Climate change and lethal violence: a global analysis

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Abstract

Purpose – The study aims to uncover the relationship between rising temperatures, increased greenhouse gas emissions and the prevalence of lethal violence, encompassing suicides and homicides. It also sought to identify how climate change affects different economic strata in countries, notably in high and middle-income nations, and across Asia and Africa.

Design/methodology/approach – This study rigorously explored the link between global climate change and lethal violence across 201 countries from 1970 to 2020. Climate change was measured using annual surface temperature fluctuations and greenhouse gas emissions, while lethal violence was estimated using data on suicides and homicides.

Findings – The analysis revealed significant positive associations between escalating temperatures, heightened greenhouse gas emissions and lethal violence. These connections were evident across different economic levels and geographic regions in Asia and Africa.

Originality/value – This study emphasizes the urgent need for comprehensive interventions to combat human-induced climate change and mitigate its extensive negative impacts on society, particularly its association with increased violent behavior.

Keywords Climate change, Lethal violence, Suicides, Homicides, Environment

Paper type Research paper

1. Introduction

The daunting specter of climate change looms large, not only as an environmental crisis but also as a catalyst for far-reaching societal implications, including the escalation of violence. Beyond its evident environmental toll, climate change has emerged as a significant contributing factor to the escalation of lethal violence in communities worldwide. As temperatures rise, ecosystems falter and natural disasters become more frequent and severe, the intricate connection between climate variations and the prevalence of lethal violence gains prominence within scholarly discourse. Lethal violence, encompassing acts of aggression leading to fatal consequences, manifests in various forms across societies, from interpersonal conflicts to collective violence. Within this milieu, the impact of climate change surfaces as a

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significant contributing factor, exacerbating existing tensions and fostering environments ripe for conflict escalation (Hawken, 2021; Mearns and Norton, 2009).

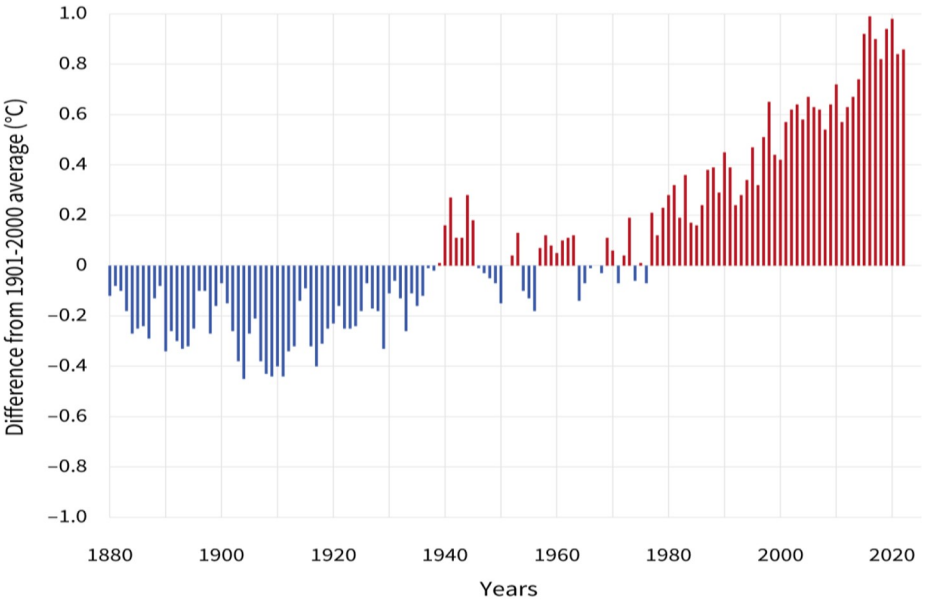
This paper investigates how climate change, through factors such as rising temperature and greenhouse gas emissions, is projected to increase lethal violence rates in communities worldwide. While discussions around climate change predominantly center on its environmental effects, its insidious role in amplifying violent behaviors remains a less explored yet pressing concern (Doherty and Clayton, 2011; Evans, 2019). According to the Environmental Performance Index (EPI-2022), which assigns weightings of 38% for climate change, 20% for environmental health and 43% for ecosystem vitality, climate change holds a substantial share. Components such as CO_2, GHG emissions, CH_4 and N_2O collectively contribute to 85% of the climate effect within the 38% allocated to climate change. Forecasts project that climate change could significantly impact societies and human behavior in the years to come. Therefore, it becomes essential to adapt to these changes and mitigate their potential influences on violent tendencies. Collaboration between interdisciplinary researchers and professionals in health care, criminology and social sciences becomes crucial in formulating research, educational initiatives and policies aimed at mitigating the implications of climate change on violent behaviors (Lawrance *et al.*, 2022; Sharpe and Davison, 2021).

These environmental consequences have a ripple effect, impacting social and economic systems, potentially amplifying societal tensions and contributing factors to conflicts and incidents of lethal violence (Hoegh-Guldberg *et al.*, 2019; Yoro and Daramola, 2020). The Earth is presently undergoing a discernible warming trend, marked by a consistent increase in global average temperatures over recent decades (Hegerl *et al.*, 2018). This warming, attributed significantly to human activities such as the burning of fossil fuels and deforestation, leads to the accumulation of greenhouse gases, thereby intensifying the greenhouse effect and trapping heat. The repercussions of this warming are extensive, impacting ecosystems, precipitating extreme weather events and contributing to rising sea levels.

Figure 1 indicates that Earth's temperature has increased at an average rate of 0.14°F (0.08°C) per decade since 1880, resulting in a total rise of approximately 2°F. Notably, the pace of warming has accelerated since 1981, with a rate of 0.32°F (0.18°C) per decade. According to NOAA's temperature data [1], 2022 ranked as the sixth-warmest year on record. The surface temperature for 2022 was 1.55°F (0.86°C) higher than the 20th-century average of 57.0°F (13.9°C) and 1.90°F (1.06°C) warmer than the preindustrial period (1880–1900). It is noteworthy that the ten warmest years in the historical record have all occurred since 2010.

Building upon the evidence of rising global temperatures and their uneven geographical distribution, a Global Climate Report (2020) by the NOAA National Centers for Environmental Information (NCEI) highlights how this disparity significantly impacts the pattern of environmental degradation. Data from the report shows record highs across continents and oceans, signifying an alarming trend. This uneven warming can lead to more severe environmental degradation in some regions compared to others [2]. A globally unprecedented heatwave gripped the planet in 2020, with record-breaking temperatures across North and South America, Europe, Asia, Africa and Oceania. This alarming trend, driven by human-caused greenhouse gas emissions, highlights the accelerating pace of climate change. Over 90% of excess heat is absorbed by oceans, impacting atmospheric warming, land temperatures and ice melt.

Reports from scientific bodies like the Intergovernmental Panel on Climate Change (IPCC), United Nations (2013, 2020) and the US Global Change Research Program (2017) attribute these changes primarily to human-generated emissions of heat-trapping gases. Climate change has emerged as a pressing global concern, profoundly impacting patterns of lethal violence across diverse continents. In Africa, extreme weather events like droughts



Source: Figure courtesy of NOAA Climate.Gov. It represents the yearly surface temperature compared to the 20th-century average from 1880–2022. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years. NOAA Climate.gov graph, based on data from the National Centers for Environmental Information at https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Figure 1. Global average surface temperature, 1880–2022

and floods lead to displacement and trauma, fostering violence. Asia's deteriorating air quality and natural disasters heighten stress and violence risks. Europe's heatwaves and economic disruptions increase tensions. In America, wildfires and hurricanes induce trauma and violence, while deforestation and water scarcity fuel conflicts. Oceania's climate impacts reverberate globally, affecting violence rates.

Record-breaking temperatures worldwide underscore the pressing need to address human-driven causes of climate change, which have already inflicted substantial harm on our planet. Amidst these concerns, emerging research highlights a connection between climate-induced mental health impacts and a potential rise in lethal violence within communities (Liu *et al.*, 2020). The intensified frequency and severity of extreme weather events are closely associated with a spectrum of mental health issues, including stress, anxiety, depression and potentially, violent behaviors like suicides and homicides (Lawrance *et al.*, 2022). Rising temperatures, fueled by climate change-induced heatwaves, contribute to physical discomfort and health risks, significantly impacting mental well-being (Basu *et al.*, 2018; Hansen *et al.*, 2008). Urban areas, especially those where energy-intensive facilities like air-conditioning amplify the urban heat island effect, further intensify these rising temperatures, which can aggravate mental health issues (Evans, 2003). While the direct relationship between climate-induced temperature increases and specific acts of lethal violence is complex and requires further investigation, the link between hotter climates and increased violent behavior is becoming increasingly apparent (Walinski *et al.*, 2023).

