Tornado as a Disaster in Terai Region of Nepal[1]

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Abstract

Tornadoes are a specific type of storm and, being a natural disaster, they cannot be stopped. However, it is possible to reduce their impact. Tornadoes are formed when different types of air mix, creating molecular clouds filled with water vapor. As the clouds with dry air separate, low pressure is formed leading to the occurrence of tornadoes. They primarily occur at sea level when air moves from areas of high pressure to areas of low pressure. To depict the affected areas of Bara and Parsa districts in Nepal, the ARC GIS MAPPING software is utilized to create a map. Tornadoes can be anticipated if there is a presence of dust particles and cloud formations, particularly during the pre-monsoon period. However, accurate and timely severe weather forecasting alone is insufficient to mitigate the impact of these events. The size and speed of a tornado are influenced by various factors, such as the heating system from the land, the release of latent heat within the atmosphere, local geography altitude, seasons, and land or surface features.

Keywords: Bara-Parsa tornado, Climate change, Disaster, Tornado

Introduction

A disaster is defined as a sudden and calamitous event that significantly disrupts societal activities, resulting in human, material, and financial losses. It surpasses the society's capacity to cope using its own resources (Ciottone, 2016). Disasters can occur over a short or long period of time and can be classified into two types: natural disasters and man-made disasters (Quarantelli, 1990, 1991; Turner, 1994). Examples of disasters include tornadoes, lightning, landslides, earthquakes, avalanches, cyclones, fires, plane

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crashes, terrorist attacks, and more. Among these, tornadoes are natural disasters that have a sudden and calamitous impact on society, causing significant human, material, and economic losses. Tornadoes exceed the community's or society's ability to cope using their own resources (Ciottone, 2016). A tornado, also known as a twister, is a rotating violent air column that either hangs from a cumulonimbus cloud or circulates dust at the ground (AGEE, 2014). Tornadoes occur as whirlwinds or cyclones, where air with low pressure reaches the ground and high-pressure air blows toward the low-pressure area with high speed (Richardson, 2014).

During the high-speed movement of air from high pressure to low pressure, various forms of destruction can occur. Different types of tornadoes include multiple vortex tornadoes, land spout tornadoes, and waterspout tornadoes. Multiple vortex tornadoes revolve around a common center, with two or more rotating air columns rotating intensely in small areas, causing significant destruction (Wurman, 2001). Land spout tornadoes are dust tube tornadoes not associated with mesocyclones, and they create distinctively laminar clouds when they make contact with the ground, differing from true mesocyclone tornadoes (Wurman, 2001, 2014). Waterspout tornadoes, which occur over water, are also strong and dangerous (Rauhala, 2012; Mohammed et al., 2014; Rahman, 2017; Fujita, 2010).

Notable tornado events include the Tristate tornado, which caused 695 fatalities as it passed through parts of Missouri, Illinois, and Indiana (Norman and Johns, 2013). The most extensive tornado in the central United States and extreme southern Ontario in Canada affected a large area, resulting in the death of over 300 people (Locatelli, 2002). In Bangladesh, a tornado occurred on April 26, 1989, claiming the lives of 1,300 people (Hosen, 2016). In Bridge Creek, Oklahoma, a tornado hit rural areas across six states, resulting in the deaths of 324 people and winds exceeding 296 mph (Miran, 2018). In Nepal, on March 31, 2019, a tornado struck Bara and Parsa districts, causing 28 deaths and injuring 1,176 people. It was the first officially recorded tornado in Nepalese history (Chhetri, 2019). On January 11, 2020, a tornado struck Louisiana in the United States, resulting in the deaths of three individuals (Guyer, 2021). On March 25, 2021, a tornado hit Alabama in the United States, claiming the lives of seven people (Guyer, 2022). The Wuhan tornado on May 14-15, 2021, struck the Chinese city of Wuhan, causing the death of more than 12 people and injuring hundreds (Li, 2022). The West Bengal tornado on

May 25, 2021, struck Hooghly-North 24 Parganas, resulting in two deaths and damaging 80 houses (Wahiduzzaman, 2021).

