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Enhancing Disaster Awareness - SDG 13th Goals Mid-term Review of Disaster Impact Global Natural Disaster Reduction Effectiveness Before and After the 2015 Sendai and Paris Agreement Conferences

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Abstract

The IPCC AR5 WGIhighlighted four priority areas for disaster risk reduction, with the first being the understanding of disaster risk. Meanwhile, the Earth is increasingly responding to climate change through natural disasters.This study proposes a Natural Disaster Impact Evaluate Formula （NDIEF）, focusing on six continents and utilizing data from 12 types of natural disasters recorded in the CRED EM-DAT database. The analysis is divided into two periods, before and after 2015, to evaluate changes over time.First, the frequency of natural disasters continues to rise. Second, although the number of fatalities has significantly decreased, both exposure levels and economic losses have surged. Lastly, unlike the 2011 Global Assessment Report （GAR）, this study finds that the impact of natural disasters is not only severe in Oceania and island nations but is also increasingly affecting North America, particularly in terms of economic damage.In conclusion, enhancing our understanding of the social and economic impacts of natural disasters and raising awareness of disaster prevention can play a crucial role in effectively mitigating disaster risks.

Keywords: *IPCC, CRED EM-DAT, Natural Disasters, Disaster Prevention Awareness, Disaster Risk Reduction.*

Introduction

The benefits of civilization and technological advancements over the past century have come at a significant cost—often at the expense of ecological balance. This imbalance has led to global warming, prompting Mother Earth（GAIA）to engage in self-regulation through natural disasters and calamities. These events have compelled humanity to finally recognize the critical importance of sustainability.

The IPCC's Fifth Assessment Report（2014）confirmed that human activities are the primary drivers of global warming. As the severity and risk of disasters continue to grow, the global community reached a consensus in 2015 through the Sendai Framework for Disaster Risk Reduction and the Paris Agreement, aiming to limit global temperature rise to within 1.5°C by 2030. Since then, nations have been actively pursuing energy conservation, carbon reduction, and disaster risk reduction （DRR） initiatives. However, as of October 2023, questions remain about the effectiveness of these efforts. This paper evaluates the impact of natural disasters as a tool for conducting an interim review of the Paris Agreement's effectiveness.

While disaster research typically focuses on the causes and environmental aspects of disasters from a micro perspective, this study adopts a macro perspective, analyzing the impact of disasters across the six continents. The goal is to determine whether DRR efforts have truly been effective or if they remain largely rhetorical.

Research Background

In harsh environmental conditions, species have only three options: to migrate, adapt, or face extinction. Demographer Thomas Robert Malthus（1798）famously argued that the pressure of population growth

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would inevitably surpass the Earth's ability to sustain humanity. However, following the Industrial Revolution around 1900, humanity experienced a dramatic increase in productivity, leading to abundant food supplies, improved living standards, and a significant reduction in mortality rates. As a result, the global population skyrocketed from 1.65 billion in 1900 to 8 billion in 2022.

This begs the question: Has the Earth's capacity been exceeded, leading to global warming ?

Climate change, once considered an uninteresting and chaotic topic, has now become central to human survival, which depends on sunlight, temperature, air, water, and food—each interdependent. Since 1989, the UNFCCC has held numerous conferences to investigate the causes of global warming. On December 12, 2015, at COP 21, 196 countries signed the Paris Agreement, the first international climate accord, which was formally signed in April 2016 and came into effect in November of the same year. The agreement aims to limit global temperature rise to below 2°C above pre-industrial levels, with efforts to cap the increase at 1.5°C.

However, according to observational data from NASA, along with organizations such as NOAA, the Berkeley Earth Research Group, the Met Office Hadley Centre, and the Cowtan and Way Analysis, global land and ocean temperature anomalies （Figure 1） show that as of October 2023, the global temperature anomaly has reached 1.43°C, with a 60-month mean. The 1.5°C threshold is now perilously close.

Figure 1. Global Land and Ocean Temperature Changes

（*From* ； *NOAA, Climate Monitoring*）

Research Motivation

The IPCC SR15 （2018） emphasized the critical need to limit global temperature rise to 1.5°C by 2030, alongside the growing severity of natural disasters. However, according to NOAA's Global Time Series data, the global average temperature had already reached 1.44°C by September 2023. This raises important questions: Are current disaster mitigation efforts proving ineffective, or must we further intensify these measures?

The IPCC AR5 WGI （2013-14） highlighted the significant impact of human activities on global climate warming. Since the adoption of the Sendai Framework for Disaster Risk Reduction on March 18, 2015, disaster risk reduction has been a shared priority among participating nations. The framework sets out four key priorities to be achieved by 2030:

- Understanding Disaster Risk

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- Strengthening disaster risk governance
- Investing in disaster risk reduction;

Enhancing disaster preparedness and promoting resilient recovery, rehabilitation, and reconstruction.

Recognizing the harm caused by natural disasters is a fundamental aspect of awareness. This study is driven by the need to answer crucial questions: Which natural disasters have the most significant impact? Which natural disasters are prevalent in human habitats? How can we objectively measure the influence of various natural disasters? These inquiries form the basis of this research on the impact of natural disasters.

Note:Hazard: Indicates the potential for causing disaster but has not yet reached the disaster threshold.

Disaster: Refers to a hazard that has reached the CRED threshold and has resulted in actual disaster events.

Research Objectives

Since 2015, has global awareness of climate change and disaster consciousness truly improved, or has it become mere rhetoric? This study interprets natural disasters as Earth's self-regulatory mechanisms in response to human impact. The research aims to analyze the impact of disasters across various geographical regions by examining changes in risk perception and conducting diagnostic assessments, ultimately providing a mid-term evaluation of disaster risk reduction efforts from 2015 to 2030.

Global research on natural disasters is relatively limited. However, with the ongoing climate changes, the nature and threats of natural disasters are evolving, diverging from their traditional classifications. In light of this, and with the aim of raising global disaster awareness, this paper adopts a top-down global approach to analyze natural disasters worldwide (Noor et al., 2022).

Focusing on the key goals of SDG Target 13.1, which include the number of deaths, exposure to disasters, and economic losses as critical indicators, this study seeks to identify the shifts in disaster impact across the six continents. The disaster impact function （F） is defined as:

$$F = (\mathbf{D, Exp, P.L}),$$

where D represents Death, Exp represents Exposure, and P.L represents Physical Loss.

The sample periods are defined as follows: 2003–December 2014, January 2015–October 2023

The objective function to measure the difference between these two periods is defined as:

$$diff = F_2 - F_1$$

This analysis aims to evaluate the differences in disaster impact between the pre- and post-2015 periods, thereby assessing whether the efforts under the Sendai Framework for Disaster Risk Reduction and the Paris Agreement have led to effective energy conservation and carbon reduction.

Scope and Subjects of the Study

This study builds upon the findings of the CRED REPORT （2004） and serves as an interim evaluation of the Paris Agreement for the period 2015–2030.

Baseline Group : December 2003 – December 2014

Observation Group : January 2015 – October 2023

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The purpose of this setup is to enable a comprehensive assessment of changes by 2030 during the final evaluation phase.

Subjects of the Study: The research focuses on the six continents, excluding Antarctica. The analysis is conducted using Microsoft Excel 2019 and PivotTable calculations.

The subsequent Chapter 2 will review the literature on disaster-related factors, including definitions and categories of disasters, disaster terminology, the EM-DAT database, data statistics, and research methods. Chapter 3 will cover the research model and design, while Chapter 4 will present verification and analysis, followed by conclusions and recommendations for future research.

Literature Review

The factors influencing climate change are highly complex, and the impacts of climate on global and regional scales vary significantly. This paper evaluates the effectiveness of the 2015 Paris Agreement by establishing geographic regions based on their attributes. The study begins by defining and categorizing disasters, followed by a statistical analysis of the frequency and intensity of disaster events before and after the Paris Agreement. A retrospective study approach is then employed for comparative analysis.

Due to the Earth's complex and uneven terrain, it is impossible to divide the globe into perfectly equal regions. Antarctica is excluded from this study because of its sparse permanent population. Furthermore, while the EM-DAT database classifies the Americas as a single region, this study divides the data into two distinct regions: ***North America***（comprising the United States, Canada, and Bermuda）and ***Latin America***（south of the United States）. This distinction is made to avoid potential biases, given that the Americas span both hemispheres.

The CRED's EM-DAT database categorizes natural disasters into five domains:

Biological 2.Climatological 3.Geophysical 4.Hydrological 5.Meteorological

Since this paper does not focus on any single domain of disasters, it does not conduct an in-depth analysis of each domain. Instead, disaster types are used as the observational variables.

The following sections will review the literature on the Sendai Framework for Disaster Risk Reduction, the definitions and categories of natural disasters, EM-DAT terminology, the EM-DAT database, and research methods.

Sendai Framework for Disaster Risk Reduction

Since the 2015 Sendai Framework for Disaster Risk Reduction（SFDRR）conference, a solid foundation has been established for global disaster risk reduction efforts. The Sendai Framework outlines four priority actions: *first,* understanding disaster risk; *second*, strengthening disaster risk governance; *third*, investing in disaster risk reduction; and *fourth*, enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction. This paper begins by addressing the understanding of disaster risk, shifting the focus from a regional to a global perspective to provide insights into disaster risk exposure and probability. The rationale behind this approach is that increased awareness leads to better psychological preparedness, allowing individuals and communities to effectively face and mitigate natural disasters, thereby reducing their threats.

The Sendai Framework sets forth seven global targets:

- Substantially reduce global disaster mortality.

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- Substantially reduce the number of affected people.
- Reduce direct disaster economic losses.
- Reduce damage to critical infrastructure and disruption of basic services.
- Increase the number of countries with national and local disaster risk reduction strategies.
- Enhance international cooperation with developing countries.
- Increase the availability and accessibility of multi-hazard early warning systems and disaster risk information.

The first four targets specifically emphasize reducing the human and economic impacts of disasters.

As previously mentioned, this paper aligns with Target 13.1 of SDG 13, evaluating the number of disaster-related deaths, affected people, and direct economic losses as key metrics. Finally, the study assesses the severity of these impacts to understand changes in disaster outcomes over time.

Definitions and Categories of Disasters

According to the Intergovernmental Panel on Climate Change （IPCC） AR5 report （FILED *et al.*, 2014）, three elements are necessary for risk to materialize:

Hazard: A potential natural or anthropogenic physical event or trend, or a physical impact.