In conclusion, while global temperatures are undeniably rising, the geographical distribution of this phenomenon plays a crucial role in shaping the patterns of environmental degradation observed around the world. Climate change-induced disasters, notably heatwaves, may play a contributory role in exacerbating conditions associated with lethal violence, including suicides, homicides and psychosis across diverse demographic segments (Crane *et al.*, 2022). Despite the limited direct empirical research elucidating the precise correlation between climatic factors and lethal violence, the escalating global temperatures raise substantive concerns regarding the broader spectrum of human well-being. This study endeavors to investigate the potential correlation between alterations in surface temperature and greenhouse gas emissions and their plausible connection to various forms of lethal violence, encompassing suicides and homicides. It aims to explore the nuanced impact of climatic variations, especially in relation to occurrences such as suicides and homicides, and their potential contribution to instances of lethal violence within societal frameworks.

This paper is structured as follows. Section 1 represents the introduction. Section 2 is the literature review section that explains how climate change affects lethal violence to motivate empirical research. Section 3 shows the theoretical framework that links climate change and lethal violence. Section 4 represents the data, methodology and statistical model. Section 5 explains the empirical findings and Section 6 shows the conclusion based on the empirical findings.

2. Literature review

Climate change poses a pervasive global challenge extending beyond environmental concerns, impacting various dimensions of human existence. Emerging literature has spotlighted the intricate link between climate change and the occurrence of lethal violence, advocating for a deeper understanding of this complex relationship. The prevalence of lethal violence incidents contributes significantly to global burdens, with studies emphasizing their substantial impact on societal well-being and safety (Whiteford *et al.*, 2015).

A growing body of research explores the multifaceted connection between climate change and violent behavior. Plante *et al.* (2017) focus on the repercussions of rapid climate change on aggression, examining both direct and indirect pathways through which climate change influences aggressive tendencies. Rogers (2023) explores the concept of climate violence, emphasizing the need for appropriate terminology to address the diverse harms inflicted by climate change. Miles-Novelo and Anderson (2022) delve into the psychological effects of climate change, particularly its potential to escalate aggressive behaviors and conflicts among individuals and groups. Meanwhile, Buhaug *et al.* (2023) analyze the risks that anthropogenic climate change poses to peace, highlighting the importance of considering perceptions and values in assessing the severity of these risks.

While these studies provide valuable insights into the complexity of climate change and its effects on human behavior, they predominantly focus on aspects such as aggression, psychological impacts and risks to peace. However, there is a notable gap in directly addressing the connection between climate change and lethal violence. This gap highlights the need for further research specifically exploring the relationship between climate change and lethal forms of violence to provide a more comprehensive understanding of the subject.

Briggs (2023) warns of the serious threat to global health from climate change, conflict and contagion. The COVID-19 pandemic, ongoing conflicts and climate crises have shattered nations, disrupted supply chains and fractured health systems. Nuclear risks and emerging diseases loom large, especially in low- and middle-income countries (LMICs), which face heightened vulnerability due to global disparities and inadequate support. Addressing inequalities and investing in LMICs' sustainable development is vital for a safer

future (Briggs, 2023). McCool *et al.* (2022) grapple with understanding the interplay between climate change and conflict-induced violence. By examining lethal violence in the Prehispanic Andes, they reveal that favorable climates fostered rapid population growth, fueling persistent warfare. This sheds light on how unstable climates could escalate future violence by encouraging population growth and straining resources.

Kim and Garcia (2023) explored how climate change heightens the risk of violent conflict through various pathways. Their analysis emphasizes that factors like migration, governance and ongoing conflict dynamics influence how climate change contributes to conflict in the Middle East and North Africa (MENA). The study reveals that societal responses to climate change in the MENA region are impacted by prior mismanagement of land and water resources, along with existing conflict dynamics. This study advocates for further empirical research to better understand the complex relationship between climate events and violent conflict in MENA, urging focus on regions like North Africa and the Gulf.

Crane *et al.* (2022) conducted an integrative review to explore the implications of anthropogenic climate change on mental health. The evidence suggests that climate change has negative effects on mental health, leading to increased rates of psychiatric diagnoses such as depression, anxiety and posttraumatic stress disorder (PTSD), as well as elevated measures of suicide, aggression and crime. The potential mechanisms involve neuroinflammatory responses to stress, maladaptive serotonergic receptors and adverse impacts on both individual and community well-being. McMichael and Kovats (2002) emphasize the compounding impact of climate-related disruptions on existing social injustices, with marginalized populations bearing a disproportionate burden. Direct exposure to climate-related extreme weather events emerges as a key factor linked to adverse mental health outcomes such as anxiety, depression and posttraumatic stress (World Health Organization, 2022).

Sakaguchi *et al.* (2017) conducted a systematic review exploring the links between climate change and violent conflict. Their analysis reveals three main findings: a mixed body of evidence regarding climate variables' impact on conflict, a weak empirical basis for proposed causal pathways and limitations in drawing clear conclusions due to methodological differences among studies. Willox *et al.* (2013) suggest that climate change disrupts land-based activities affecting mental health by increasing family stress, contributing to substance use, amplifying previous traumas and raising the potential for suicide ideation. This study highlights climate change as an additional mental health stressor for resource-dependent communities. Heeren *et al.* (2023) investigate the associations among cognitive-emotional features of climate, anxiety, daily life, functional impairments, experience of climate change, pro-environmental behaviors and general worry in an international community sample. The authors suggested that cognitive-emotional features of climate anxiety may serve as a hub connecting these variables.

The link between temperature and suicide rates has been explored in several studies, with the findings summarized in Table 1. This table highlights ecological studies examining the correlation between various temperature measures (e.g. heatwaves, daily mean temperature) and suicide rates across different geographical regions (e.g. India, the USA, Mexico). Notably, several studies observed a positive correlation, suggesting that increased temperatures might contribute to higher suicide rates (Burke *et al.*, 2018; Carleton, 2017; Florido Ngu *et al.*, 2021; Mullins and White, 2019). This finding aligns with the broader understanding of how climate change can negatively impact mental health, potentially increasing the risk of suicidal behavior.

Table 1. Overview of the literature

Authors	Sample/ regions	Outcome measures	Main themes
Florido Ngu *et al.* (2021)	Ecological 60 countries worldwide	Heatwaves temperature and/or relative humidity suicides rate	In countries with a significant impact, a 3.5% increase in suicide is observed for every unit rise in heatwave counts. About half of the countries show a notable increase in suicide relative to changes in relative humidity
Carleton (2017)	Ecological 1956–2000 India	Temp (daily mean) suicide rates	A 1°C rise in daily temperature during days above 20 °C in India's growing season corresponds to an annual increase of 0.008 suicides per 100,000 people, with no significant impact observed during nongrowing season
Burke *et al.* (2018)	Ecological US: 1968–2004 Mexico: 1990–2010 N(USA) = 851,088 N(Mexico) = 611, 366 USA, Mexico	Temp (monthly mean, monthly), suicide rates	A 1°C increase in monthly mean temperature is linked to a 0.6% rise in US county suicide rates and a 2.1% increase in Mexican municipalities. This effect holds in both hotter and cooler regions. Unlike all-cause mortality, suicide rates increase at higher temperatures, decrease at colder temperatures and this pattern persists over time, unaffected by income or air conditioning adoption
Mullins and White (2019)	Ecological *N*(ED) = 8,294 *N*(Suicides) = 2,096,460 *N*(self-reported mental health) = 4,120,514 USA	Temp (daily mean) daily precipitation, humidity, daily sunlight ED visits related to mental health, self-reported mental health, suicide rates	Higher temperatures led to increased ED visits for mental illness, suicides and self-reported poor mental health days. There's no evidence of adaptation; the temperature relationship remains stable over time, unaffected by baseline climate, air conditioning rates and mental health service accessibility
Tiihonen *et al.* (2017)	Ecological 1996–2013 *N* = 551,529 Finland	Temp (monthly mean) Violent crime (proxy for aggression)	A robust correlation was noted between the monthly violent crime rate and the monthly mean ambient temperature. The ambient temperature explained 10% of the variance in violent crime, indicating a 1.7% increase for every 1°C rise
Xue *et al.* (2019)	Difference-in-difference study 2010–2014	Temp (long-term level of temp, temp variability)	A 1°C increase in temperature variability within a year was correlated with a 15% risk of decreased mental health scores, strongly linked to higher probabilities of