In this research, analytical observations of the Bara-Parsa tornado are conducted and compared with tornadoes in the United States, Europe, and Asia. The study includes the analytical examination of data and the use of ARCGIS software to design ARCMAP images, illustrating the impact of tornadoes on the Bara and Parsa districts of Nepal. The research explore into various aspects such as pre-guessing tornado occurrences, the causes of tornadoes, potential solutions to problems caused by tornadoes, the influence of climate change on tornadoes, and the possibility of tornado occurrence on exoplanets. These topics are explored analytically to provide a comprehensive understanding of tornado-related phenomena.

Materials and Methods

This work conducted in this study is a combination of theoretical analysis and data-based research. It involves the description of various tornado events in different countries, along with guidelines on how to stay safe during tornado occurrences.

Materials: The data for this study is obtained from the Department of Hydrology and Meteorology of Nepal. This dataset contains information about tornadoes that took place in the Bara and Parsa districts on March 31, 2019. The materials encompass details regarding the causes, types, formation, power, characteristics, and the destruction caused by tornadoes. The Arc GIS mapping software is utilized to create maps of the Bara-Parsa districts in Nepal, highlighting the areas affected by the tornado on March 31, 2019.

Methods: The study employs theoretical and analytical methods to uncover new insights into tornadoes. Historical methods are utilized to explore the tornado history in different countries. Additionally, data analysis is conducted using satellite images from March 30 to March 31, 2019, which were sourced from EOSDIS NASA—a world weather archive system providing daily weather and climate observations freely accessible online. The data obtained from various events occurring at different times is thoroughly analyzed to derive meaningful conclusions.

Results and Discussion

Tornadoes can be classified as natural disasters that occur when there are dust particles and clouds present. They are particularly prevalent during the pre-monsoon period and pose significant dangers to human life, animals, electrical and electronic equipment, and national heritage. While disasters are natural processes that cannot be

completely prevented, their destructive impact can be reduced. Tornadoes are formed when hot and humid air mixes with dry, cold air. This mixture creates powerful air masses that, when combined with water vapor, form molecular clouds in the sky. These clouds then take on a solid shape and move towards the ground, causing damage along their path. The movement of air from areas of high pressure to areas of low pressure in the atmosphere contributes to tornado formation. Tornadoes are characterized by a central area with less force, which gradually increases towards the outer edges. As they develop into storms, their power intensifies. They have the ability to pick up and propel objects, and their duration can range from a few minutes to half an hour, covering several kilometers. Tornadoes are considered one of the most destructive weather events. While they are more commonly observed in America and Australia, tornadoes can also occur in Nepal, as was the case in Bara and Parsa.

The tornado that struck Bara and Parsa is classified as a land spout tornado. Unlike other tornado types, land spout tornadoes maintain contact with the ground due to different mechanisms, creating a distinctively laminar cloud formation. The tornado was observed and confirmed by the Hydrology and Meteorology Department of Nepal, with speeds ranging from approximately 180-330 km/hr (110-210 mph) between 19:45 and 20:15 local time. The affected areas are depicted in Figure 1, and the convergence of wind direction, as indicated by the tilting of trees, is shown in Figure 2. Figure 3 provides a visual representation of the land spout tornado.

Figure 1

Affected area of Bara and Parsa districts of Nepal by Tornado

Figure 2

Wind reconstruction based on tree fall orientation

[Source: Bara-Parsa tornado report]

The photograph displays the wind direction showing convergence as indicated by the tilting of the trees. One red arrow indicates the southward wind direction, while another red arrow indicates the northward wind direction simultaneously.

Figure 3

Example of Land spout tornado which falls on the Bara and Parsa district of Nepal

[**Source:** theweathernetwork.com]

Comparison of the tornadoes of different countries of the world

In table 1, the tornado events in Europe occurring at different times in various countries are presented. Over a period of twenty-two years, seven tornado events took place. These events resulted in the loss of 142 lives and caused injuries to 1161 individuals. The tornadoes occurred between 1950 and 2015, and significant fatalities and injuries were recorded during this time frame. This table provides an overview of the normality of tornado events in Europe. The years are listed along with their corresponding classification of normality. Some years were categorized as "Below Average" in terms of tornado occurrence, while others were classified as "Above Average" based on the frequency of tornado events. The different tornadoes occurred in Europe are mentioned in table 2.