Exposure: The degree to which human systems are subject to the influence or impact of such factors.

Vulnerability: The degree to which a system is susceptible to negative impacts.

Vulnerability encompasses multiple concepts, including sensitivity, susceptibility to harm, and lack of capacity to cope and adapt.

When these three elements are present, a risk event occurs. If the impact or damage of a risk event surpasses a threshold, it results in a disaster. The Centre for Research on the Epidemiology of Disasters CRED, 2004） defines a disaster as “an unpredictable, high-severity event or situation that exceeds the affected area's capacity to cope and requires external assistance.” The EM-DAT database constructed by CRED sets four criteria for defining a disaster:

- At least 10 deaths.
- At least 100 people affected.
- A call for international assistance.
- Declaration of a state of emergency.

G. Shen & S. Hwang （2019） analyzed natural disasters from 1900 to 2015 using EM-DAT data, focusing on geography, meteorology （short-term）, hydrology, climatology （long-term）, and biology. Their research examined the top 30 countries in terms of deaths, injuries, affected populations, and losses. Regina

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Below *et al.,*（2009） defined a disaster as a sudden or abnormal event or situation that exceeds the affected area's capacity to cope and requires national or international external assistance, leading to significant losses or damage. David J. Frame *et al.,*（2020） described disasters as hazard events that, through the interaction of exposure and vulnerability, cause one or more types of losses or damages to human, material, economic, and environmental assets within communities or societies of varying scales.

In summary, scholars generally agree on the following aspects of disasters:

- They are hazardous events or types.
- They exceed the affected society's capacity to cope. The severity of a disaster depends on exposure and vulnerability.
- They are often unpredictable.
- They result in significant losses and damages.
- They often require international assistance.

EM-DAT and Terminology

The definitions of disaster terminology often differ between the insurance industry and the academic community. To avoid confusion, the CRED and Munich Reinsurance Company published the "Disaster Category Classification and Peril Terminology for Operational Purposes" in 2009, which standardized all disaster-related terminology. Consequently, to prevent misinterpretation, this paper primarily references literature published after 2009.

The EM-DAT database categorizes disasters into two main groups: natural and technological. Originally, the database divided regions into five continents, but for this study, it is divided into six continents, as previously explained. The database includes data from 216 countries and categorizes disasters into 12 types（excluding extraterrestrial impacts） and 42 subtypes. This paper focuses solely on the impact of natural disasters, using disaster types as research variables. The natural disaster types include: ***Drought, Flood, Earthquake, Epidemic, Extreme temperature, Volcano*, *Glacial lake outburst flood*（GLOF）, *Infestation, Mass movement*（wet）, *Mass movement*（dry）, *Storm*, and *Wildfire*.** These categories are based on the "triggering hazard/event" principle.

Natural disaster events can be broadly categorized into four types based on their predictability and the degree to which they can be prepared for :

- *Black Swan Events*: Unpredictable and unpreparable disasters.
- *Gray Rhino Events*: Predictable but often ignored, leading to insufficient preparation.
- *Mermaid Events*: Predictable events with clear signs allowing for early preparation.
- *Meerkat Events*: Events with low predictability but high preparedness potential Additionally,

The EM-DAT database includes three key data points for post-disaster analysis: the number of deaths, the number of affected people, and adjusted economic losses. These are defined as follows:

- *Number of Deaths （Killed）: The total number of confirmed deaths and those presumed dead, including missing persons.*

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- *Number of Affected People （Affected）: The number of people requiring immediate assistance during an emergency, including those needing relocation and evacuation.*

- *Physical Damage （Damage）: Economic data on global disaster impacts, measured in US dollars and adjusted for accuracy.*

For the purposes of this study, these three metrics are used to represent the components of the objective function （F） for each period: Death, Exposure, and Physical Loss.

Notes

Black Swan and Gray Rhino events have been defined in existing literature.

Mermaid events are observed by Nordic fishermen as signs of impending sea storms.

Meerkat events are named after the highly vigilant animals of the grasslands, symbolizing events that require high alertness.

EM-DAT Database

The EM-DAT database, developed by CRED, compiles information from the United Nations, non-governmental organizations, reinsurance companies, and research institutions. It covers data from 1900 to the present, with over 20,000 disaster records collected to date （as illustrated in Figure 2）.

The statistical data and adjustments related to various natural disasters are discussed in the following subsections.

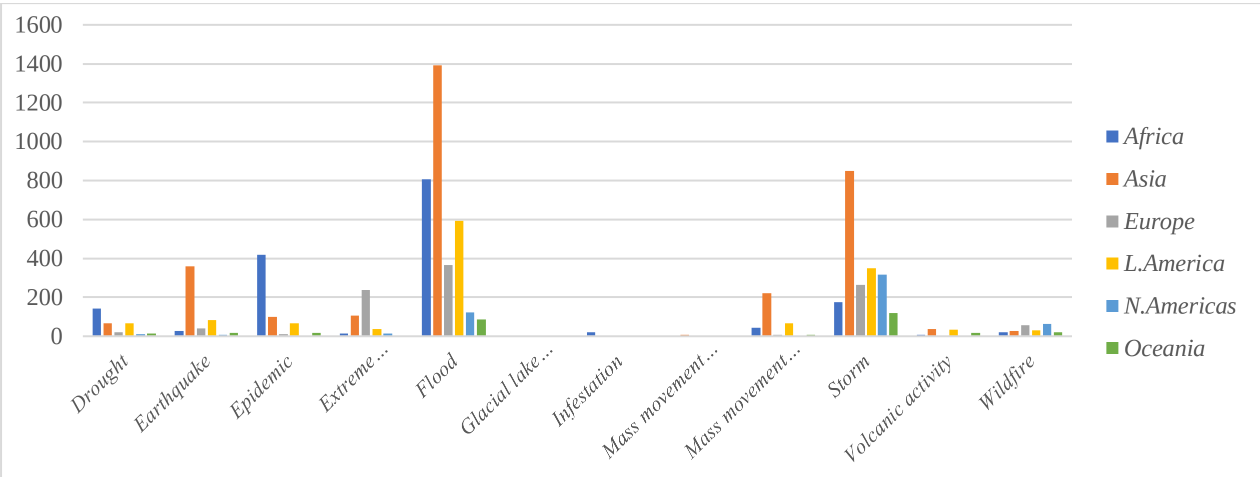

Figure 2. Number of Natural Disasters in Six Global Regions （2003-2023）

Statistical Data Before and After the Sendai Conference

From January 2003 to December 2014, spanning a total of 144 months, there were 4,850 recorded disasters. The probability of disasters before the Sendai Conference is calculated as 4,850/144 = 33.68 events per month, as shown in Table 1.

From January 2015 to October 2023, covering 106 months, there were 3,444 recorded disasters. The probability of disasters after the Sendai Conference is calculated as 3,444/106 = 32.49 events per month.

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The ratio of the periods is 106/144 = 0.736. Based on this ratio, the estimated number of natural disasters from 2015 to October 2023 would be 3,570 events.

However, according to EM-DAT, only 3,444 disasters occurred during this period, suggesting a potential improvement in disaster management effectiveness.

Table 1. Statistics of Natural Disasters in Different Regions Before and After 2015

Region	*Africa*		*Latin.Americas*		*N.Americas*		*Asia*		*Europe*		*Oceania*		*Total*	
Disaster types \ Periods	2003-2014/Dec	2015-2023/Oct	2003-2014/Dec	2015-2023/Oct	2003-2014/Dec	2015-2023/Oct	2003-2014/Dec	2015-2023/Oct	2003-2014/Dec	2015-2023/Oct	2003-2014/Dec	2015-2023/Oct	2003-2014/Dec	2015-2023/Oct
Drought	79	***64***	44	***22***	5	***6***	37	***30***	12	***8***	4	***11***	181	***141***
Earthquake	22	***5***	48	***36***	5	***3***	225	***156***	22	***19***	11	***8***	333	***227***
Epidemic	323	***103***	47	***20***	2		71	***32***	10		8	***8***	461	***163***
Extreme temperature	4	***9***	35	***1***	12	***6***	69	***43***	159	***78***	2	***1***	281	***138***
Flood	489	***339***	321	***301***	77	***50***	812	***622***	241	***134***	56	***35***	1996	***1481***
Glacial lake outburst flood	0	***0***	0	***0***	0	***0***	0	***3***	0	***1***	0	***0***	0	***4***
Infestation	14	***8***	0	***0***	0	***0***	0	***2***	0	***0***	1	***0***	15	***10***
Mass movement (dry)	1	***0***	2	***0***	0	***0***	4	***2***	0	***1***	1	***0***	8	***3***
Mass movement (wet)	14	***31***	40	***29***	2	***1***	143	***89***	3	***9***	6	***3***	208	***162***
Storm	100	***85***	207	***151***	170	***153***	489	***390***	156	***123***	70	***55***	1192	***957***
Volcanic activity	6	***3***	22	***14***		***1***	25	***14***	1	***1***	10	***8***	64	***41***
Wildfire	11	***9***	15	***15***	32	***35***	11	***18***	31	***31***	11	***9***	111	***117***
Total :	1063	***656***	781	***589***	305	***255***	1886	***1401***	635	***405***	180	***138***	4850	***3444***

The ratio of probabilities between the two periods is 33.68/32.49. The frequency of disaster occurrences decreased by approximately 1.2 events per month. Does this indicate that all signatory countries are actively working towards disaster reduction? However, the most significant reduction is observed in epidemic-related disasters. This raises the question: Is this reduction due to technological advancements that make it easier to mitigate the impact of epidemics, thereby reducing vulnerability or exposure and effectively lowering the number of such disasters? If we exclude the 298 instances of reduced epidemic-related disasters, the ratio becomes 33.68/35.3, indicating a slight increase in other types of natural disasters.

As shown in Table 1, ***floods*** and ***storms*** have the highest frequency of occurrences. ***Glacial lake outburst floods*** （***GLOF***） are emerging as a new type of disaster. ***Epidemic*** occurrences have decreased the most, especially in ***Africa***. However, post-2015, **drought** occurrences in ***North America*** and ***Oceania*** have surpassed previous period data. Asia remains a hotspot for disasters.