(*continued*)

Table 1. Continued

Authors	Sample/ regions	Outcome measures	Main themes
	N = 21,543 China	Self-reported mental health scores, depression scale test	feeling nervous, upset, hopelessness and meaninglessness
Basu *et al.* (2018)	Ecological 2005–2013 *N* = 219,942 US	Temp (daily mean, maximum, minimum) ED visits related to mental health, external-cause injuries	In the warm season, a 5.6°C increase in same-day mean apparent temperature is associated with 4.8%, 5.8% and 7.9% higher risks of visits for mental health disorders, self-injury/suicide and intentional injury/homicide, respectively
Hansen *et al.* (2008)	Ecological *N* = 171,614 1993–2006 AUS	Mortality attributed to mental, behavioral and cognitive disorders on temperature	Episodes of extreme heat poses a salient risk to the health and well-being of the mentally ill
Dang *et al.* (2022)	Cross-sectional 2017–2019 *N* = 7,780 Vietnam	Heatwaves combination of intensity and duration admissions for psychiatric illness to mental health hospital	Heatwaves increased all-cause psychiatric hospitalizations by 62% for the main effect and 8% for the added effect. Hospitalizations for psychoactive substance use significantly rose with the main effect of heatwaves. Psychotic disorders were highly vulnerable to both main and added effects
Di Giorgi *et al.* (2020)	*N* = 100 Cross-sectional Italy	Perception of climate change, loss of social capital and mental health (depressive and anxiety symptoms)	Individuals migrating from African nations, facing severe and elevated susceptibility to the effects of climate change, currently reside in Northern Italy
Bundo *et al.* (2021)	Ecological 1973–2017 *N* = 89,996 Switzerland	Temp (daily mean) psychiatric hospitalizations	A 10°C rise in daily mean temperature leads to a 4.0% linear increase in the risk of hospitalization for mental disorders, even when controlling for air pollution and meteorological factors. The greatest risk is seen in diagnosis of schizophrenia or developmental disorders

Notes: ED = emergency department; Temp = Temperature; AUS = Australia; US = United States of America
Source: Created by the author

Emerging research suggests a concerning link between climate change and an increase in violent behaviors, including suicide rates. The literature provides an overview of various studies examining the relationship between climate factors and violent behaviors, including suicide rates, violent crime and self-reported mental health scores (Amin *et al.*, 2022; Amin and Ahmad, 2020). Each study explores different aspects of this complex relationship, highlighting the diverse impacts of climate change on violent behaviors across different regions and populations, such as the increased risk of suicide in some areas. As shown in Table 1, various studies suggest a potential link between temperature and suicide rates, highlighting the need for further investigation into the underlying mechanisms.

However, despite the valuable insights provided by existing research, it is essential to acknowledge the significant gaps and limitations in the current understanding of the connection between climate change and lethal violence. While some studies have investigated the direct and indirect impacts of climate change on lethal violence, a comprehensive and empirical understanding remains incomplete. This study aims to address these substantial gaps in the literature by conducting a thorough analysis of the relationship between climate change and lethal violence across continents, focusing on Asian, European, American, African and Oceanian countries.

3. Theoretical framework

In examining the theoretical framework linking climate change to lethal violence, it is crucial to consider environmental determinants and their influence on societal behaviors (DeWall *et al.*, 2011; Hsiang *et al.*, 2015). Research by DeWall *et al.* (2011) has highlighted the intricate interplay between environmental factors and aggressive behaviors, emphasizing the role of environmental cues in shaping human responses. Similarly, studies by Hsiang *et al.* (2015) have underscored the importance of understanding how environmental changes, such as those induced by climate change, can impact social dynamics and conflict patterns. These studies indicate the importance of integrating insights to enhance our understanding of how shifts in climate patterns may contribute to the escalation of lethal violence. Environmental stressors resulting from climate change, including extreme weather events and ecological disruptions, have the potential to directly and indirectly influence societal behaviors, thereby exacerbating tensions and heightening the risk of violent conflicts (Burke *et al.*, 2018).

This framework elucidates the intricate ways in which shifts in climate patterns impact human behavior, particularly concerning aggression and violence. Climate, shaped by human actions, is undergoing substantial transformations that warrant close examination (Seth *et al.*, 2023). Scholarly interest in environmental impacts on human health has roots in the environmental and ecological movements of the 1960s, primarily driven by biological scientists (Evans, 1984). The growing field of human-environment studies, emerging in the late 1960s and early 1970s, initially focused on two overarching themes: the impact of design on user satisfaction and human responses to issues such as pollution and overpopulation (Craik, 1973; Kates and Wohlwill, 1966).

Biological models of the human−environment interface derive from animal models and emphasize the interactions between environmental constituents and the physiological response of the organism. Although the biological perspective has undoubtedly made enormous contributions to understanding the human−environment interface, it has important limitations. Some of these led to the emergence of human-environment studies as a focus of inquiry for social scientists. In direct effects, one limitation of the biological perspective is the emphasis of biological models on direct environmental effects on human health. Rene (1965) was among the first biologists to note the role of cognitive mediators between physical stimuli

and human responses. Human beings, to a much greater extent than other animals, interact with the symbolic, cognitively constructed world.

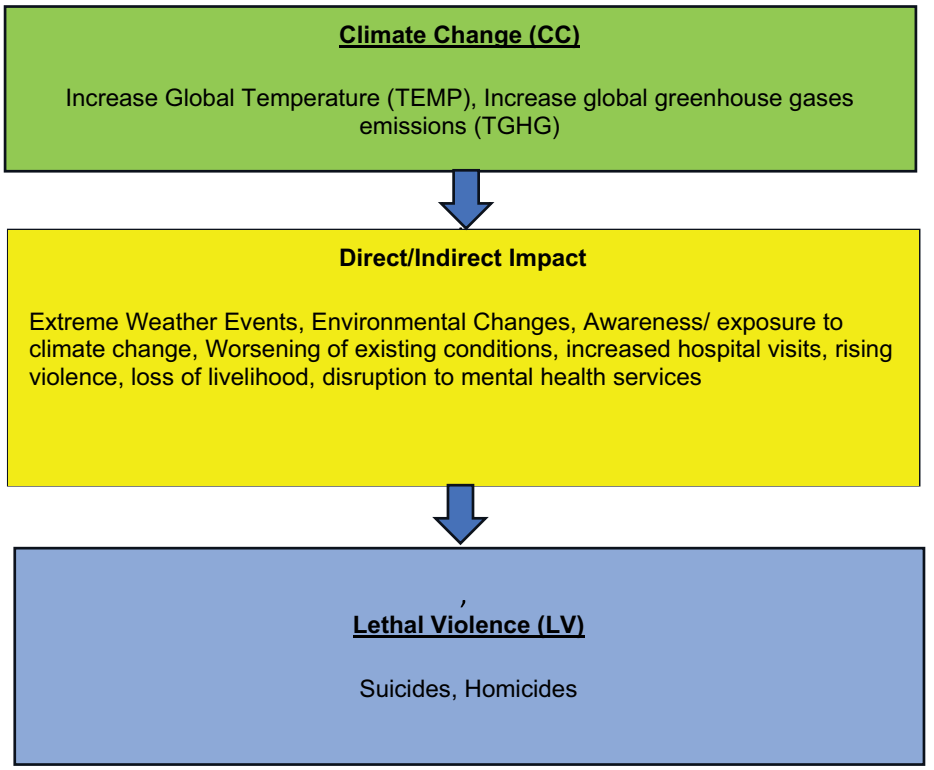
Both biological and ecological research strategies have been criticized on methodological grounds. Researchers working on environmental stress need to evaluate the implicit models of stress that they use in their research. Unfortunately, not enough careful thought has been given to the empirical and conceptual implications of these various models. There are other possible explanations for the environmental stress process, but the arousal, overload and systems approaches represent the major models used in research on environmental stress (Evans, 1984). In addition to the traditional models of the stress process, there have been several less-encompassing models that significantly influenced environmental stress research. These models primarily derive from the psychological stress tradition, although some influence of the physiological tradition is also found. Each elaborates on the nature of properties of the environment and the individual that lead to a stress response, and/or the linkage between environmental stressors and a specific type of outcome (Evans, 1984).