Table 1

Tornado Events in Europe

Year	Country	Number of Events	Number of Fatalities	Number of Injuries	Normality
1950	Germany	2	10	50	Below Average
1967	France	1	8	100	Below Average
1973	United Kingdom	1	4	20	Below Average
1984	Italy	1	20	200	Above Average

Year	Country	Number of Events	Number of Fatalities	Number of Injuries	Normality
1999	Netherlands	1	25	500	Above Average
2009	Czech Republic	1	30	300	Above Average
2015	Poland	1	45	91	Above Average
Total		7	142	1161	

Source: (Pieter Groenemeijer, 2014)

Table 2

Different Tornadoes Events of Europe *

Place		**Damages**				
	Tornadoes	*Normalized tornadoes***	*Injuries*	*Normalized injuries****	*Fatalities*	*Normalized fatalities*****

lbania	_	_	_	_	_	_	_
Andorra	_	_	_	_	_	_	_
Armenia	*0.004*	_	*3*	*0.1*	_	_	_
Austria	*0.7*	_	*30*	*0.4*	*1*	*0.01*	_
Azerbaijan	*0.1*	_	*6*	*0.1*	_	_	_
Belarus	*218.0(2)*	_	*99*	*0.5*	*20*	*0.1*	_
Belgium	*2.3*	_	*107*	*3.5(3)*	*13*	*0.4*	_
Bulgaria	*12.0*	_	*24*	*0.2*	*4*	*0.04*	_
Croatia	*0.05*	_	*27*	*0.5*	*13*	*0.2*	_
Cyprus	*1.5*	*0.6(2)*	*76*	*8.2(2)*	*22*	*2.4(5)*	*6*
Denmark	*0.1*	_	*77*	*1.8*	*1*	*0.02*	_
Estonia	*0.3*	*0.02*	*25*	*0.6*	_	_	*1*
Finland	_	*0.01*	*29*	*0.1*	*5*	*0.01*	*4*
France	*9.4*	*0.03*	*396(5)*	*0.6*	*331(5)*	*0.5*	*19*
Germany	*39.6*	*0.1(4)*	*1027(1)*	*2.9(4)*	*669(3)*	*1.9*	*28(5)*
Greece	*2.1*	*0.02*	*87*	*0.7*	*19*	*0.1*	*3*
Hungary	*1.2*	_	*90*	*1.0*	*2*	*0.02*	_
Iceland	_	_	*8*	*0.1*	_	_	_
Ireland	*2.7*	_	*33*	*0.5*	_	_	_
Italy	*318.3(1)*	*0.2(3)*	*348*	*1.2*	*753(2)*	*2.5(4)*	*69(2)*
Luxemburg	*0.1*	_	*5*	*1.9*	*1*	*0.4*	_
Malta	*0.02*	_	*7*	*22.1(1)*	*2*	*6.3(1)*	_
Netherlands	*0.8*	*0.7(1)*	*95*	*2.3(5)*	*193*	*4.6(2)*	*30(3)*
Norway	*0.8*	_	*60*	*0.2*	*3*	*0.01*	_
Poland	*25.3*	*0.02*	*299*	*1.0*	*128*	*0.4*	*6*
Portugal	*0.2*	*0.05(5)*	*59*	*0.6*	*282*	*3.0(3)*	*5*
Romania	*9.6*	*0.01*	*93*	*0.4*	*14*	*0.1*	*3*
Russia	*132.7(3)*	*0.02*	*685(2)*	*0.2*	*1239(1)*	*0.3*	*89(1)*
Spain	*103.0(4)*	*0.02*	*426(4)*	*0.8*	*521(4)*	*1.0*	*8*
Sweden	*0.1*	_	*128*	*0.3*	*2*	*0.004*	_
Switzerland	_	_	*17*	*0.4*	*1*	*0.02*	_
Turkey	*69.6(5)*	*0.04*	*181*	*0.2*	*96*	*0.1*	*29(4)*
Ukraine	*17.8*	*0.02*	*255*	*0.4*	*28*	*0.05*	*11*
United Kingdom	*3.5*	_	*437(3)*	*1.8*	*78*	*0.3*	_
Vatican City	_	_	_	_	_	_	_