Data Adjustments

This study follows the EM-DAT data fields, using regions to represent continents. While the EM-DAT database continues to use the traditional geographic division of five continents, the following adjustments have been made to present a more accurate analysis:

- In the original data file, the *Americas* included both *North* and South America, but they are affected differently by natural climates. Therefore, the original region has been split into *North American* and *Latin American* groups. The United States, Bermuda, and Canada belong to the former, while the remaining countries are classified under ***Latin America***. Thus, this study will analyze six continents as sample subjects.
- From 2003 to 2023, there were 46 droughts, 19 epidemics, and 1 flood that spanned multiple periods, making them difficult to categorize. However, they are still included in the analysis.
- The 2014 Niger hippo incident, although classified as a biological event, has an unclear cause and is therefore excluded from this study. The incident resulted in the deaths of 12 children.

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- This study focuses on natural disaster changes; hence, the 2013 extraterrestrial （E.T.） event, being an external factor to Earth, is excluded from the sample count, and the related impact is removed from the database.
- Infestations, such as insect plagues and locust swarms, are biological disasters that can devastate vegetation. Due to their significant impact, these events are included in the analysis.
- Some records were originally in French and Portuguese; these have been translated into English for consistency in statistical analysis.

Research Methods

The six continents, each afflicted by various natural disasters, can be likened to patients with different symptoms. Therefore, this study adopts a medical approach to diagnose the conditions of the six continents. It examines whether there have been changes in the disaster situations compared to the previous period. The study aims to assess whether global adherence to the Sendai Framework for Disaster Risk Reduction, following the Paris Agreement, has been effective in disaster prevention and whether there have been observable results.

Risk

In the medical field, risk assessment often involves rating and scoring systems, dimensional calculations, and matrix formation. Methods such as FEMA, VHA, and RCA analyze and categorize risks, assess them, and then determine treatment priorities.

Common formulas include Risk（R） = Probability（P）* Severity（S） or Risk Priority Number （RPN） = Severity（S）* Occurrence（O）* Detection（D）. However, these models can be influenced by subjective human perceptions, making impartial assessments challenging.

This study adopts the case-control study（CCS）method from the medical field to compare data from before and after the study periods. It uses the odds ratio （OR）to evaluate and understand changes in the impact of different disaster types on each continent between the periods. By objectively assessing the probability of disaster occurrence, the study aims to measure disaster impact based on three main criteria: number of deaths, number of affected people, and amount of economic loss.

Therefore, the estimation of disaster impact will focus on these three criteria to align with the 13.1 target of SDG 13. The study will first analyze each criterion separately and then integrate their product to interpret the overall severity of natural disasters.

Case-Control Study Method

The case-control study （CCS） method is a retrospective research approach. It examines the presence or absence of disease outcomes by comparing the conditions of a control group and an observation group. This method identifies differences in disease occurrence and pre-disease risk factors between the two groups, with one serving as the control group and the other as the observation group.

Typically, this method compares individuals with a disease to those without, dividing them into groups of patients who received treatment and those who did not. The effectiveness of the treatment is then observed to determine the efficacy of the intervention. The advantages of CCS include its speed, cost-effectiveness, and efficiency, allowing for quick results. Although its credibility may be questioned, it remains widely used in the medical field due to successful case applications.

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A. Yari *et al.*, (2021, 2022) employed CCS to investigate flood-related mortality. Lu *et al.,* (2021) used CCS to study the changes ten years after the Wenchuan earthquake. L. Fontanesi *et al.,* (2023) applied it to research the sex ratio at birth following disasters. These examples demonstrate that CCS is also suitable for studying natural disasters.

Odds Ratio

The odds ratio (OR) compares the occurrence of a certain event to its non-occurrence within a group. In CCS, the OR is used to express the ratio of the occurrence of a certain event (such as a disease) in the experimental group compared to the control group.

When applied to natural disaster research, the OR can be interpreted as the ratio of disaster occurrence in exposed groups compared to non-exposed groups. In this study, natural disasters are viewed as conditions affecting the continents, and the OR is used to estimate the likelihood of disaster occurrence relative to non-occurrence.

Summary

Based on the literature review, the summary of the key points is as follows:

- *Fatality* : One of the key thresholds of a disaster. This study uses the number of deaths as a target metric.
- *Exposure*: The number of people affected by a certain natural disaster in a specific location and period.
- *Vulnerability*: This study uses physical loss as a substitute for vulnerability.
- *Severity* (S): Represented as Severity = Exposure * Vulnerability * Fatality Rate.
- Disaster Impact: The sum of all types of disasters, calculated as the probability of each disaster type multiplied by its severity.
- Odds Ratio (OR): Used to compare the ratio of the occurrence of a certain event (number of affected individuals) to the non-occurrence in two groups. It represents the risk of the observation group relative to the control group.
- *Objective Evaluation of SDG 13.1 Target*: This approach allows for a more objective assessment of the SDG 13.1 target.

Research Methods

The six continents are viewed as six individual patients, each with distinct geographical characteristics and varying levels of disaster impact and improvement. This study first formulates research hypotheses and then explains the research design. Each continent is treated as a patient, and the case-control study method is used to outline the research framework. The impact calculation equation and parameter estimation are developed, followed by the final calculations

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Problem Definition

Is the global community adhering to the Paris Agreement and the Sendai Framework for Disaster Risk Reduction（2015）? How can we assess the impact of natural disasters on different regions of the world and conduct a mid-term evaluation of disaster reduction effectiveness under climate change? This involves analyzing hazard（Hazard）, fatality（number of deaths）, exposure（Exposure）, affected population（number of people affected）, and vulnerability（Vulnerability）or loss degree across continents to measure the impact of natural disasters. Finally, an overall assessment is conducted based on disaster severity.

Research Framework

- Data Source: The EM-DAT database serves as the primary data source. However, this database may undergo post-event adjustments, leading to minor sample size discrepancies.
- Disaster Definition: Disasters are defined according to EM-DAT thresholds.
- Timeframe: The study period is divided with January 2015 as the boundary. The baseline period（control group）is from January 2003 to December 2014, and the observation period is from January 2015 to October 2023, serving as a mid-term evaluation for the period 2015-2030.

Therefore, the research framework is as illustrated in Figure 4.

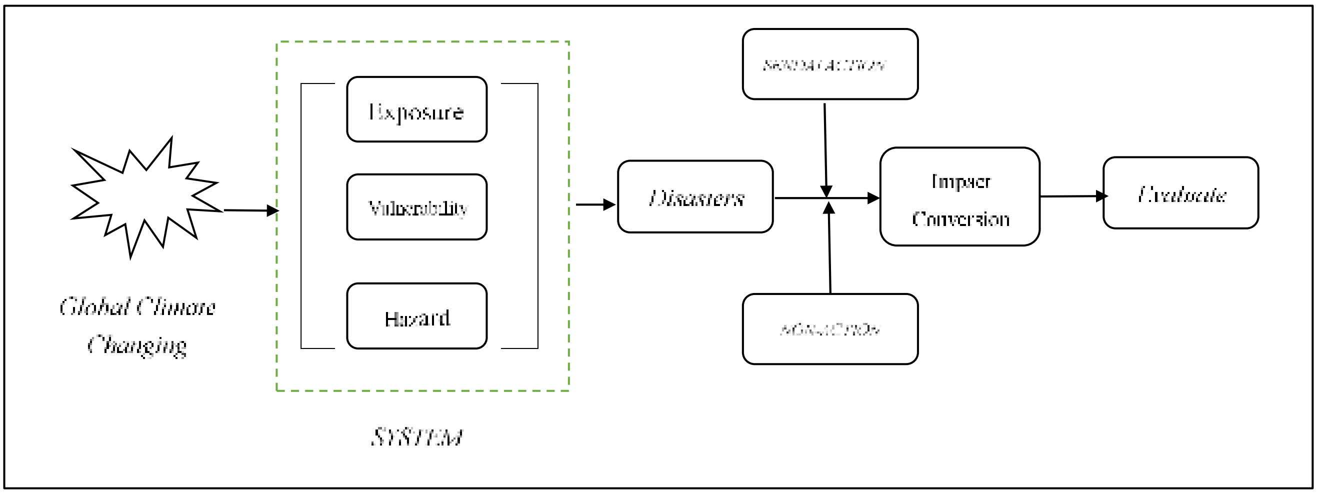

Figure 3. Research Framework

Research Hypothesis

This study adopts a retrospective research approach, with two conditions:

- Treatment behavior has been implemented.
- Results have emerged.

In the context of this study, the treatment refers to the Sendai Framework for Disaster Risk Reduction（DRR）, and the results refer to the current data on natural disasters. The research hypotheses are as follows :

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- Since the approval of the ***Sendai Framework for Disaster Risk Reduction*** on March 18, 2015, DRR has become a global consensus, leading to proactive measures.
- Human-induced factors are excluded; the focus is on the impact of natural disasters.
- Natural disasters are viewed as Gaia's （Mother Earth's） self-regulating mechanisms.
- This study examines the regulatory effects on each continent from the perspective of the Earth itself, evaluating disaster events, death tolls, affected populations, and economic losses.

Variable Definitions

i： Period ： =1 indicates 2003-2014/Dec ； =2 indicates 2015-2023/Oct

j： Continent: =1indicates Africa ; =2 indicates Latin America ; =3 indicates North America ; =4 indicates Asia ,; =5 indicates Europe ; =6 indicates Oceania;

k : Disaster Type

=1 indicates ***Flood***（***Fd***）; =2 indicates ***Storm***（***Storm***）;

=3 indicates ***Earthquake***（***Eq***）； =4 indicates ***Drought***（***D***）;

=5 indicates ***Mass movement***（***dry***）（***mmd***）; =6 indicates ***Mass movement***（***wet***）（***mmw***） ;

=7 indicates ***Epidemic***（***Ep***）; =8 indicates ***Extreme temperature***（***E.t***）;

=9 indicates ***Wildfire***（***Wf***）; =10 indicates ***Volcanic activity***（***Vol.a***）;

=11 indicates ***Glacial lake outburst flood***（***GLOF***）;=12 indicates ***Infestation***（***inf***）

m : Measurement Dimension

m=1: Fatality Rate （measured in number of deaths）

m=2: Exposure （measured in number of affected people）

m=3: Adjusted Economic Loss （measured in USD/person）

Research Model

The impact of natural disasters is often studied by focusing on specific disaster types affecting local regions, while global studies are relatively rare. This paper seeks to establish a macro-level *Natural Disasters Impact Evaluation Formula* （NDIEF） using EM-DAT data and terminology. The objective is to interpret global changes in natural disasters and empirically translate their impact into quantifiable data.