The environmental stressor model offers a theoretical framework for understanding how environmental changes, including those induced by climate change, can serve as stressors contributing to the escalation of lethal violence (Evans, 1984). In the context of climate change, a spectrum of environmental stressors such as extreme weather events, ecological disruptions and rising temperatures may directly and indirectly impact the propensity for lethal violence. Similarly, gradual alterations in ecosystems might trigger feelings of loss, existential distress and anxiety, potentially influencing individuals to internalize these environmental shifts. This model highlights the environment's role as a catalyst for stress, interacting with individual and community dynamics in fostering conditions conducive to lethal violence (Evans, 1984, 2003).

Research indicates that the impacts of climate change can extend beyond mental health, potentially escalating lethal violence within communities. Extreme weather events intensified by climate change, like hurricanes or prolonged droughts, can disrupt livelihoods and access to resources, triggering conflicts over essential needs such as water and food. These disruptions might exacerbate tensions and contribute to instances of violence and aggression within affected areas (Burke *et al.*, 2018). In addition, the strain on resources due to environmental changes might lead to displacement and migration, creating situations where conflicts arise over territory and limited resources, potentially increasing the risk of lethal violence (Ebi *et al.*, 2021; McMichael, 2017). Understanding these connections is pivotal in developing strategies to mitigate the potential for violence within communities affected by climate-induced changes.

It is crucial to continuously update our understanding of the implications of climate change on lethal violence, given the expanding research in health and climate change. Yet, discussions often neglect the correlation between lethal violence and climate change compared to physical health concerns, mirroring a broader tendency of overlooking lethal violence issues globally (Whiteford *et al.*, 2015). This oversight persists despite the high global prevalence of lethal violence issues. However, considering the potential lethal violence consequences of a changing climate − especially regarding the risks of escalated conflicts and community displacement − underscore the urgent need to prioritize lethal violence in the discourse surrounding climate change's multifaceted impacts.

Figure 2 outlines the relationship between climate change and lethal violence, depicting how climate-related factors can contribute to and influence instances of lethal violence. While the connection between climate change and mental health is being studied, the direct link to lethal violence remains less established. The pathway between climate change and



Sources: Created by the author. Adapted in part from World Health Organization (WHO), Mental Health and Climate Change: Policy Brief (June 3, 2022) and Emily Hough and Nathaniel Counts, "How Climate Change Affects our Mental Health, and What We Can Do About It" CommonWealth Fund, March 29, 2023

Figure 2. The relationship between climate change (CC) and lethal violence (LV)

lethal violence is intricate and multifaceted, with numerous interconnected factors contributing to this relationship. Changes in climate patterns and extreme weather events can directly impact social, economic and environmental conditions, influencing the occurrence and intensity of lethal violence. Extreme weather events, such as hurricanes, floods and droughts, often linked to climate change, can lead to the displacement of communities, resource scarcity and social upheaval. These disruptions can exacerbate existing tensions, increase competition for limited resources like food and water and intensify socioeconomic disparities. In turn, such circumstances may elevate the risk of conflict and violence within affected communities.

In addition, climate-induced stressors can have indirect effects on mental health and well-being, which, in certain cases, might contribute to the escalation of violent behaviors. Heightened stress, anxiety and emotional distress resulting from climate-related changes can potentially lead to aggressive behavior or exacerbate existing tensions, indirectly influencing

the occurrence of lethal violence. Furthermore, shifts in environmental conditions can impact livelihoods, agricultural productivity and economic stability, potentially leading to social unrest and conflicts over resources. This disruption in social and economic systems can create conditions conducive to various forms of violence, including both homicides and suicides.

4. Description of statistical methods and data sources

This section describes the approaches and methods used in the empirical analysis of this study. Understanding the specific impact of climate change on lethal violence is not straightforward and lacks a simple theory to rely on. It is important to note that lethal violence consequences are not homogeneous, and some regions may experience more severe effects than others. The database contains diverse income groups as well as geographical variations regarding the environmental damage. The study uses data of 201 countries worldwide regional level across continents, i.e. Asian, European, American, African and Oceanian countries covering the period from 1970 to 2020. Lethal violence is evaluated through various indicators, i.e. suicide rates, homicide rates and lethal violence as a combination of homicide and suicide rates. Climate change (CC) is examined through the proxies of annual surface's temperature change (TEMP) and total greenhouse gas emission (TGHG).

This study used panel fixed-effect analysis in the empirical findings to examine the association between various forms of climate change and lethal violence. Fixed-effects models are particularly effective for analyzing panel data, as they help account for potential heterogeneity among countries by controlling or partially isolating the effects of time-invariant variables (Gujarati and Porter, 2003). The data on homicides and suicide rates have been obtained from the Mortality database, World Health Organization (WHO) [3]. The model predicts that changes in climates would affect lethal violence, but the direction of this effect is unclear and depends on whether a country's region has an abundance of labor or capital. The study adopted the standard specification proposed by James Amos (2023) and Sui *et al.* (2023) for empirical analysis, which is represented by the following equation:

$$L_{Viol_{i,t}} = \alpha + \theta_1 CC_{i,t} + \tau_2 X_{i,t} + \varphi_t + \in_{i,t}$$

where $L_{Viol_{i,t}}$ is the lethal violence, which sums up homicide and suicide rates for country i at the time t, whereas, climate change (CC) includes annual surface temperature change (TEMP) and total greenhouse gas emission (TGHG). Finally, $X_{i,t}$ is the set of control variables including unemployment rate (UN), KOF Globalization Index (GLOB), annual growth rate (GDPG) and population in urban areas (URB). The φ_t fixed-effect model control for all the potential confounding factors. Data on the description, symbols, expected signs and source of the variables can be seen in Table 2.

5. Empirical findings

This study conducted a thorough analysis, exploring environmental, economic and violence-related variables across diverse regions. Using multiple regional data sets featuring observations on annual surface temperature change, greenhouse gas emissions, globalization, unemployment, urbanization and gross domestic product (GDP) growth, the study aims to uncover the intricate relationships among these factors.

Table 3 presents the descriptive statistics for several pivotal variables. Lethal violence (LV) presents a mean of 17.11 and a median of 14.41, with a range from 0.0091 to 137.74. Annual surface temperature change (TEMP) indicates a mean of 0.595, ranging from −2.06

Table 2. Description of the variables used and their expected signs in the regression

Variable type	Symbols	Variable description/definition		Database
Dependent variables				
Suicides	S	Suicide and suicide attempts. This covers crucial suicide registration, hospital-based suicide attempt registries and nationally representative surveys that gather data on self-reported suicide attempts. (ICD-10 codes: X60-X84, Y870)		International Classification of Diseases (ICD), WHO mortality database (MDB), www.who.int/data/data-collection-tools/who-mortality-database
Homicides	H	Homicide is the killing of a person by another with the intent of causing death or serious injury, by any means. (ICD-10 codes: X85-Y09, Y871)		
Lethal violence	LV	Suicides + homicides		
Independent variables (IV)	*Symbols*	*Variable description/definition*	*Exptd. sign*	*Database*
Annual surface temperature change	TEMP	Temperature change with respect to a baseline climatology (°C), i.e. surface temperature change	+	Food and Agriculture Organization of the United Nations (FAO) 2022. FAOSTAT Climate Change www.fao.org/faostat/en/#data/ET
Total greenhouse gas emissions	TGHG	The total greenhouse gas emissions, measured in kilotons of CO_2 equivalent, encompass several components. This includes the total CO_2 emissions, CH_4 (methane), N_2O (nitrous oxide) and F-gases (fluorinated gases, including HFCs, PFCs and SF6). The measurement provides a comprehensive assessment of various human-induced activities contributing to greenhouse gas emissions	+	World Bank, Climate Watch Historical GHG Emissions (1990–2020) 2023. Washington, DC: World Resources Institute. Available online at: www.climatewatchdata.org/ghg-emissions
Unemployment	UN	% of unemployed population (out of total population)	+/−	WDI
GDP growth	GDPG	Annual gross domestic product growth	+/−	WDI
Globalization Index	GLOB	The KOF Globalization Index is measured by the economic, social and political aspects of globalization	+/−	KOF GLOBALIZATION INDEX
Urbanization	URB	% of urbanization population (out of total population)	+/−	WDI