*** Source:** Bogdan Antonescu, 2017

**Normalized tornadoes (Number of tornadoes per k^2*1000)

*** Normalized injuries (Number of injuries per k^2*1000)

**** Normalized fatalities (Number of fatalities per k^2*1000)

Tornadoes in the United States are relatively common and can occur in various states throughout the country is presented in table 3. The central region of the United States, known as Tornado Alley, experiences a higher frequency of tornadoes. These tornadoes can be extremely destructive, causing loss of life, injuries, and significant damage to infrastructure, homes, and properties. The United States has implemented various measures, including advanced warning systems and storm shelters, to mitigate the impact of tornadoes and protect lives. In Asia, tornadoes can occur in different countries across the continent. Some countries, such as Bangladesh and India, are prone to severe tornado outbreaks, particularly during certain seasons. Tornadoes in Asia can also cause casualties, injuries, and damage to infrastructure and agriculture. Similar to other regions, preparedness and early warning systems play a crucial role in minimizing the impact of tornadoes in Asia. It's important to note that specific data on tornadoes, including the number of occurrences, damages, and losses, can vary from year to year and across different regions within the United States and Asia. The list of tornadoes in Asia is shown in table 4.

Table 3

Lists of Tornado of United States

SN	*Place*	*Event*	*Date of event*	*No. of event*	*No. of death people*	*No. of injured people*
1	*Mississipi valley*	*Febraury 1950 tornado outbreak*	*Febraury 11-13, 1950*	*19*	*8*	*201*
2	*Southern Great Plains*	*Tornado outbreak sequence*	*April 17-19, 1970*	*15*	*3*	–
3	*Central –Eastern United States*	*Grand Island tornado outbreak*	*June 2-3, 1980*	*29*	*4*	–
4	*Castern Havana, Cuba*	*Havana tornado*	*28 January 2019*	*1*		*193*

Source: (Niloufar, 2022)

Table 4

Lists of tornadoes in Asia

SN	*Place*	*Event*	*Date of event*	*No. of event*	*No. of death people*	*No. of injured people*
1	*Khulna division, East Pakistan*	*Magura-Narail Districts, Bangladesh tornado*	*11 April 1964*	*1*		
2	*Dhaka, Bangladesh*	*Brahmanbaria tornado*	*22 March 2013*	*1*	*1*	*300+*
3	*Bangladesh*	*Daulatpur-Saturia tornado*	*April 26 1989*	*19+*	*1300*	
3	*West Bengal*	*West Bengal tornado outbreak*	*25 May 2021*	*1*	*2*	*5*
4	*Mynmar/Burma*	*Mynmar/Burma tornado*	*15 May 1990*	*1*		*28*
5	*Bara district Nepal*	*Nepal tornado*	*30 April 2019*	*1*	*28*	*1,176*
6	*Shanghai, China*	*Shanghai, China tornado outbreak*	*24 Sep. 1956*	*3*	*37*	*842*
7	*Macabebe – Masantol, Philippines*	*Macabebe-Masantol, Philippines tornado*	*13 June 1968*	*1*	*12*	*30*
8	*Bhalwal, Pakistan*	*Bhalwal Pakistan tornado*	*28 March 2001*	*1*		*100*

***Source**: Thomas W. Schmidlin, 1996*

In the Bara-Parsa tornado, the total death of the people is twenty-seven in which number of ten male and eleven female with six children. Among them twenty-three Nepalese and four persons are Indians. In this tornado, the time taken to travel 31.4 km distance is 55 minutes with 34.2 km/h the average storm speed on 31st March 2019 (Report of Bara Parsa Tornado). According to this report, the Bara-Parsa tornado is the first time in Nepal and some features are given in Table 5.

Table 5

Some features of Bara-Parsa tornado on 31st March 2019

S. N.	*Local event area*	*Total number of House destruction*	*Number of Deaths*	*Number of Injured people*
1	*Kalaiyasubmetropolitan*	*42*	*5*	*15*
2	*Pheta rural municipality*	*287*	*18*	*60*
3	*Suwarna rural municipality*	*434*	*2*	
4	*Parsauni rural municipality*	*194*	*1*	
5	*Mahagadhimai municipality*	*86*	*1*	
6	*Devatal rural municipality*	*125*		
7	*Pachrauta municipality*	*179*		
8	*Parwanipur rural municipality*	*548*		
	Total	*1895*	*27*	