The equation is as follows:

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Let $\boldsymbol{Y}$ represent the natural disaster impact on each continent for each period, and $\boldsymbol{x}$ represent the disaster variables.

x_{fd} =flood ; x_{storm}= storm ; x_{eq} =earthquake ; x_D =drought ;

x_{mmd} =mass movement (dry) ; x_{mmw} =mass movement (wet) ;

x_{ep} =epidemic ; $x_{E.t}$=ex-temperature ; x_{wf}=wildfire ; $x_{Vol.a}$ =volcanic activity ;

x_{GLOF} = glacial lake outburst flood (GLOF) ; x_{inf}=infestation ;

The influence (**Y**) can be represented by the following equation (1) :

$$\boldsymbol{Y_{ijkm}} = \sum \left(\prod_{i=1}^{2} \prod_{j=1}^{6} \prod_{k=1}^{12} \prod_{m=1}^{3} \boldsymbol{\alpha_{ijkm}} * \boldsymbol{x_{ijkm}} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$\boldsymbol{Y_{ijkm}}$:

represent the total impact of natural disaster *k* on category *m* in region (continent) *j* during period *i*.

$\boldsymbol{\alpha_{ijkm}}$:

represent the weight of natural disaster *k* on category *m* in region (continent) *j* during period *i*.

$\boldsymbol{x_{ijkm}}$:

represent the value of natural disaster *k* on category *m* in region (continent) *j* during period *i*.

3-6 Parameter Estimation

Given that each continent has a bounded scope and that events are independent with the number of occurrences within a unit of time being discrete and random, these events follow a Poisson distribution (λ) .

Common methods for parameter estimation include the Least Squares Method (LSM) and Maximum Likelihood Estimation (MLE) . The former is suitable for small samples, while the latter may overlook samples with low frequencies, such as new types of disasters.

This study adopts the PERT three-point estimation method. The advantage of this method is its ability to estimate values for low-frequency or new types of disasters, clearly identify peak values, and easily calculate the most likely values. The weights for each disaster are set as follows:

The Weights

= **[(Minimum Occurrences+4* (Average) +Maximum Occurrences) /6]*100%**

(the number of times the disaster occurs each month within a year) ……………. (2)

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Verification and Analysis

This study continues the research conducted by CERD and examines the implementation of the 2015 Sendai Framework for Disaster Risk Reduction and the Paris Agreement to determine whether countries have genuinely implemented substantial disaster reduction measures. Data on natural disasters from January 2003 to October 2023 was extracted from the EM-DAT database.

Using January 2015 as the dividing line, the period from January 2003 to December 2014 serves as the pre-implementation control group （i=1）, comprising a total of 144 months, while the period from January 2015 to October 2023 serves as the post-implementation observation group （i=2）, comprising a total of 106 months. The ratio of months between the two periods is 106/144 = 0.736. Therefore, data from 2015 onwards can be used to estimate whether the number of natural disasters from 2015 to October 2023 has increased or decreased.

A difference test of natural disasters was conducted on these two groups, evaluating hazard, exposure, per capita economic loss, and disaster severity to determine whether the disaster reduction efforts initiated in 2015 were effective or merely rhetorical.

Regional Population

As the model will use the three elements of risk—hazard, exposure, and vulnerability—for evaluation, it is necessary to include population statistics as the sample base. According to the Worldometer.com and PRB.org world population datasheets, the estimated total population for the six continents in October 2023 and 2014 are presented in Table 2 below.

Table 2. Population Numbers of Six Continents Worldwide （2014/2023）

（unit : million people）

Region \ Period	**2014**	**2023/oct**
Africa	1,136	1,460
Latin America & Caribbean	618	665
Northern America	353	379
Asia	4,351	4,753
Europe	741	742
Oceania	39	456

（*Data*；Worldometer.com & PRB.org）Compiled by the Author

Disaster Weights

The estimated values （a\alphaα）for each type of disaster（Disaster k）from equation （2） are applied to the natural disaster occurrences in the control group （i=1） and the observation group （i=2） across the six continents. The results are presented in Tables 3 and 4 below.

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Table 3. Weights of Natural Disasters in Six Continents （January 2003 - December 2014）

Disaster types \ Region		Africa	Latin -America	N. American	Asia	Europe	Oceania
Fd	*α1*	40.256	43.229	23.088	43.206	27.960	14.326
Storm	*α2*	9.537	35.914	51.374	25.310	24.649	17.868
Eq	*α3*	3.713	6.771	2.314	10.450	3.401	3.849
D	*α4*	6.067	7.953	2.923	1.854	1.889	1.786
mmd	*α5*	0.903	1.563		0.575		0.940
mmw	*α6*	1.388	5.816	1.522	7.254	1.360	2.600
Ep	*α7*	30.762	7.726	2.192	3.437	5.063	2.524
E.t	*α8*	0.903	8.478	5.882	5.049	26.675	1.880
Wf	*α9*	2.559	2.778	10.705	1.419	7.643	50.000
Vol.a	*α10*	1.174	3.854		1.447	1.360	3.289
GLOF	*α11*						
Inf	*a12*	2.739					0.940

（Compiled by the Author）

Table 4. Weights of Natural Disasters in Six Continents （January 2015 - December 2023）

Disaster types \ region		Africa	Latin -America	N.American	Asia	Europe	Oceania
Fd	*α1*	41.665	43.188	18.158	42.311	24.420	18.497
Storm	*α2*	11.499	28.624	54.082	24.514	21.771	30.649
Eq	*α3*	3.544	5.746	2.128	10.268	4.009	6.446
D	*α4*	9.615	5.107	4.894	2.812	3.594	8.757
mmd	*α5*				0.770	2.073	
mmw	*α6*	4.403	4.466	1.277	6.374	3.456	7.662
Epid	*α7*	14.341	3.735		3.696		8.854
E.t	*α8*	4.489	1.724	5.107	4.378	24.881	5.108
Wf	*α9*	2.646	4.473	13.077	1.668	11.650	6.932
Vol.a	*α10*	2.127	2.937	1.277	1.668	2.073	7.095
GLOF	*α11*				0.770	2.073	
Inf	*α12*	5.671			0.770		

（Compiled by the Author）

Dividing into two main groups （i=1 & i=2） and applying the weights to equation （1）:

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Control Group （i=1, Pre-Energy Conservation and Carbon Reduction）

i=1（2003/jan-2014/dec）Disaster Impact；

Y_{11} =40.256* X_{fd} + 9.537* X_{storm} + 3.713* X_{eq} + 6.067* X_D + 0.903* X_{mmd} + 1.388*X_{mmw}+30.762*X_{ep}+0.903*$X_{E.t}$+2.559*X_{Wf}+1.174*$X_{Vol.a}$+0*X_{GLOF} +

2.739* X_{inf} ………………………………………………….. （1-11）

Y_{12} =43.229* X_{fd} +35.914* X_{storm} + 6.771 * X_{eq} + 7.953* X_D + 1.563* X_{mmd} + 5.816*X_{mmw}+7.726*X_{ep}+8.478*$X_{E.t}$+2.778*X_{Wf}+3.854*$X_{Vol.a}$ +0*X_{GLOF} +

0* X_{inf} …………………………………………………………（1-12）

Y_{13} =23.088* X_{fd} +51.374* X_{storm} + 2.314 * X_{eq} + 2.923* X_D + 0* X_{mmd} + 1.522* X_{mmw} +2.192* X_{ep} +5.882* $X_{E.t}$ +10.705* X_{Wf} +0* $X_{Vol.a}$ +0* X_{GLOF} + 0* X_{inf} ……………………...…………………………………（1-13）

Y_{14} =43.206* X_{fd} +25.310* X_{storm} + 10.450 * X_{eq} + 1.854* X_D + 0.575* X_{mmd} + 7.254* X_{mmw} +3.437* X_{ep} +5.049* $X_{E.t}$ +1.419* X_{Wf} +1.447* $X_{Vol.a}$ +0* X_{GLOF} + 0* X_{inf} ……………………………………………………………..（1-14）

Y_{15} =27.960* X_{fd}+24.649* X_{storm} + 3.401*X_{eq}+ 1.889*X_D + 0*X_{mmd}+

1.360* X_{mmw} +5.063* X_{ep} + 26.675* $X_{E.t}$ + 7.643* X_{Wf} + 3.854* $X_{Vol.a}$ +0* X_{GLOF} + 0* X_{inf} ………..…………………………………………..……………（1-15）

Y_{16} =14.326* X_{fd}+17.868* X_{storm} + 3.849*X_{eq}+ 1.786*X_D + 0.940*X_{mmd}+

2.600* X_{mmw} + 2.524* X_{ep} +1.880* $X_{E.t}$ + 50.000* X_{Wf} + 3.289* $X_{Vol.a}$ +0* X_{GLOF} + 0* X_{inf} ……..………………………………………………..……….（1-16）

Observation Group （i=2, after energy saving and carbon reduction）

（i=2） 2015-2023/Oct Impact ；（Energy Saving and Carbon Reduction Implemented）

Y_{21} =41.665* X_{fd} + 11.499* X_{storm} + 3.544* X_{eq} + 9.615* X_D + 0* X_{mmd} + 4.403* X_{mmw} + 14.341* X_{ep} +4.489* $X_{E.t}$ +2.646* X_{Wf} + 2.127* $X_{Vol.a}$ +0* X_{GLOF} + 5.671 * X_{inf}……………………………………………………………………………………（1-21）

Y_{22} =43.188* X_{fd} +28.624* X_{storm} + 5.746 * X_{eq} +5.107* X_D +0 * X_{mmd} + 4.466* X_{mmw} + 3.735* X_{ep} +1.724* $X_{E.t}$ +4.473* X_{Wf} +2.937* $X_{Vol.a}$ + 0* X_{GLOF} + 0* X_{inf} ……………………………………………………………………………………（1-22）

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Y_{23} =18.158* X_{fd} +54.082* X_{storm} + 2.128 * X_{eq} + 4.894* X_D + 0* X_{mmd} + 1.277* X_{mmw} + 0* X_{ep} +5.107* $X_{E.t}$ +13.077* X_{Wf} +1.277* $X_{Vol.a}$ +0* X_{GLOF} + 0* X_{inf} …………………………………………………………………………………… (1-23)