Source: Created by the author

Table 3. Descriptive statistics

Variables	Mean	Median	Maximum	Minimum	SD	Sum	Observations
LV	17.1123	14.41442	137.74	0.009161	13.26279	95229.94	5,565
S	10.33018	7.83	92.64	0.009161	8.859882	56309.81	5,451
H	7.081449	3.89	114.3514	0.02147	9.617969	38700.12	5,465
TEMP	0.595836	0.544	3.058	−2.062	0.623348	5308.901	8,910
TGHG	43.26419	9.836533	2519.02	−85.2779	155.6238	165139.4	3,817
UN	8.201684	6.349	38.8	0.1	6.402226	43526.34	5,307
GLOB	49.71542	47.16284	90.90649	14.14877	16.60661	446444.5	8,980
GDPG	3.694198	3.772843	149.973	−64.0471	6.178302	30680.31	8,305
URB	52.28379	51.8095	100	2.845	24.67649	525033.8	10,042

Source: Created by the author

to 3.05. Total greenhouse gas emissions (TGHG) exhibit a mean of 43.26419, with a median of 9.83, encompassing a range from −85.27 to 2519.02. Unemployment (UN) demonstrates an average of 8.201, spanning from 0.1 to 38.8. Globalization Index (GLOB) records an average of 49.71 and a median of 47.16, fluctuating between 14.14 and 90.90. GDP growth (GDPG) displays an average of 3.694, varying from −64.04 to –149.9. Urbanization (URB) demonstrates an average of 52.28, ranging from 2.845 to 100. The utilization of tables presenting descriptive statistics aids in evaluating these variables, indicating a well-organized data set with characteristics conducive to further empirical analysis.

Table 4 indicates the climate change's potential impact on lethal violence, the regression analysis revealed significant associations between temperature change (TEMP) and total greenhouse gas emissions (TGHG) with various forms of lethal violence, namely, suicides (S), homicides (H) and overall lethal violence (LV). For the full sample, an increase in temperature exhibited a significant positive relationship with lethal violence (LV), suicides (S) and homicides (H) at coefficients of 1.983, 0.804 and 1.153, respectively. This indicates that higher temperatures are linked to increased rates of these forms of violence. Regarding greenhouse gas emissions a significant positive relationship emerged with overall lethal violence (LV) 0.0087, and homicides (H) 0.007. These findings imply that increased greenhouse gas emissions may be linked to heightened rates of overall lethal violence and specifically homicides. These outcomes underscore the robust interplay between climate factors and various forms of lethal violence, highlighting the importance of further exploration in understanding and mitigating these concerning trends.

Table 5 illustrates the estimation results exploring the intricate relationship between climate change indicators and lethal violence, considering diverse income levels − high, middle and low income. Across the full sample, temperature change (TEMP) demonstrates a statistically significant positive association with lethal violence (1.244, $p < 0.001$), emphasizing that rising temperatures are linked to increased instances of lethal violence. Notably, in high-income countries, the effect of TEMP remains significantly positive (1.102, $p < 0.001$), mirroring the overall trend. However, in middle-income nations, this relationship is more pronounced, showing a higher positive effect (1.541, $p < 0.001$). Intriguingly, for low-income countries, the association between TEMP and lethal violence turns negative (−0.308), albeit statistically insignificant. Regarding total greenhouse gas emissions (TGHG), a significant positive association emerges in high-income (0.053, $p < 0.001$) and low-income (0.002, $p < 0.05$) countries, suggesting that increased emissions may contribute to heightened lethal violence, while remaining inconclusive for middle-income nations.

Table 4. Climate change and lethal violence fixed effects robust estimation

	Full sample					
	Lethal violence (LV)		Suicides (S)		Homicides (H)	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
TEMP	1.983*** (0.233)		0.804** (0.121)		1.153*** (0.183)	
TGHG		0.0087*** (0.002)		0.0003 (0.001)		0.007*** (0.001)
C	18.58*** (0.199)	18.324*** (0.163)	10.72*** (0.104)	10.81*** (0.088)	8.173*** (0.157)	7.746*** (0.121)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.7744	0.859	0.859	0.901	0.747	0.859
No. of observations	5,181	2,796	184	173	183	173
Cross-sections	185	173	5,067	2,771	5,081	2,764

Notes: *, **, ***represent 10%, 5 and 1 level of significance, respectively
Source: Created by the author

Table 5. Climate change and lethal violence estimation results

	Dept: Lethal violence							
	Full sample		High-income		Middle-income		Low-income	
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TEMP	1.244*** (0.245)		1.102*** (0.279)		1.541*** (0.421)		−0.308 (0.214)	
TGHG		0.006** (0.002)		0.053*** (0.005)		0.0002 (0.003)		0.002 (0.001)
UN	0.108*** (0.040)	0.173*** (0.048)	0.160*** (0.047)	0.278*** (0.051)	0.032 (0.068)	0.094 (0.081)	0.173*** (0.059)	0.205*** (0.075)
GLOB	−0.197*** (0.035)	−0.180*** (0.040)	−0.099** (0.045)	−0.077 (0.047)	−0.292*** (0.055)	−0.381*** (0.066)	−0.189*** (0.030)	−0.044 (0.036)
GDPG	−0.084*** (0.018)	−0.076*** (0.019)	−0.025 (0.040)	0.040 (0.042)	−0.111*** (4.243)	−0.127*** (0.026)	0.0001 (0.010)	−0.020 (0.014)
URB	0.193*** (0.042)	0.137** (0.058)	0.325*** (0.067)	0.556*** (0.076)	0.153** (0.059)	−0.005 (0.082)	0.182*** (0.043)	0.325*** (0.075)
C	18.95*** (3.191)	19.77*** (4.007)	−2.159 (6.266)	−23.00*** (7.041)	28.20*** (0.025)	38.96*** (5.189)	2.140 (2.181)	3.589 (3.113)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.849	0.870	0.8213	0.882	0.858	0.872	0.980	0.977
No. of observations	3,738	2,616	1,297	914	1,987	1,355	405	306
Cross-sections	173	164	52	48	95	90	24	24

Notes: (i) Lethal violence is aggregated form of suicides and homicides, TGHG is the combined effect of CO_2, CH_4 and N_2O; (ii) *, **, ***represent 10, 5 and 1% level of significance, respectively
Source: Created by the author

The observed associations between temperature change (TEMP) and total greenhouse gas emissions (TGHG) with lethal violence can be illuminated by several interconnected factors. Rising temperatures and extreme weather events induced by climate change can introduce uncertainties, disrupt daily life and foster stress − an established precursor to violent behaviors. Environmental disruptions such as natural disasters and shifts in ecosystems may displace communities, cause social upheaval and consequently contribute to an increase in lethal violence. Furthermore, climate-related health issues, coupled with socioeconomic disparities exacerbated by climate change, could influence variations in lethal violence outcomes.

In high-income countries, despite economic prosperity, exposure to extreme weather events due to climate change can heighten stress, anxiety and PTSD, potentially impacting levels of lethal violence. Advanced health-care infrastructure and genetic research may exist, yet these nations face unique challenges from climate-induced events like extreme heat, influencing mental well-being (Ebi *et al.*, 2021). However, individuals in developing nations may face heightened vulnerability to these direct environmental impacts. For instance, climate change may alter soil quality, affecting agricultural practices essential for food supply. Ongoing climate change could lead to environmental degradation, negatively impacting food and freshwater resources, resulting in population displacement and loss of livelihoods. Consequently, climate change's adverse effects on the physical environment may worsen poverty, malnutrition and disease, serving as independent risk factors for youth depression in developing nations (Cianconi *et al.*, 2020).

The estimation results in Table 5 also indicate that the control variables such as unemployment (UN) exhibits a consistent positive correlation with lethal violence across income brackets. Specifically, higher unemployment rates are significantly associated with increased instances of lethal violence in high, middle and low-income countries. Conversely, the Globalization Index (GLOB) illustrates divergent patterns. While high and middle-income nations portray a negative relationship between globalization and lethal violence, indicating that higher globalization levels might contribute to reduced violence (both $p < 0.05$), this association remains statistically insignificant in low-income countries. Moreover, GDP growth (GDPG) demonstrates a mixed impact across income groups. High and middle-income countries showcase a negative correlation between GDP growth and lethal violence (both $p < 0.001$), hinting that higher GDP growth might correspond to decreased violence, while low-income countries exhibit inconclusive results due to a substantial standard error. Notably, urbanization (URB) consistently reveals a positive link with lethal violence across all income categories. Elevated urbanization rates are significantly associated with increased lethal violence in high, middle and low-income nations (all $p < 0.001$), accentuating the intricate interplay between urban development and violent tendencies within diverse socioeconomic contexts.