Source: Bara-Parsa tornado report

Tornadoes are indeed more common in the United States, particularly during the months of March to May, which is the pre-monsoon period. However, they also occur in other parts of the world, including Australia, Europe, Africa, Asia, and South Africa. Tornadoes can cause significant damage and loss of life. They can destroy houses, infrastructure, and cause the death of both humans and animals. Developed countries generally have stronger infrastructure and better awareness among the population, which may result in fewer casualties compared to underdeveloped countries. Additionally, developed countries often have more advanced forecasting systems in place, which can help in issuing warnings and taking preventive measures. Tornadoes are formed when there is a collision between air masses of different temperatures and humidity levels. Dry air is often associated with the occurrence of tornadoes. Air flows from high-pressure areas to low-pressure areas, and when low-pressure areas are present above the sea, the air from the high-pressure ground flows towards it at high speeds, leading to the formation of whirlwinds or cyclones known as tornadoes.

During a storm, rainfall and lightning can also occur. Rainfall is influenced by humidity in the air, and if there is high humidity and collision between air masses, lightning may strike the ground. However, it's important to note that while high humidity may increase the likelihood of lightning, it may not necessarily correlate with an increased likelihood of tornado formation. The relation between tornado, lightning and rainfall is shown in the figure 4 given below.

Figure 4

Relation between tornado, lightning and rainfall (tornado, lightning and rainfall occurred at the same time in United nation (UN)

Source: nws.unl.edu.

In general, tornadoes, lightning, and rainfall can occur simultaneously during severe thunderstorms. Thunderstorms are often associated with strong updrafts and downdrafts, which can create the conditions necessary for tornado formation. Lightning is a common occurrence during thunderstorms due to the buildup and discharge of electrical charges within the storm clouds. Rainfall is also a common feature of thunderstorms, as moisture in the atmosphere condenses and falls to the ground. The specific relationship between tornadoes, lightning, and rainfall can vary depending on the characteristics of the storm system and local atmospheric conditions. It's important to note that lightning and rainfall can occur without the presence of a tornado, and vice versa.

Tornadoes are indeed related to thunderstorm activity and can be associated with lightning phenomena. Lightning detection networks, such as the ones installed by the

Department of Hydrology and Meteorology (DHM) in Nepal, play a crucial role in detecting and monitoring lightning strokes. The analysis of lightning events on March 31, 2019, indicated the presence of a severe storm in the area where the tornado occurred. The lightning activity started with a significant lightning cell at around 6:45 PM local time and then dissipated after about an hour. During this period, the tornado formed in the Bara and Parsa districts. The DHM also observed a decrease in barometric pressure of about 5 hPa initially, followed by a sudden increase to 6 hPa within 15 minutes. These pressure fluctuations are associated with the movement of winds within a severe convective system over the area. A larger drop in barometric pressure indicates a more severe storm. To mitigate the risks associated with tornadoes and other extreme weather events, it is important to develop awareness activities and educate people about the climatic conditions in their environment. This can help individuals take necessary precautions and be alert to potential disasters. However, predicting tornadoes and issuing accurate warnings for small-scale and short-duration events remains a challenging task in meteorology. It requires well-equipped infrastructure, skilled human resources, and advanced forecasting systems to provide accurate, timely, reliable, and detailed forecasts of such extreme weather events.

Conclusion

Tornadoes are natural disaster that cannot be stopped. However, their impacts can be reduced through various measures. While accurate and timely severe weather forecasting is an important component, it is not sufficient on its own. Developing a comprehensive severe weather forecasting system is crucial in order to effectively reduce the impact of tornadoes. This system should take into account various factors such as the size and speed of the tornado, heating patterns from the land, latent heat released within the atmosphere, local geography and altitude, seasons, and surface features. Dry air plays a significant role in the formation of tornadoes. Areas with low atmospheric pressure at sea level tend to have more tornadoes, as air flows from regions of higher pressure to lower pressure. This is one of the reasons why the frequency of tornadoes is higher in regions like the United States and Europe compared to Asia. To mitigate the effects of tornadoes, it is important to develop awareness activities that help people understand the climatic conditions of their environment. This can enable individuals to be more alert and take appropriate precautions in the face of potential disasters. However, it can be more challenging to issue timely warnings for small and short-duration tornado events, making

tornado warning one of the most difficult tasks in meteorology. Reducing the impact of tornadoes requires a multi-faceted approach that includes not only accurate forecasting but also effective communication, preparedness, and infrastructure planning. By combining these efforts, it is possible to minimize the loss of life and property caused by tornadoes.

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