Y_{24} =43.311* X_{fd} +24.514* X_{storm} + 10.268 * X_{eq} + 2.812* X_D + 0.77* X_{mmd} + 6.374* X_{mmw} + 3.696* X_{ep} +4.378* $X_{E.t}$ +1.668* X_{Wf} +1.668* $X_{Vol.a}$ +0.77* X_{GLOF} + 0.77* X_{inf} …………………………………………………………………………………… (1-24)

Y_{25} =24.42* X_{fd} +21.771* X_{storm} + 4.009 * X_{eq} + 3.594* X_D + 2.073* X_{mmd} + 3.456* X_{mmw} + 0 * X_{ep} +24.881* $X_{E.t}$ +11.650* X_{Wf} +2.073* $X_{Vol.a}$ +2.073* X_{GLOF} + 0* X_{inf} …………………………………………………………………………………… (1-25)

Y_{26} =18.497* X_{fd} +30.649* X_{storm} + 36.446 * X_{eq} +8.757* X_D +0 * X_{mmd} + 7.662* X_{mmw} + 8.854* X_{ep} +5.108* $X_{E.t}$ +6.932* X_{Wf} +7.095* $X_{Vol.a}$ +0* X_{GLOF} + 0* X_{inf} …………………………………………………………………………………… (1-26)

Case Fatality Rate （CFR）

In medical terms, the Case Fatality Rate （CFR） refers to the proportion of individuals who die from a specific disease （event） within a certain period. In this study, the six continents are considered as patients, and various disasters are treated as diseases. Therefore, the population that dies due to various disasters is applicable to this cause-specific mortality rate （CSMR） definition. The CSMR is calculated as follows:

$$\textbf{CSMR}=\frac{(\textbf{(TOTAL DEATH)}k)\ ij}{(\textbf{total population})\ ij}=\frac{\sum_{i=1}^{2}\sum_{j=1}^{6}\sum_{k=1}^{12}\textbf{deaths}}{\sum_{i=1}^{2}\sum_{j=1}^{6}\textbf{population}\ (\textbf{in millions})}$$

Therefore, the impact of disaster mortality can be incorporated into equation （1）.

$$\textbf{Death impact}_{ij}$$

$$=\sum(a_1x_{fd}+a_2x_{storm}+a_3x_{eq}+a_4x_D+a_5x_{mmd}+a_6x_{mmw}+a_7x_{ep}+a_8x_{E.t}+a_9x_{wf}+a_{10}x_{vol.a}+a_{11}x_{GLOF}+a_{12}x_{inf})\ \ldots\ldots\ (3)$$

Hazard: Represented as the number of deaths due to a specific disaster within a certain period / the total population in the region during the same period （measured per million people）. The impact of deaths caused by various disasters is shown in Table 5.

Organized By the Author

As shown in Table 5, the impact of natural disasters on human mortality has significantly decreased to 32.22% since the Sendai Framework for Disaster Risk Reduction conference. The top three regions with the greatest reductions are:

Latin America, which saw a reduction to only 9.35%; ***Asia,*** which decreased to 17.7%; and ***Africa***, which decreased to 38.23%.

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Table 5. Mortality Impact of Various Disasters in Different Periods

2003-2014	*impact*	2015-2023/oct	*impact*	*diff Ratio*
Africa	1804.43	*Africa*	689.79	38. 23%
Latin America	3721.26	*Latin America*	347.93	9. 35%
N.American	658.59	*N.American*	344.07	52. 24%
Asia	2610.61	*Asia*	462.20	17. 70%
Europe	4983.42	*Europe*	2549.66	51. 16%
Oceania	551.97	*Oceania*	222.93	40. 39%
Summary :	14330.28	Summary :	4616.57	32. 22%
Death impact Ratio :				0.3222

Table 6. 2203-2014 & 2015-2023 /Oct Case of Death Statistics

P.m=People In million

Region	*P.m*	*Period*	*D*	*EQ*	*Ep*	*ET*	*FD*	*Glof*	*Inf*	*MM.D*	*MM.W*	*Storm*	*VOL.A*	*W.F*	*Total*
Africa	1,136	2003-2014/dec	20,242	3,294	51,077	75	8,086		-	98	620	1,752	6	128	85,378
	1,460	2015-2023/Oct	2,465	2,521	24,063	145	1,187		-		2,029	13,306	33	230	45,979
		Total	***22,707***	***5,815***	***75,140***	***220***	***9,273***	***-***	***-***	***98***	***2,649***	***15,058***	***39***	***358***	***131,357***
la. America	618	2003-2014/dec	4	223,932	8,207	2,139	10,127			48	1,207	7,158	23	64	252,909
	665	2015-2023/Oct	8	3,806	1,720	21	2,987				1,381	2,311	463	72	12,769
		Total	***12***	***227,738***	***9,927***	***2,160***	***13,114***	***-***	***-***	***48***	***2,588***	***9,469***	***486***	***136***	***265,678***
N. America	353	2003-2014/dec	-	3	43	477	343				58	4,290		76	5,290
	379	2015-2023/Oct	181	2		1,140	314				21	2,082	-	410	4,150
		Total	***181***	***5***	***43***	***1,617***	***657***	***-***	***-***	***-***	***79***	***6,372***	***-***	***486***	***9,440***
Asia	4,351	2003-2014/dec	134	452,695	5,065	7,943	50,287			117	8,243	171,360	436	69	696,349
	4,753	2015-2023/Oct	88	74,387	3,196	5,359	27,832	428	-	30	2,740	8,200	525	139	122,924
		Total	***222***	***527,082***	***8,261***	***13,302***	***78,119***	***428***	***-***	***147***	***10,983***	***179,560***	***961***	***208***	***819,273***
Europe	741	2003-2014/dec	-	355	1	136,815	1,064				16	416	-	249	138,916
	742	2015-2023/Oct	-	395		74,997	568	11		8	60	288	-	335	76,662
		Total	***-***	***750***	***1***	***211,812***	***1,632***	***11***	***-***	***8***	***76***	***704***	***-***	***584***	***215,578***
Oceania	39	2003-2014/dec	-	436	200	486	193		-	10	107	287	-	205	1,924
	46	2015-2023/Oct	24	198	83	-	74				33	188	25	36	661
		Total	***24***	***634***	***283***	***486***	***267***	***-***	***-***	***10***	***140***	***475***	***25***	***241***	***2,585***
World	7,238	2003-2014/dec	20,380	680,715	64,593	147,935	70,100	-	-	273	10,251	185,263	465	791	1,180,766
	8,045	2015-2023/Oct	2,766	81,309	29,062	81,662	32,962	439	-	38	6,264	26,375	1,046	1,222	263,145
		Total	***23,146***	***762,024***	***93,655***	***229,597***	***103,062***	***439***	***-***	***311***	***16,515***	***211,638***	***1,511***	***2,013***	***1,443,911***

（Statistic by author）

According to TABLE 6 - Case of death statistics:

The top three causes of disaster-related deaths before 2015 were: ***Earthquakes***（680,715 deaths）, ***Storms***（185,263 deaths）, and ***Extreme Temperatures***（147,935 deaths）.

After 2015, the leading causes of disaster-related deaths changed to :

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Extreme Temperatures （81,662 deaths）, ***Earthquakes*** （81,309 deaths）, and ***Floods*** （42,962 deaths）.

Disasters with increased mortality post-2015 include *earthquakes*, ***glacial lake outburst floods*** （*GLOF*）, ***volcanic activity***, and ***wildfires.*** A new type of disaster causing deaths is ***GLOF***, with 439 deaths reported in both ***Europe*** and ***Asia***. The regional statistics are as follows:

- † ***Latin America***: Earthquake-related deaths decreased from 223,932 before 2015 to 3,806 afterward.

- *Asia:* Earthquake-related deaths decreased from 452,695 before 2015 to 74,387 afterward.
- *Africa:* Epidemic-related deaths decreased from 51,077 to 24,063, while storm-related deaths increased from 1,752 to 13,306.
- North America: The highest mortality is from storms and extreme temperatures.
- *Europe*: Extreme temperatures caused 74,997 deaths, and floods caused 568 deaths post-2015.
- *Oceania*: New disaster types include drought （24 deaths） and volcanic activity （36 deaths）.

The impact ratio of disaster mortality is calculated as follows:

$$\Delta \mathbf{impact}_{Fatality} = 4616.574/14330.281 = 0.322$$

This indicates that the number of deaths due to natural disasters has significantly decreased since 2015. As shown in Table 6 :

Earthquake-related deaths decreased from 680,715 to 81,309.

Storm-related deaths decreased from 185,263 to 26,375.

Deaths due to e***xtreme temperatures*** decreased from 147,935 to 81,662.

Except for ***earthquakes***, which are considered black swan events and are unpredictable, the reduction in fatalities can be attributed to increased disaster awareness and technological advancements that enhance disaster resilience.

Before 2015, there was insufficient public awareness of the dangers posed by ***storms*** and ***extreme temperatures***, leading to higher fatalities. The subsequent reduction in deaths indicates improved public and governmental awareness of natural disasters and a deeper ingrained disaster prevention consciousness.

The distribution of disaster-related fatalities shows an even spread across ***earthquakes, extreme temperatures, floods, storms, landslides*** and ***wildfires***. Governments must pay special attention to disaster prevention and response measures for these hazards.

However, increased population numbers could introduce bias by inflating sample sizes. This is particularly relevant for regions like ***Africa*** and ***Asia,*** where population changes must be carefully considered during evaluations to avoid skewed results.

Disaster Exposure

In medicine, exposure generally refers to factors that influence the occurrence of diseases. Geographically, the continents are fixed and cannot relocate to avoid disasters, and their varying terrains result in different levels of disaster exposure across continents.

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This study focuses on disaster types and their impact on populations. Therefore, disaster exposure in this context is calculated based on population. The common formula for exposure is:

Exposure= Number of people affected by various disasters/Total population. Exposure: Represented as the number of people affected by a specific disaster within a certain period / the total population in the region during the same period （measured per million people）.