Table 6 shows the estimation outcomes examining the intricate association between climate change and incidences of suicides across different income classifications. In the full sample, the variable capturing temperature change (TEMP) presents a statistically significant positive correlation with suicides (0.429, $p < 0.001$), suggesting that heightened temperatures correspond to an increase in suicide rates. Within high-income countries, this relationship strengthens (0.691, $p < 0.001$), signifying a more pronounced impact of rising temperatures on suicide occurrences. However, for middle-income nations, while a positive association persists (0.094), it lacks statistical significance. Surprisingly, in low-income countries, despite a positive coefficient (0.621, $p < 0.001$), the association between temperature change and suicides diverges notably from high and middle-income groups. Regarding total greenhouse gas emissions (TGHG), varying impacts emerge across income categories. High

Table 6. Climate change and suicides estimation results

	Dept: Suicides							
	Full sample		High-income		Middle-income		Low-income	
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TEMP	0.429*** (0.136)		0.691*** (0.187)		0.094 (0.235)		0.621*** (0.198)	
TGHG		0.0008 (0.001)		0.032*** (0.004)		0.005*** (0.001)		0.002* (0.001)
UN	0.128*** (0.022)	0.146*** (0.025)	0.220*** (0.031)	0.208*** (0.039)	0.034 (0.038)	0.112*** (0.039)	0.145*** (0.054)	0.099 (0.063)
GLOB	−0.046** (0.019)	−0.038* (0.020)	0.019 (0.030)	0.023 (0.036)	−0.148*** (0.031)	−0.176*** (0.032)	−0.088*** (0.028)	−0.069** (0.030)
GDPG	0.0007 (0.010)	0.004 (0.010)	−0.026 (0.027)	−0.008 (0.032)	−0.002 (0.014)	−0.008 (0.012)	0.012 (0.009)	0.001 (0.012)
URB	0.117*** (0.023)	0.130*** (0.030)	0.291*** (0.045)	0.451*** (0.059)	0.013 (0.033)	−0.014 (0.040)	0.036 (0.040)	0.149** (0.063)
C	5.399*** (1.773)	4.314** (2.091)	−12.23*** (4.204)	−24.32*** (5.482)	16.23*** (2.369)	18.61*** (2.532)	2.186 (2.017)	4.948* (2.630)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.880	0.9117	0.883	0.906	0.874	0.914	0.943	0.943
No. of observations	3,721	2,611	1,296	914	1,988	1,355	405	306
Cross-sections	173	164	52	48	85	90	24	24

Notes: *, **, ***represent 10, 5 and 1% level of significance, respectively
Source: Created by the author

and middle-income nations reveal a positive and significant link between TGHG and suicides (both $p < 0.001$), indicating that increased emissions might contribute to elevated suicide rates. Conversely, the relationship remains statistically insignificant in low-income countries.

These results are supportive by literature such as Ebi *et al.* (2021) show that heat-related mortality in LMICs exists due to data scarcity, with over half of the studies focusing on China (56%) and other Asian countries (14%). LMICs, characterized by resource constraints and lower air conditioning prevalence, often rely on behavioral adaptations and personal cooling measures, such as applying ice or towels, wetting the skin or using water-saturated clothing along with additional ventilation (e.g. fans) for heat mitigation. The analysis also indicates the findings regarding unemployment (UN), globalization (GLOB), GDP growth (GDPG) and urbanization (URB) concerning suicide rates across income groups. Unemployment consistently shows a positive association with suicide rates across high, middle and low-income countries (all $p < 0.001$). Globalization exhibits mixed results, with high and middle-income nations suggesting a negative correlation (both $p < 0.05$), while low-income countries lack conclusive evidence. GDP growth does not significantly impact suicide rates in high and middle-income countries, while in low-income countries, a tentative negative link is observed. Urbanization positively associates with suicide rates across all income groups (all $p < 0.001$), revealing the intricate dynamics between urban development and incidence of suicide within diverse economic contexts.

The estimation results presented in Table 7 extend crucial insights into the association between climate change variables and incidences of homicides across varying income classifications. Temperature change (TEMP) exhibits a significant positive correlation with homicides across the full sample (0.803, $p < 0.001$). Interestingly, this relationship remains statistically significant in high-income countries (0.421, $p < 0.001$) and low-income countries (0.312, $p < 0.05$), suggesting that elevated temperatures might contribute to increased homicide rates. However, for middle-income nations, while a positive association exists (1.447, $p < 0.001$), the effect appears substantially higher than in high and low-income categories. Total greenhouse gas emissions (TGHG) portray diverse impacts across income groups. High and middle-income countries demonstrate a positive correlation between TGHG and homicides (both $p < 0.05$), indicating that increased emissions might be associated with higher homicide rates. Conversely, low-income countries showcase a statistically insignificant association.

Climate patterns, when disrupted, can create ripple effects across various societal aspects in both high and middle-income countries. In high-income nations, while the direct impacts might be somewhat mitigated by better infrastructure, technology and resources, the indirect consequences of climate change can still trigger stress, resource shortages and social tensions, which might indirectly influence conflicts or violence. Similarly, in middle-income countries, rapid urbanization and resource constraints may intensify due to climate change, affecting economic stability and social harmony. These nations might encounter amplified challenges in managing the social impacts of climate-induced stressors, potentially contributing to elevated tensions or conflicts within communities.

Regarding other socioeconomic factors, the relationship between unemployment (UN) and homicides varies across income categories, with only middle-income nations displaying a statistically significant positive association (0.063, $p < 0.01$). Globalization (GLOB) exhibits a consistently negative correlation with homicides across all income groups (all $p < 0.001$), suggesting that higher globalization levels might correspond to reduced homicide rates. GDP growth (GDPG) demonstrates a negative link with homicides in high, middle and low-income countries (all $p < 0.001$), indicating that higher GDP growth might be associated

Table 7. Climate change and homicides estimation results

	Dept: Homicides							
	Full sample		High-income		Middle-income		Low-income	
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TEMP	0.803*** (0.184)		0.421*** (0.159)		1.447*** (0.307)		0.312* (0.166)	
TGHG		0.006*** (0.001)		0.021*** (0.002)		0.004* (0.002)		7.40E- (0.0008)
UN	−0.023 (0.030)	0.024 (0.037)	0.063** (0.026)	0.069*** (0.023)	−0.001 (0.049)	−0.017 (0.064)	0.027 (0.046)	0.106** (0.048)
GLOB	−0.149*** (0.026)	−0.137*** (0.030)	−0.123*** (0.025)	−0.100*** (0.021)	−0.144*** (0.040)	−0.204*** (0.052)	0.100*** (0.023)	0.113*** (0.023)
GDPG	−0.084*** (0.014)	−0.081*** (0.015)	0.0006 (0.023)	−0.049*** (0.019)	−0.108*** (0.018)	−0.119*** (0.020)	−0.012 (0.007)	−0.022** (0.009)
URB	0.082** (0.032)	0.018 (0.045)	0.035 (0.038)	0.105*** (0.034)	0.140*** (0.043)	0.008 (0.065)	0.145*** (0.033)	0.176*** (0.048)
C	13.17*** (2.387)	14.67*** (3.085)	10.31*** (3.575)	1.322 (3.192)	11.93*** (3.097)	20.35**** (4.107)	−0.045 (1.698)	−1.359 (2.014)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.847	0.865	0.799	0.881	0.833	0.823	0.972	0.976
No. of observations	3,713	2,600	1,296	914	1,988	1,355	405	306
Cross-sections	173	164	52	48	95	90	24	24

Notes: *, **, ***represent 10, 5 and 1% level of significance, respectively
Source: Created by the author

with lower homicide rates. Urbanization (URB) also exhibits diverse relationships across income groups, with significant positive associations observed in middle and low-income nations (both $p < 0.001$), underscoring the complex dynamics between urban development and homicide rates within varied economic contexts.

The findings presented in Table 8 shows the intricate interplay between climate change variables and lethal violence across different continents. Temperature change (TEMP) exhibits divergent relationships with lethal violence across continents. In Asia, a statistically significant positive association suggests that higher temperatures might correspond to increased incidents of lethal violence. Conversely, in European and Oceanian regions, the observed relationships appear weaker and lack statistical significance. The American and African continents display diverse and inconsistent connections between temperature change and lethal violence, indicating the presence of nuanced regional dynamics that warrant further investigation. The impact of total greenhouse gas emissions (TGHG) varies across continents. While Asia and parts of Europe reveal positive correlations between emissions and lethal violence, implying a potential link between increased emissions and higher violence rates, the American, African and Oceanian regions demonstrate nonsignificant relationships.

