial factor influencing the damage effects caused by strong wind and storm events. Thus, to determine this correlation, Pearson correlation coefficients were used between the wind duration and categorized damage effect indicators, and the results are detailed in *Table 6*.

Table 6. Correlation between the duration of wind and storm and damage effects

Duration period	Damaged & destroyed properties	Affected population	Perished livestock	Lost livestock
Dust and sand storms	0.28	0.53	0.67	0.59
Strong storms	0.05	0.16	0.75	0.69

According to the findings presented in *Table 6*, there are notable observations of low correlations between the duration of the winds and storms and the numbers of affected populations and damaged & destroyed properties. However, contrasting high correlations exist between the duration of the winds and storms and the numbers of both perished and lost livestock.

This analysis indicates that shorter-duration wind and storm events tend to affect mainly properties, whereas longer-duration events are associated with significantly negative impacts on livestock.

Three. Examining the wind and storm event from 13-15 March 2021 as an extremely hazardous phenomenon

Over the past two decades, strong wind and storm hazardous events, considering as extremely hazardous phenomena or/and disastrous phenomena, affecting more than 30 percent of Mongolia's territory [6], have occurred an average of 16 times per year [7,8,9]. The frequency of these events appears to be increasing, as shown in *Figure 4*.

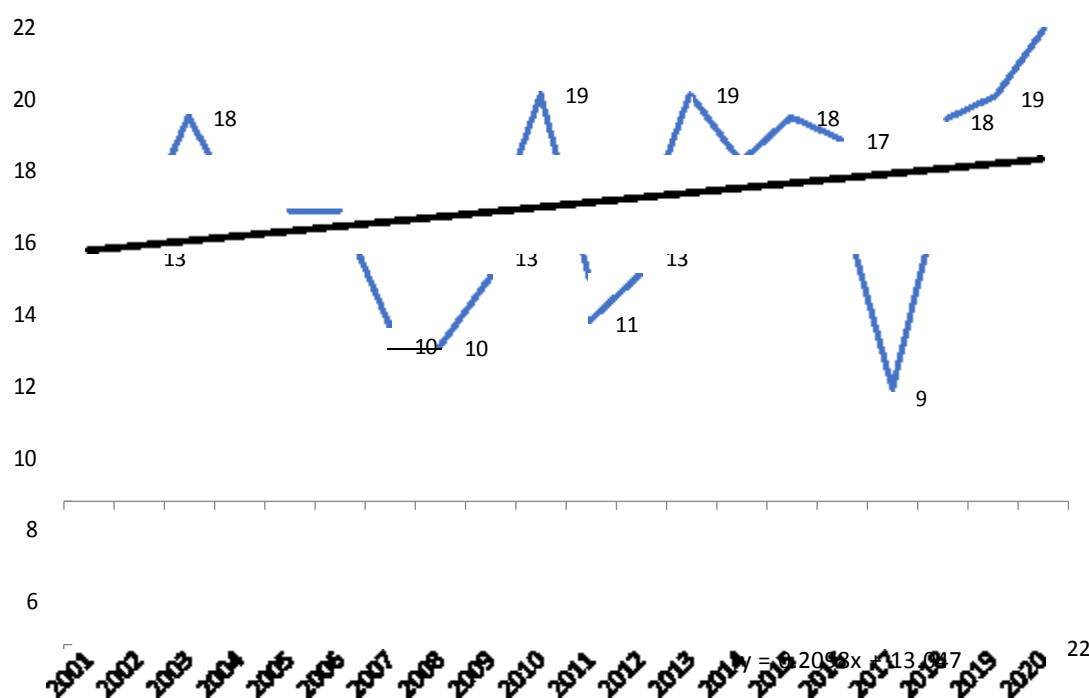


Figure 4. Frequency of strong winds and storms

In the last 20 years, a total of 171 human mortalities and approximately 800,000 livestock losses have been recorded [7,8,9] due to extremely hazardous or/and disastrous phenomena resulting from strong winds and storms. The study contrasts the most damaging strong wind and storm events in the recorded ones with the conditions of the wind and storm hazardous event of 13-15 March 2021.