By incorporating the exposure levels of various disasters into equation （1）, we obtain:

Exposure impact $_{ij}$

$$= \sum \left(a_1 x_{fd} + a_2 x_{storm} + a_3 x_{eq} + a_4 x_D + a_5 x_{mmd} + a_6 x_{mmw} + a_7 x_{ep} + a_8 x_{E.t} + a_9 x_{wf} + a_{10} x_{vol.a} + a_{11} x_{GLOF} + a_{12} x_{inf} \right) \quad (4)$$

The impact of disaster exposure levels before and after 2015 can be incorporated to derive Table 7.

Table 7 shows that overall global exposure to natural disasters has increased by 13.14% since 2015. Significant increases are observed in ***North America, Oceania***, and ***Africa***. ***North America*** leads with a 595.23% increase in exposure, followed by ***Oceania*** at 422.54%, indicating exponential growth.

Table 7. Impact of Exposure to Various Disasters （January 2003 - December 2014）

2003-2014	*impact*	2015-2023	*impact*	*diff Ratio*
Africa	2.0815	*Africa*	2.6656	128.06%
Latin America	3.6610	*Latin America*	2.9565	80.76%
N.American	2.1026	*N.American*	12.5154	595.23%
Asia	12.9861	*Asia*	3.7913	29.19%
Europe	0.2347	*Europe*	0.0508	21.63%
Oceania	0.5991	*Oceania*	2.5314	422.54%
Summary :	21.6650	Summary :	24.5109	113.14%
Exposure (population affectived)				1.1314

Compiled by the Author

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Table 8. Exposure - Population Affected

Region	P.m	Period	D	EQ	Ep	ET	FD	Glof	Inf	MM.D	MM.W	Storm	VOL.A	W.F	Total
Africa	1,136	2003-2014/dec	159,648,046	393,788	1,790,962	7,613	32,167,941		2,800,000	697	35,618	3,815,141	297,500	15,241	200,972,547
	1,460	2015-2023/Oct	232,706,779	1,158,057	2,555,377	2,720,111	34,720,154		-		192,518	13,294,440	308,657	144,812	287,800,905
		Total	***392,354,825***	***1,551,845***	***4,346,339***	***2,727,724***	***66,888,095***	**-**	***2,800,000***	***697***	***228,136***	***17,109,581***	***606,157***	***160,053***	***488,773,452***
la. America	618	2003-2014/dec	44,930,620	9,571,442	2,382,839	5,365,199	29,796,192			3,028	107,565	13,521,037	465,740	144,648	106,288,310
	665	2015-2023/Oct	8,141,057	3,622,864	555,955	200,620	21,982,578				167,705	31,299,921	2, 869, 851	10,448,066	79,288,617
		Total	***53,071,677***	***13,194,306***	***2,938,794***	***5,565,819***	***51,778,770***	**-**	**-**	***3,028***	***275,270***	***44,820,958***	***3,335,591***	***10,592,714***	***185,576,927***
N. America	353	2003-2014/dec	-	9,672	237	31	11,452,875				165	9,139,447		770,598	21,373,025
	379	2015-2023/Oct		282		25	228,466				1,366	87,512,093	2,500	485,185	88,229,917
		Total	**-**	***9,954***	***237***	***56***	***11,681,341***	**-**	**-**	**-**	***1,531***	***96,651,540***	***2,500***	***1,255,783***	***109,602,942***
Asia	4,351	2003-2014/dec	255,200,602	80,489,735	931,389	85,508,737	1,059,703,667			360	3,307,866	353,349,213	632,263	25,135	1,839,148,967
	4,753	2015-2023/Oct	456,177,248	29,682,668	1,227,060	2,697,069	307,708,890	88,424	-		702,280	138,215,765	1,164,310	1,181,258	938,844,972
		Total	***711,377,850***	***110,172,403***	***2,158,449***	***88,205,806***	***1,367,412,557***	***88,424***	**-**	***360***	***4,010,146***	***491,564,978***	***1,796,573***	***1,206,393***	***2,777,993,939***
Europe	741	2003-2014/dec	1,278,769	239,418	28	621,557	4,319,390				160	988,173	-	1,169,787	8,617,282
	742	2015-2023/Oct	-	478,475		58,219	1,017,622			200	4,580	311,154	328	227,816	2,098,394
		Total	***1,278,769***	***717,893***	***28***	***679,776***	***5,337,012***	**-**	**-**	***200***	***4,740***	***1,299,327***	***328***	***1,397,603***	***10,715,676***
Oceania	39	2003-2014/dec	6,384	631,317	15,782	2,000	726,273		-		10,921	535,295	43,679	14,783	1,986,434
	46	2015-2023/Oct	2,736,884	573,014	9,835	-	384,373				100	2,547,110	128,704	11,248	6,391,268
		Total	***2,743,268***	***1,204,331***	***25,617***	***2,000***	***1,110,646***	**-**	**-**	**-**	***11,021***	***3,082,405***	***172,383***	***26,031***	***8,377,702***
World	7,238	2003-2014/dec	461,064,421	91,335,372	5,742,766	1,069,397,900	1,138,166,338	-	2,800,000	4,085	3,462,295	381,348,306	1,439,182	2,140,192	2,178,386,565
	8,045	2015-2023/Oct	699,761,968	35,515,360	4,348,227	5,676,044	366,042,083	88,424	-	200	1,068,549	273,180,483	4,474,350	12,498,385	1,402,654,073
		Total	***1,160,826,389***	***126,850,732***	***10,090,993***	***1,075,073,944***	***1,504,208,421***	***88,424***	***2,800,000***	***4,285***	***4,530,844***	***654,528,789***	***5,913,532***	***14,638,577***	***3,581,040,638***

（Statistic by author）

Table 8.（Exposure - Population Affected） provides the following details:

- ***Volcanic activity***（Vol.a） increased from 1,439,182 to 4,474,350 people.
- *Drought*（D） affected populations rose from 461,064,421 to 699,761,968 people.
- *Wildfires*（Wf） surged nearly sixfold from 2,140,192 to 12,498,385 people.
- *Glacial Lake Outburst Flood*（GLOF）, a new disaster type, affected 88,424 people.

Regional Analysis

Africa: The total affected population increased by 43.2% from the pre-2015 period. While insect ***infestations***（inf） and ***dry mass movements***（mmd） decreased, other disaster types saw significant increases. ***Extreme temperatures***（***E.t***） affected 2,720,111 people, a 3572-fold increase from 7,613. ***Storms*** grew by 3.5 times, ***landslides*** by 5.4 times, and ***wildfires*** by 9.5 times.

Latin America: The most significant increase was in *wildfire*（***Wf***） exposure, which soared from 140,000 to 10.45 million people. ***Volcanic activity***（***Vol.a***） increased from 460,000 to 2.87 million people. ***Storms*** affected 31.3 million people in the later period. Other disasters like ***drought***（8.14 million）, ***earthquakes***（3.62 million）, and ***floods***（21.98 million） had widespread impacts despite not increasing in frequency.

North America: The most impactful disaster was ***storms,*** affecting 87.51 million people post-2015. This significantly raised the overall affected population ratio to 4.128.

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Asia: A major disaster zone, with several disasters affecting over 100 million people post-2015: *drought* （450 million）, ***floods*** （310 million）, ***earthquakes*** （290 million）, and ***storms*** （140 million）. ***Wildfires*** （Wf） saw the highest growth, nearly 47 times, affecting around 1.18 million people. ***Volcanic activity*** （Vol.a） affected 1.16 million people, and ***GLOF*** impacted 88,424 people. Overall, the affected population ratio decreased to 0.51.

Europe: The most significant decrease in disaster impact was observed here, with the affected population ratio dropping to 0.244 post-2015. While ***floods*** and ***landslides*** increased, effective ***drought*** prevention reduced affected numbers to zero.

Oceania: Disasters impacted a diverse range of areas. The most severe was ***drought***, affecting 2.73 million people post-2015, followed by ***storms*** affecting 2.54 million. The substantial increase in ***drought*** exposure （428 times） raised the overall affected population ratio to 3.217.

Although global disaster-affected populations decreased after 2015, several disasters continued to affect over 100 million people, including ***droughts*** （in ***Africa*** and ***Asia***）, ***floods*** （in ***Asia***）, and ***storms*** （in ***Asia*** and ***North America***）. Additionally, ***earthquakes*** （in ***Asia***）, ***volcanic activity*** （in ***Latin America*** and ***Asia***）, and ***wildfires*** （in ***Latin America*** and ***Asia***） each affected over 10 million people. Notably, ***wildfires*** in ***Asia*** and ***Latin America*** surged 5.84 times post-2015. Overall, the exposure impact ratio increased slightly to 1.1314, indicating a marginal rise in disaster exposure impact.

$$: \Delta \mathbf{impact}_{exposure} = 21.665/24.5109 = 1.1314$$

Economic Per Capita Loss （Physical Loss）

The term "vulnerability" encompasses various abstract concepts. Many disaster studies measure economic vulnerability using GDP as the unit of analysis. However, as noted by Inez Primanti *et al.*, （2018）, the significance of GDP varies between wealthy and poor countries or regions. A 1% reduction in the GDP of a strong nation could offset the losses experienced by a weaker nation over many years. Additionally, the EM-DAT database includes "Total damage" and "Total Damage adjusted" columns. This study uses the "Total Damage adjusted" as the basis for calculating losses. Therefore:

$$\textbf{Physical impact}_{ij} = \sum \left(a_1 x_{fd} + a_2 x_{storm} + a_3 x_{eq} + a_4 x_D + a_5 x_{mmd} + a_6 x_{mmw} + a_7 x_{ep} + a_8 x_{E.t} + a_9 x_{wf} + a_{10} x_{vol.a} + a_{11} x_{GLOF} + a_{12} x_{\text{inf}} \right) \quad (5)$$

Economic Per Capita Loss （Physical Loss）: Represented as the amount of economic loss （in millions of USD） due to a specific disaster within a certain period / the total population in the region during the same period （measured per million people）. By incorporating the economic losses caused by various disasters into calculation formula （5）, the impact of disaster losses for the periods before and after 2015 is shown in Table 9.