In Asia, climate change has multifaceted implications for lethal violence. The region faces diverse challenges due to changing climate patterns, including extreme weather events, rising temperatures and ecological disruptions. These factors can indirectly contribute to increased stress, resource scarcity and social tensions within communities, potentially exacerbating conflicts and instances of lethal violence. In Asian countries, changing climate patterns have direct consequences on livelihoods reliant on agriculture, particularly in regions where farming is a primary source of income. Shifts in rainfall patterns, increased droughts or floods and unpredictable weather can lead to crop failures, financial strain and food insecurity. These issues can intensify existing social pressures and economic disparities, increasing the risk of conflicts and violence over limited resources. In support of our findings, a study conducted in Ethiopia, a low-income country heavily reliant on the local environment for basic human and animal needs, revealed that seasonal environmental changes, particularly those related to water security, expose populations to significant emotional distress (Cooper *et al.*, 2019). Research conducted in Tuvalu, a small Pacific Island threatened by sea-level rise, highlights individual experiences of distress in the face of climate change, emphasizing the importance of providing culturally informed social and mental health services in the region (Gibson *et al.*, 2020). In Bangladesh, three studies have documented adverse effects on emotional well-being resulting from climate-induced immobility (Ayeb-Karlsson *et al.*, 2020).

The results also indicate that the control variables, unemployment (UN) demonstrates a notable positive correlation with lethal violence across Asia, Europe and the Americas, indicating that higher unemployment rates might be associated with increased violent incidents. However, in African and Oceanian regions, these associations appear mixed or statistically insignificant, signaling the presence of more complex relationships shaped by distinct regional influences. The impact of globalization (GLOB) on lethal violence appears variable and less pronounced across continents. While Asia shows a negative correlation, other continents exhibit diverse and often nonsignificant associations, underscoring the multifaceted nature of globalization's influence on violent occurrences within different regional landscapes. GDP growth (GDPG) and urbanization (URB) display varying relationships with lethal violence across continents, ranging from negative associations (as observed in parts of Asia, Europe and Oceania) to mixed or nonsignificant relationships in other regions. These diverse patterns emphasize the need for a nuanced understanding of

Table 8. Regional/continent specific analysis between climate change and lethal violence

	Dept: Lethal violence									
	Asian		European		American		African		Oceanian	
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TEMP	0.801** (0.404)		0.637* (0.368)		−0.688 (1.289)		1.074** (0.535)		−0.496 (0.467)	
TGHG		0.006 (0.004)		0.031* (0.016)		−0.013 (0.008)		−0.002 (0.002)		−0.004 (0.003)
UN	0.305*** (0.085)	0.140 (0.109)	0.278*** (0.050)	0.231*** (0.056)	0.289* (0.147)	0.429** (0.175)	0.673*** (0.081)	0.408*** (0.083)	0.356** (0.124)	0.195 (0.142)
GLOB	−0.129** (0.054)	−0.096 (0.075)	−0.173*** (0.048)	−0.045 (0.049)	−0.165 (0.126)	−0.096 (0.140)	−0.024 (0.079)	−0.262*** (0.076)	−2.79E- (0.054)	0.054 (0.070)
GDPG	−0.249*** (0.027)	−0.268*** (0.031)	−0.015 (0.046)	−0.084* (0.044)	−0.212* (0.109)	−0.191* (0.115)	−0.004 (0.019)	−0.004 (0.017)	0.074** (0.032)	0.103*** (0.034)
URB	0.280*** (0.064)	0.348*** (0.101)	0.394*** (0.082)	0.397*** (0.094)	−0.138 (0.136)	−0.424** (0.164)	−0.187** (0.073)	−0.526*** (0.106)	−0.005 (0.107)	0.017 (0.140)
C	3.074 (4.690)	−0.435 (6.948)	1.646 (7.400)	−7.410 (8.119)	40.91*** (9.111)	53.03*** (10.39)	34.32*** (5.489)	57.17*** (6.064)	16.19*** (6.121)	11.20 (7.380)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.813	0.837	0.866	0.913	0.756	0.798	0.947	0.965	0.964	0.969
No. of observations	916	613	984	745	752	540	930	601	157	118
Cross-sections	44	41	40	38	31	29	50	48	8	8

Notes: *, **, ***represent 10, 5 and 1% level of significance, respectively
Source: Created by the author

how economic and urban factors interact with violent incidents, shaped by the specific contextual influences within each continent.

Table 9 presents a continent-specific analysis of the relationship between climate change variables and suicide rates across different regions. Temperature change (TEMP) shows varied associations across continents. European and American regions indicate positive correlations, suggesting that higher temperatures might correspond to increased suicide rates, although only the European correlation reaches statistical significance. Total greenhouse gas emissions (TGHG) exhibit diverse relationships with suicide rates. The American continent shows a notable positive correlation between emissions and suicides, suggesting a potential linkage between increased emissions and higher suicide rates. Conversely, other continents display mixed or statistically insignificant relationships, implying the presence of additional factors shaping these associations differently in Asian, European, African and Oceanian regions. Climate change can have various implications for mental health issues like suicides in the Americas. Rising temperatures, extreme weather events and environmental changes associated with climate change can directly and indirectly impact mental well-being, potentially contributing to an increased risk of suicides. Extreme weather events such as hurricanes, wildfires and floods, which are becoming more frequent and severe due to climate change, can lead to trauma, displacement and loss of livelihoods. These events often result in significant emotional distress and psychological trauma for affected individuals, potentially leading to increased stress, anxiety, depression and PTSD, all of which are risk factors for suicidal behavior.

Unemployment (UN) demonstrates varied associations with suicide rates across continents. In most regions, including Asian, European, American, and African continents, higher unemployment rates display positive correlations with increased suicide rates, with statistical significance observed in several cases. The impact of globalization (GLOB), GDP growth (GDPG) and urbanization (URB) on suicide rates varies across continents. These variables exhibit mixed correlations with suicide rates, with inconsistent statistical significance across different continents. This suggests that the influences of globalization, economic growth, and urban development on suicide rates are multifaceted and influenced by region-specific factors within each continent.

Table 10 presents the results of continent-specific estimations exploring the relationship between climate change variables and homicide rates across different regions. Temperature change (TEMP) shows mixed associations across continents. While the Asian and American continents exhibit positive correlations with homicide rates, the correlations for European, African, and Oceanian regions nonstatistical significance, indicating diverse impacts of temperature change on homicide rates among continents. Total greenhouse gas emissions (TGHG) also reveal varied associations. Notably, the American continent displays a statistically significant positive correlation between emissions and homicide rates, suggesting a potential linkage between higher emissions and increased homicide rates. However, other continents exhibit mixed relationships or nonsignificant associations, indicating the presence of region-specific nuances or additional contributing factors shaping these relationships differently.

In both Asia and America, climate change-related factors have multifaceted implications for social, economic, and environmental stability, influencing the potential for conflicts and violence. In Asia, the environmental stressors triggered by climate change, such as extreme weather events and altered rainfall patterns, can significantly impact resource availability. These changes might lead to scarcities in essential resources like water and agricultural land, intensifying existing socio-economic tensions within communities. Competing demands for these diminishing resources may fuel conflicts and exacerbate underlying social grievances,

Table 9. Regional/continent specific analysis between climate change and suicides