1. From 26-27 May 2008, the wind speed reached 15-26 m/s across most regions of Mongolia, escalating to 28-34 m/s in Tuv, Khentii, Dornogovi, Sukhbaatar, Dornod, and Govisumber provinces, and reaching 40 m/s in some soums across Khentii and Sukhbaatar provinces. The atmospheric conditions deteriorated, reducing visibility to 20-50 meters, and the severe dust and snow storm lasted for 17-53 hours. Consequently, this disastrous phenomenon resulted in the human mortality of 38 adults and 14 children, as well as the loss of 362,200 livestock. Additionally, 110 buildings

damaged, 221 Ger, traditional dwelling collapsed, and the storm felt down 62 electric poles and 668 communication poles. Approximately 1 billion MNT was allocated from the Government Reserve Fund to provide compensation for the caused damages.

2. From 03-04 April 2015, precipitation totaling 1.0-10.0 mm of snow fell in the areas of Khuvsgul, Bulgan, Arkhangai, Uvurkhangai, Tuv, Khentii, Sukhbaatar provinces, followed by windspeeds ranging from 16-28 m/s in northern Govi-Altai, southern Bulgan, Uvurkhangai, Umnogov, Dundgovi, Dornogovi, and Tuv provinces, and the severe snow storm lasted for 1-26 hours. It resulted in 4 human deaths and 181,000 livestock loss, and the damage totaled 5.3 billion MNT.
3. On 10-12 May 2019, precipitation totaling 0.1-18.6 mm of snow fell in the various areas, including Govi-Altai, Bayankhongor, Uvurkhangai, Tuv, Dundgovi, Govisumber, Umnogov, Dornogovi, Khentii, Sukhbaatar provinces. During the given period, the wind speeds ranged from 18-20 m/s with occasional instantaneous wind escalating to 24-30 m/s accompanied by severe dust and snow storms. This weather disastrous phenomenon resulted in 6 human deaths and about 14.3 thousand livestock loss.
4. On 14-15 March 2021, the severe wind and storm conditions extended widely across areas of 154 soums in 16 provinces, including Zavkhan, Tuv, Khuvsgul, Bulgan, Selenge, Darkhan-Uul, Dornod, Uvurkhangai, Bulgan, Umnugovi, Dundgovi, Dornogovi, Govi-Altai, Bayankhongor, Arkhangai, Khentii, Sukhbaatar provinces. Following the wind and storm disaster, 706 individuals were lost in the storms, which of 10 persons lost their lives, 531 Gers, traditional dwellings and 2,235 fences and sheds collapsed. Additionally, the roofs of 283 buildings were torn off, and 128 electric pillar poles supporting 220V overhead power lines fell in seven provinces, the damage totaled 1.4 billion MNT [2,8,9,11].

The results of comparing some characteristics of above-mentioned severe winds and storms are presented in Table 7.

Table 7. The comparison of some indicators of strong windsandstorms with significant damage in the Mongolia's territories over the past two decades

Duration		26-27 May 2008	03-04Apr 2015	10-12 May 2019	14-15 Mar 2021
Affected areas	Name of Province	Tuv, Khentii, Dornogovi, Sukhbaatar, Dornod, Govisumber	Khuvsgul, Bulgan, Arkhangai, Uvurkhangai, Tuv, Khentii, Sukhbaatar Govi-Altai, Bulgan, Umnogovi, Dundgovi, Dornogovi,	Govi-Altai, Bayankhongor, Uvurkhangai, Tuv, Dundgovi, Govisumber, Umnogov, Dornogovi, Khentii, Sukhbaatar	Zavkhan, Tuv, Khuvsgul, Bulgan, Selenge, Darkhan- Uul, Dornod, Uvurkhangai, Bulgan, Umnugovi, Dundgovi, Dornogovi, Govi- Altai, Bayankhongor, Arkhangai, Khentii, Sukhbaatar
	The number (#)	6	11	10	16
Features	Storm types	Dust and snow storms	Snow storms	Dust and snow storms	Dust and snow storms
	Wind speed	28-40m/c	16-28 m/c	24-30m/c	16-40m/c
Damage effects	# of missing individuals	242	344	100	707
	# of human deaths	52	4	6	10
	# of perished livestock	362200	181000	14300	140347
	Destroyed Ger, traditional dwellings	221	3	1	531
	Damaged buildings & facilities	110	1	10	283
	Collapsed electric poles	62	-	-	128
	Total damage by MNT	1 billion MNT	5.3 billion MNT	-	1.4 billion MNT