Table 9. Economic Loss Impact of Various Disasters

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2003-2014	impact	2015-2023	impact	diff Ratio
Africa	251.507	Africa	369.552	146.94%
latin America	6,210.544	latin America	5,970.379	96.13%
N.American	96,976.013	N.American	96,832.577	99.85%
Asia	5,313.749	Asia	2,987.653	56.22%
Europe	5,763.766	Europe	2,809.291	48.74%
Oceania	19,966.806	Oceania	16,484.339	82.56%
Summary :	134,482.385	Summary :	125,453.791	93.29%
Damage (Physical Loss) :				0.933

Compiled by the Author

Table 10. Total Damage *Adjusted*

('000 US$)

Region	P.m	Period	D	EQ	Ep	ET	FD	Glof	Inf	MM.D	MM.W	Storm	VOL.A	W.F	Total
Africa	1136	2003-2014/dec	708,531	8,969,983			5,630,324					2,093,255		584,487	17,986,580
	1460	2015-2023/Oct	5,748,145	558,466			10,432,476				68,493	3,801,040	1,080,028	501,449	22,190,097
		Total	6,456,676	9,528,449	-	-	16,062,800	-	-	-	68,493	5,894,295	1,080,028	1,085,936	40,176,677
la. America	618	2003-2014/dec	11,325,187	55,142,377		1,906,781	24,448,858				1,136,557	63,818,994	353,066	599,516	158,731,336
	665	2015-2023/Oct	16,131,381	16,485,864		116,066	10,335,207				127,955	116,561,895	1,091,854	1,426,660	162,276,882
		Total	27,456,568	71,628,241	-	2,022,847	34,784,065	-	-	-	1,264,512	180,380,889	1,444,920	2,026,176	321,008,218
N. America	353	2003-2014/dec	39,044,669	1,418,054		5,093,556	42,814,420				24,724	640,176,991		19,431,802	748,004,216
	379	2015-2023/Oct	48,846,233	503,330			50,051,135				1,048,914	638,640,653	582,730	77,198,312	816,871,307
		Total	87,890,902	1,921,384	-	5,093,556	92,865,555	-	-	-	1,073,638	1,278,817,644	582,730	96,630,114	1,564,875,523
Asia	4351	2003-2014/dec	18,094,752	516,894,236		30,957,125	299,458,380			10,050	1,526,845	180,896,995	229,934	382,694	1,048,451,011
	4753	2015-2023/Oct	35,347,518	113,018,732		2,169,240	207,910,685	226,806			1,404,956	168,097,750	391,751	2,170,135	530,737,573
		Total	53,442,270	629,912,968	-	33,126,365	507,369,065	226,806	-	10,050	2,931,801	348,994,745	621,685	2,552,829	1,579,188,584
Europe	741	2003-2014/dec	10,883,722	26,465,370		22,038,422	75,548,426					54,790,033		14,351,184	204,077,157
	742	2015-2023/Oct	2,746,031	22,266,651		6,048,157	59,915,002				147,000	15,783,874	134,028	2,347,869	109,388,612
		Total	13,629,753	48,732,021	-	28,086,579	135,463,428	-	-	-	147,000	70,573,907	134,028	16,699,053	313,465,769
Oceania	39	2003-2014/dec	1,033,903	32,389,935			16,693,761					14,329,269		3,140,311	67,587,179
	46	2015-2023/Oct	1,478,687	4,826,591			16,223,723					12,263,263	118,000	3,021,743	37,932,007
		Total	2,512,590	37,216,526	-	-	32,917,484	-	-	-	-	26,592,532	118,000	6,162,054	105,519,186
World	7238	2003-2014/dec	81,090,764	641,279,955	-	59,995,884	464,594,169	-	-	10,050	2,688,126	956,105,537	583,000	38,489,994	2,244,837,479
	8045	2015-2023/Oct	110,297,995	157,659,634	-	8,333,463	354,868,228	226,806	-	-	2,797,318	955,148,475	3,398,391	86,666,168	1,679,396,478
		Total	191,388,759	798,939,589	-	68,329,347	819,462,397	226,806	-	10,050	5,485,444	1,911,254,012	3,981,391	125,156,162	3,924,233,957

（Statistic by author）

Based on the economic loss impact ratio for various disasters shown in Table 9, all regions except ***Africa*** have experienced a decrease. Further analysis from Table 10 reveals the financial losses （in USD） due to natural disasters in each region. Overall, there is a slight increase in total economic losses by 2.2%.

Regional Analysis

- *Africa:* Drought （D） losses grew nearly eightfold in the later period, with the highest loss amounting to $5.75 billion, followed by storms （Storm） at $3.8 billion. New disaster volcanic activity （Vol.a） resulted in losses of $1.08 billion, and floods caused $1.04 billion in losses.

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- *Latin America*: Post-2015, storms （Storm） caused the largest losses, totaling $116.5 billion. Earthquakes （Eq） resulted in $16.4 billion in losses, droughts （D） $16.1 billion, wildfires （Wf） $1.42 billion, volcanic activity （Vol.a） $1.09 billion, and floods （Fd） $1.03 billion.

- *North America:* Losses increased by 9.2%. The most devastating were storms, causing $638.6 billion in losses, followed by wildfires at $77.2 billion, floods at $50 billion, and droughts at $44.8 billion.

- *Asia:* The three major disasters were floods （$207.9 billion）, storms （$168 billion）, and earthquakes （$113 billion）. Wildfires increased 5.67 times, resulting in significant losses, and droughts grew 1.92 times, causing $35.3 billion in losses.

- *Europe:* Landslides （mmw） and volcanic activity （Vol.a） emerged with losses of $140 million and $130 million, respectively, while other disaster types saw a slight decrease.

- *Oceania:* Droughts increased by 1.43 times （$1.47 billion） and volcanic activity caused $118 million in losses. Overall, losses were only 0.561 times the amount of the earlier period.

Storms remain the disaster with the highest economic losses. However, the greatest growth in losses between the pre- and post-2015 periods was seen in ***volcanic activity*** （5.82 times）, *wildfires* （2.25 times）, ***droughts*** （1.361 times）, and ***landslides*** （1.04 times）. The overall economic loss ratio is 0.933.

Therefore, the physical economic impact ratio due to disasters is:

$$\Delta impact_{physcial} = 134{,}482.385/125{,}453.791 = 0.933$$

Disaster Severity

Disaster severity for various disasters before and after 2015 is calculated as:

$$Disaster\ Severity == (Fatality\ Rate * Exposure\ (Population\ Affected\ Ratio) * Economic\ Loss\ Rate\ (Per\ Capita\ Loss))$$

However, according to data from the World Meteorological Organization （WMO）, the estimated global temperature up to October 2023 was 1.4 ± 0.12°C. Conversely, the Berkeley Earth report on January 12, 2024, indicated that the average global temperature in 2023 was 1.54 ± 0.06°C.

As shown in Table 11, disaster severity increased in North America and Oceania, while the other four continents showed a decrease. Overall, the global disaster impact has decreased by two-thirds. Although regional disaster impacts fluctuate, there seems to be a general trend of reduced disaster impact worldwide.

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Table 11. Severity and Differences of Disasters in Two Periods

Region	*i=1*	*i=2*	*diff*
Africa	944,619.64	679,492.95	-265,126.69
Latin America	84,609,921.20	6,141,378.07	-78,468,543.13
N.American	134,289,241.33	416,971,932.43	282,682,691.10
Asia	180,145,100.91	5,235,329.82	-174,909,771.09
Europe	6,740,006.41	363,561.62	-6,376,444.80
Oceania	6,602,736.17	9,302,618.16	2,699,881.99
Summary :	41,752,066,211.23	14,195,896,841.50	-27,556,169,369.73

(Compiled by the Author)

Odds Ratio

The Odds Ratio (OR) represents the ratio of the number of people experiencing a certain event to those not experiencing the event. Since this study employs the case-control method, the OR is used to evaluate the odds of various disasters. The OR is calculated as follows:

OR = Control Group (*i*=1) /Observation Group (*i*=2)

The following sections will examine the OR for fatality rates, affected populations, economic losses, and severity in sequence.

Note: Some values are extremely small, and their decimal places are too minute to be displayed accurately; however, they are not zero. This distinction is important as it reflects their different implications.

Mortality Risk Ratio

Odds Ratio of Mortality Risk in Medicine

$$= \left(\frac{\frac{\text{Number of Deaths in Event } k}{\text{Total Population}}}{\frac{\text{Number of People Not Affected by Event } k}{\text{Total Population}}} \right)_{i=1} \Bigg/ \left(\frac{\frac{\text{Number of Deaths in Event } k}{\text{Total Population}}}{\frac{\text{Number of People Not Affected by Event } k}{\text{Total Population}}} \right)_{i=2} ;$$

Substitute to Obtain :

From Table 12, analyzing the odds ratio (OR) of death risks between the two periods, it is observed that during the observation period (*i*=2) , the death odds ratio increased for ***volcanic activity*** (*Vol.a*) by 2.02 times and for ***wildfires*** (***Wf***) by 1.39 times compared to the control period (*i*=1) . For all other natural disasters, the death odds ratio (OR) decreased. Additionally, a new disaster event, ***Glacial Lake Outburst Flood*** (***GLOF***) , emerged, causing 439 deaths in Europe and Asia, resulting in a comparative odds ratio that is infinitely large.

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Table 12. Odds Ratios of Mortality Risk in Two Periods

TOTAL DEATH	Early-stage death toll / unaffected population ratio	Late-stage death toll / unaffected population ratio	OR ratio
Fd	0.000010	0.000005	0.551456
Storm	0.000026	0.000003	0.128097
Eq	0.000094	0.000010	0.107469
D	0.000003	0.000000	0.122122
mmd	0.000000	0.000000	0.125247
mmw	0.000001	0.000001	0.549834
Ep	0.000009	0.000004	0.404841
E.t	0.000020	0.000010	0.496697
Wf	0.000000	0.000000	1.390085
Vol.a	0.000000	0.000000	2.024069
glof		0.000000	
Inf		0.000000	
Total	0.000163	0.000033	0.205155

(Compiled by the Author)

Overall, the risk of death from natural disasters in the control group was nearly five times higher than in the observation group. The significant reduction in disaster-related deaths post-2015 suggests that public and governmental awareness, communication, and risk management related to natural disasters have improved, fostering a collective disaster prevention consciousness. As hazard levels increase, effective disaster mitigation can reduce the impact of disasters and lower their overall consequences.

Exposure - Affected Population Odds Ratio

From January 2003 to December 2014:

2178（million people affected by disasters）/7238（global million population） =30.10% 。

From January 2015 to October 2023:

1400（million people affected by disasters）/8045（global million population）=17.40%

Considering the affected population, the odds ratio of exposure for various disasters is shown in Table 13.

Table 13. Odds Ratios of Exposure （Affected Population）in Two Periods

Exposure/ affected	Early-stage affected population / unaffected population ratio	Late-stage affected population / unaffected population ratio	OR ratio
Fd	0.015976	0.047674	2.984109
Storm	0.005297	0.035155	6.637207
Eq	0.001263	0.004435	3.509919
D	0.006411	0.095280	14.862273
mmd	0.000000	0.000000	0.440539
mmw	0.000048	0.000133	2.777243
Ep	0.000071	0.000541	7.643424
E.t	0.001266	0.000706	0.557833
Wf	0.000030	0.001556	52.627186
Vol.a	0.000020	0.000557	27.989411
glof	0.000000	0.000011	
Inf	0.000039	0.000000	0.000000
Total	0.031030	0.211200	6.806230

（Compiled by the Author）

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Comparing the overall exposure and affected population between the two periods:

- From 2015 to October 2023, the overall risk of being affected increased by 6.8 times compared to the previous period.
- The risk of being affected by ***extreme temperatures*** （*ext*） and ***non-water-related mass movements*** （mmd） decreased, with the former at 0.558 times and the latter at 0.44 times.
- Disasters with an exposure risk exceeding 10 times, in descending order, are: ***wildfires*** （52.63 times）, ***volcanic activity*** （27.99 times）, and ***drought*** （15.86 times）.
- Other disasters include ***epidemics*** （7.64 times）, ***storms*** （6.64 times）, ***earthquakes*** （3.51 times）, ***floods*** （2.98 times）, and the newly observed ***glacial lake outburst flood*** （***GLOF***）.

The increase in the overall exposure ratio indicates that, despite the probability of disaster occurrence not significantly increasing, the exposure level has surged. This suggests that the intensity of disasters has strengthened, the affected areas have expanded, or disasters are occurring in densely populated areas, leading to a rise in the number of affected people.

Economic Loss （Physical Loss） Odds Ratio

Based on Table 14, the odds ratio for economic losses（Physical Loss） is as follows:

Table 14. Economic Losses from Disasters Before and After 2015

（Unit: Million USD per Million People）

Physcial Loss	Amount of early-stage disaster losses / unaffected population ratio	Amount of late-stage disaster losses / unaffected population ratio	OR ratio
Fd	0.0685909	0.0461519	0.6728576
Storm	0.1522002	0.1347395	0.8852783
Eq	0.0972119	0.0199915	0.2056484
D	0.0113304	0.0139025	1.2270036
mmd	0.0000014	0.0000000	0.0000000
mmw	0.0003715	0.0003479	0.9363290
Ep	0.0000000	0.0000000	
E.t	0.0083583	0.0010371	0.1240754
Wf	0.0053462	0.0108914	2.0372162
Vol.a	0.0000806	0.0004227	5.2468644
glof	0.0000000	0.0000282	
Inf	0.0000000	0.0000000	
Total	0.4495823	0.2638651	0.5869116

（Compiled by the Author）

Based on Table 14, the odds ratio for economic losses （*Physical Loss*） indicates:

- Overall, the risk of economic losses due to disasters in the 2015-2023 observation period decreased to 0.589 times compared to the previous period.
- The risk of economic loss increased for ***volcanic activity*** （5.247 times）, **wildfires** （2.04 times）, and ***drought*** （1.23 times）.

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- The risk of economic losses decreased for ***water-related mass movements*** （*mmw*） （0.937 times）, ***storms*** （0.886 times）, ***floods*** （0.673 times）, ***earthquakes*** （0.206 times）, and ***extreme temperatures*** （0.124 times）.

Notably

Glacial Lake Outburst Floods （GLOF） are a new disaster type with no prior comparison, but they have already emerged.

Epidemics do not directly cause physical losses but may lead to unmeasurable hidden structural damages.

Insect Infestations （inf） and ***dry mass movements*** （mmd） present minimal economic loss risks.

Without adjusting for the time ratio, the actual amounts of economic loss may appear higher. R.K. Bhandari （2014） discusses such rapidly occurring （***flash***） disasters—including ***sudden temperature fluctuations***, ***heavy rain*** or ***snowfall***, and ***prolonged droughts***—in "Disaster Education and Management." Due to the limited response time, mechanisms that were initially within a disaster's manageable range may escalate to severe levels because of timing issues.

Drought, in particular, is a latent threat with an unclear start and an unknown end. Its long duration, combined with favorable conditions, can result in so-called "***flash droughts***" with greater destructive power, which merits attention.

Management Implications

Based on the above verification and analysis, the management implications are as follows:

For the control group period of 144 months（12 years） and the observation group period of 106 months （8 years and 10 months）, assuming the natural disaster occurrence probability remains consistent, the observation group values are estimated at 0.736 times those of the control group. When simply considering the ratio and the relationship between disaster occurrences, global natural disasters are evidently on the rise, indicating that the effects of climate change have not diminished.

In terms of severity, although the fatality rate significantly decreased during the observation period, the adjusted economic losses are slightly higher when considering the time ratio. Exposure levels were notably higher than in the previous control period.

This trend partially aligns with the 2011 Global Disaster Report （GAR）, but there are some regional differences, with ***North America*** and ***Oceania*** showing the most significant increases.

The significant increase in the ***affected population***, coupled with a decrease in death risk, suggests a marked improvement in global disaster prevention awareness.

Storms and ***floods*** remain the most severe natural disasters, especially in ***North America***, where their impact is particularly pronounced.

Discussions on natural disasters or hazards often focus on specific countries, regions, or cities, which are small areas on a global scale. This approach may introduce ***biases***.

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The emergence of new disasters such as ***glacial lake outburst floods*** （GLOF） presents risks to countries with high mountains and glaciers, such as those in ***Europe*** and ***Asia***. Effective disaster prevention should involve close monitoring of ***glacier*** changes and the management of downstream populations.

Droughts are often difficult to assess accurately due to unclear start dates or prolonged durations, leading to post-event recognition and gaps in data regarding fatalities, affected populations, and economic losses. This results in an underestimation of their impact （often reflected as gaps in databases）.

Wildfires have seen a significant increase in frequency since 2015, with substantial growth in the number of affected individuals and economic losses. This necessitates strengthened prevention and control efforts by governing authorities.

Volcanic activity remains a major concern due to its direct impact, though its unpredictability continues to be a challenge requiring further scientific research.

The impact of ***epidemics*** has decreased significantly, likely due to improved ***global prevention measures.***

Since 2023, ***earthquakes*** have consistently contributed to the number of incidents, fatalities, affected populations, and economic losses. Unfortunately, current predictive technologies have yet to effectively reduce their severity.

Conclusion and Future Research Recommendations

Rising temperatures are an undeniable fact that humanity must address to achieve sustainable development. The 2015 Sendai Framework for Disaster Risk Reduction outlines four main priorities focused on identifying and addressing risks and disasters:

- *Understanding disaster risk: Recognizing and assessing the intensity and impact of risks.*
- Strengthening disaster risk governance.
- Investing in disaster risk reduction.
- Enhancing preparedness for response and recovery.

This paper has analyzed the impacts and influences of various disaster types on human environments and societies using EM-DAT data, providing an objective analysis through the proposed model. The conclusions are as follows:

Conclusion

This study adopts a macro perspective and an objective model to explore the probability and impact of disasters across different regions（continents）. By examining disaster probability, impact, and severity, the following key findings were identified:

- Probability of Occurrence: Overall, there was a slight decrease in disaster occurrence, with a minor increase in ***droughts*** and a decrease in ***epidemics*** and ***earthquakes***.
- Impact: There was a significant reduction in fatality rates but a noticeable increase in both exposure and economic losses.

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- Severity: The impact of natural disasters increased in ***North America*** and ***Oceania***, while it decreased in other regions.

- New Disasters （***GLOF***）: The occurrence of ***glacial lake outburst floods***（***GLOF***） suggests that melting glaciers, which previously supported mountain rocks, are leading to potential collapses. Countries with high mountainous areas must consider disaster mitigation and emergency planning.

- Forests as Carbon Sinks: ***Wildfires*** have a devastating effect on forests, leading to increased air pollution and land desertification. Accelerated reforestation is needed, and this challenge requires interdisciplinary research.

The 2011 Global Assessment Report on Disaster Risk Reduction （**GAR**） presented several critical observations:

Reduced Fatality Rates: However, economic losses have increased.

Severity of Concentrated Disasters: Particularly for disasters affecting large populations, as seen in 2023.

Increased Economic Risk: This leads to a rise in poverty, urbanization, and desertification of farmlands.

The 2015 GAR further emphasized that the nature and scope of natural disasters are changing and expanding, a view supported by the findings of this study. However, it also warned of the potential for countries to fall into ***a poverty trap if they are caught in a cycle of destruction and reconstruction.***

Future Research Recommendations

This study primarily evaluates the global impact of the Sendai Framework for Disaster Risk Reduction. Further research is needed to assess the broader effects of disaster changes on global supply chains. Special attention should be given to the following types of disasters:

Drought: A silent and slow-onset disaster with unclear start dates and long durations. In agricultural powerhouse nations, prolonged droughts can lead to intangible impacts that surpass those of visible disasters. Initiatives like ***Drought.gov*** are now operational, with scholars using the ***Normalized Difference Vegetation Index***（***NDVI***） to assess ***drought*** conditions.

Extreme Temperatures: There is no clear international definition, with many countries relying on statistical percentiles. This can lead to misunderstandings and difficulties in estimating risks.

Melting Phenomena: Melting is not confined to polar ice caps. In high-altitude regions, glaciers supporting mountain structures may silently melt, leading to collapses. For instance, the September 16, 2022, disaster in Pakistan resulted in approximately 1,500 deaths and impacted 33 million people.

Flexible Model: The proposed model can be easily adapted to include new variables or changes, such as ***lightning strike*** events.

As prevention is better than cure, UNESCO's ***Disaster Management program*** emphasizes raising ***awareness*** and *preparedness* through knowledge dissemination, which is essential for effective ***disaster risk reduction.***

This paper aims to identify disaster risks by informing about the potential distribution, frequency, hazard, and severity of disasters. Raising public awareness is the first step toward effective disaster management. The COP 28 seminar on November 30, 2023, underscored the ongoing severity of global climate change,

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emphasizing the need for collective global efforts to reduce energy consumption and carbon emissions to control temperature rises, which is the cornerstone of sustainable human development.

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