The following conclusion can be merged from the comparison of the four storms identified as having caused the most substantial damage among the strong winds and storms experienced in the past two decades.

- The scope of hazardous and catastrophic phenomena associated with strong winds and storms has expanded
- Regarding the parameters used in comparisons of the mentioned hazardous events, it is observed not noticeable changes; however, due to increased occurrences of instantaneous high wind speeds, the extent of damaged and destroyed properties resulting in the storms has markedly risen.
- For the most recent hazardous phenomenon, there has been a sharp rise in the number of missing individuals. According to the Meteorological Organization, widespread drought occurred in most regions in the summer of 2021, and minimal snowfall were in most areas of the Gobi regional provinces in the winter of 2020-2021. These conditions resulted in substantial amounts of soil and dust being carried into the air, leading to prolonged periods of limited visibility.

Regarding the results of the study, it is apparent that the wind and storm event occurring from 13- 15 March 2021 is an extremely hazardous phenomenon with the most significant damage in variety of indicators except human mortality in the last 20 years.



Figure 5. Situation of Dundgovi province resulting from the wind and storm event from 13-15 March

(Source: Emergency Management Department, Dundgovi province)

To sum up, there are several factors to occur the exceptionally hazardous phenomenon from winds and storms on 13-15 March 2021, as follows. Firstly, in the summer of 2020, a severe drought affected most areas of Bayankhongor, Govi-Altai, Dundgovi, Uvurkhangai, and Umnogov provinces, secondly, in pasture overgrazing and severe land surface degradation in these provinces, lastly, minimal snowfall across most of the Gobi regional provinces in the winter of 2020-2021. We consider these factors contributed to exacerbate soil destabilization and lead to severe dust storms.

Conclusion

In Mongolia, frequencies and intensities of exceptionally hazardous weather phenomena from winds and storms are increasing and even likely to increase further due to climate change, global warming and soil degradation.

The conditions to occur an exceptionally hazardous phenomena from winds and storms from 13- 15 March 2021 in Mongolia with huge amount of damage in human mortality and properties resulted from a severe drought affecting extensive areas of Mongolia in the summer of 2020, followed by pasture overgrazing and severe land surface degradation, as well as minimal snowfall and dry air across most areas of the Gobi provinces in the winter. These factors contributed to substantial amounts of soil and dust being carried into the air, leading to prolonged periods of limited visibility.

There is a highly noticeable correlation between the duration of severe winds and storms and the numbers of perished livestock. Hence, the prolonged occurrence of severe wind and storm from 13-15 March 2021 stands out as a primary factor increasing adverse impacts on livestock. Moreover, it analyzes that higher wind speeds and longer-duration events are associated with significantly negative impacts on livestock, whereas instantaneous high wind speeds directly contribute to property damage. It is feasible to enhance disaster prevention and preparedness for overcoming disasters with the smallest damage effects through receiving weather forecasts carefully for herders, forecasting wind speeds and gaining awareness regarding the importance of getting ready for hazards.

Over the past two decades, there has been a significant increase in the frequency of severe wind and storm events categorized as extremely hazardous or disastrous phenomena. According to the findings of the study, the severe wind and storm event occurring from 13-15 March 2021 represents an exceptionally hazardous phenomenon, marking it as the most damaging event in the given period.

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