	Dept: Suicides									
	Asian		European		American		African		Oceanian	
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TEMP	0.129 (0.219)		0.388* (0.231)		0.713** (0.351)		0.791 (0.523)		−0.132 (0.277)	
TGHG		0.003 (0.002)		0.010 (0.010)		0.009*** (0.002)		−0.002 (0.002)		0.001 (0.001)
UN	0.263*** (0.046)	0.125** (0.059)	0.218*** (0.031)	0.190*** (0.035)	0.265*** (0.040)	0.235*** (0.051)	0.661*** (0.079)	0.425*** (0.085)	−0.100 (0.073)	−0.062 (0.077)
GLOB	−0.028 (0.029)	−0.008 (0.040)	−0.012 (0.030)	0.063** (0.030)	−0.087** (0.034)	−0.065 (0.041)	−0.050 (0.077)	−0.269*** (0.078)	0.017 (0.032)	0.054 (0.038)
GDPG	−0.063*** (0.014)	−0.083*** (0.016)	0.044 (0.029)	0.010 (0.027)	−0.022 (0.029)	−0.053 (0.033)	0.0006 (0.019)	0.0007 (0.017)	0.028 (0.019)	0.047** (0.018)
URB	0.119*** (0.034)	0.196*** (0.054)	0.311*** (0.051)	0.352*** (0.059)	−0.066* (0.037)	−0.129*** (0.048)	−0.227*** (0.072)	−0.504*** (0.108)	0.094 (0.063)	0.185** (0.075)
C	1.297 (2.539)	−2.274 (3.741)	−7.556 (4.663)	−15.29*** (5.065)	13.71*** (2.486)	17.56*** (3.038)	27.51*** (5.363)	46.43*** (6.197)	5.781 (3.630)	−0.788 (3.993)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.903	0.916	0.894	0.931	0.841	0.846	0.877	0.905	0.990	0.992
No. of observations	917	613	984	745	752	540	930	601	157	118
Cross-sections	44	41	40	38	31	29	50	48	8	8

Notes: *, **, ***represent 10, 5 and 1% level of significance, respectively
Source: Created by the author

Table 10. Regional/continent specific analysis between climate change and homicides

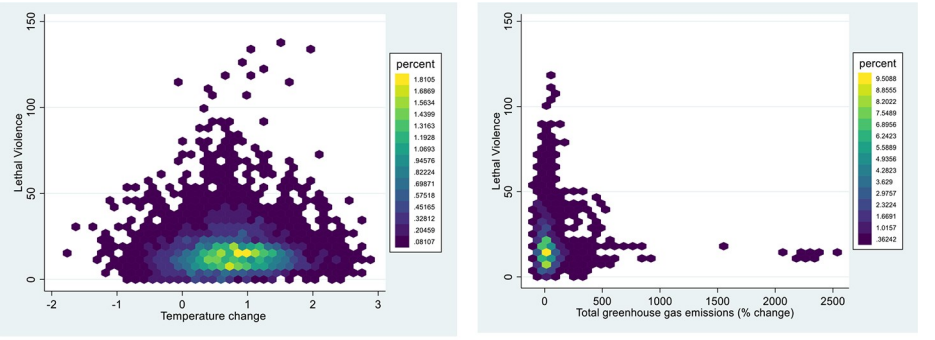
	Dept: homicides									
	Asian		European		American		African		Oceanian	
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TEMP	0.672** (0.300)		0.248 (0.183)		1.401** (1.217)		0.283** (0.137)		−0.364 (0.316)	
TGHG		0.003* (0.003)		0.020 (0.009)		0.022*** (0.008)		0.0002 (0.0006)		−0.006** (0.002)
UN	0.043 (0.063)	0.014 (0.086)	0.059** (0.025)	0.041 (0.030)	0.023 (0.139)	0.194 (0.162)	−0.011 (0.020)	0.017 (0.022)	0.255*** (0.084)	−0.132 (0.099)
GLOB	−0.100** (0.040)	−0.087 (0.059)	−0.160*** (0.024)	−0.108*** (0.026)	−0.077 (0.119)	−0.031 (0.130)	0.026 (0.020)	0.006 (0.020)	−0.017** (0.037)	−0.0003 (0.048)
GDPG	−0.185*** (0.020)	−0.184*** (0.024)	−0.059** (0.023)	−0.094*** (0.024)	−0.190* (0.103)	−0.138 (0.106)	−0.004 (0.005)	−0.005 (0.004)	0.046 (0.021)	0.055** (0.024)
URB	0.161*** (0.047)	0.151* (0.079)	0.082** (0.041)	0.045 (0.051)	−0.072 (0.128)	−0.295* (0.152)	0.040** (0.018)	−0.021 (0.028)	−0.100 (0.072)	−0.167* (0.097)
C	1.740 (3.475)	1.838 (5.480)	9.202** (3.694)	7.887* (4.363)	27.19 (8.603)	35.47*** (9.603)	6.817*** (1.407)	10.73*** (1.612)	10.41** (4.143)	11.99** (5.137)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.699	0.703	0.792	0.854	0.790	0.833	0.981	0.988	0.955	0.949
No. of observations	917	613	984	745	752	540	930	601	157	118
Cross-sections	44	41	40	38	31	29	50	48	8	8

Note: *, **, ***represent 10, 5 and 1% level of significance, respectively
Source: Created by the author

potentially culminating in violent confrontations, including homicides. Conversely, America faces its own set of challenges stemming from climate change. The increased frequency and severity of extreme weather events, coupled with rising temperatures, pose significant threats. Natural disasters like hurricanes or prolonged droughts can displace communities, disrupt livelihoods, and strain local economies. Economic hardships resulting from agricultural failures or water shortages might instigate social unrest and heighten vulnerabilities, potentially contributing to escalated conflicts and incidents of violence, including homicides.

Unemployment (UN) exhibits inconsistent correlations with homicide rates across continents. The results vary, showing statistically significant positive correlations in certain regions, such as the American continent, while other continents, including Asian, European, African and Oceanian regions, display nonsignificant associations. Globalization (GLOB), GDP growth (GDPG) and urbanization (URB) demonstrate diverse relationships with homicide rates across continents. These variables exhibit mixed correlations with homicide rates, with varying statistical significance across different continents.

Figure 3 provides a global heat plot visualizing the interrelationship between lethal violence and annual surface temperature changes (Panel A) and the correlation between total greenhouse gas emissions and lethal violence (Panel B). This graphical representation uses hexagonal shapes, each encapsulating clusters of data points. The shading intensity within these hexagons reflects the density of lethal violence incidents or the magnitude of temperature variations and greenhouse gas emissions specific to each continent. In Panel A, the color gradations within the hexagons depict temperature changes ranging from 0°C to 2°C, showcasing a pronounced correlation with lethal violence levels spanning from 0 to 50 incidents. Panel B illustrates the strong relationship between greenhouse gas emissions and lethal violence, indicated by a correlation close to zero and lethal violence incidents ranging between 0 and 50. The legend accompanying the plot elucidates the color scheme, with warmer colors denoting higher correlation strength, while cooler shades indicate medium to lower correlations. This visualization reveals compelling patterns, notably in lethal violence occurrences concerning temperature fluctuations and greenhouse gas emissions.



(a) **(b)**

Source: Created by the author

Figure 3. Global heat plot using hexagons between climate change and lethal violence

6. Conclusion and policy implications

This paper examines the intricate relationship between global climate change and lethal violence across diverse income and geographical groups. The results underscore a significant positive association between climate change, encompassing annual surface temperature changes and greenhouse gases emission and lethal violence. The empirical findings align with existing literature, that suggests climate change, beyond numerical shifts in temperature, introduces a spectrum of stressors (Clayton, 2021; Evans, 1984). These include extreme weather events and prolonged high temperatures, which contribute to heightened psychological stress. These stressors disrupt daily routines, induce uncertainty and evoke anxiety, highlighting the complex interplay between environmental changes and violence (Evans, 1984). The uncertainties tied to climate change foster societal unease, amplifying existing tensions and increasing the potential for lethal violence. Climate-induced displacement and environmental disruptions intensify social strains, creating conditions ripe for violence. These pressures, exacerbated by extreme weather and poor air quality, underscore the intricate link between environmental factors and the heightened risk of lethal violence (Andersson *et al.*, 2021; Hegerl *et al.*, 2018).

The findings emphasize the correlation between environmental shifts and lethal violence, advocating for comprehensive strategies that address climate change's root causes, reduce emissions and build community resilience. Recognizing the benefits of climate action in preventing violence is crucial. Initiatives like promoting renewable energy sources, sustainable transportation infrastructure (e.g. public transport networks) and the creation of green spaces can foster social cohesion, reduce stress and ultimately contribute to a decrease in violence. The study underlines the inseparable link between climate change and lethal violence, urging tailored policies to mitigate these impacts and foster safety globally. By investing in climate mitigation strategies, building community resilience and promoting sustainable development, a future can be created where environmental factors are not drivers of violence, but rather catalysts for a more peaceful and secure world.

While a significant association between climate change and lethal violence is identified, some limitations influence the precision of the findings. Data scarcity, particularly the lack of information specifically linking climate change to violence, hinders the analysis. In addition, data collection infrastructure in vulnerable regions relevant to this study may be insufficient, leading to missing data points. Furthermore, the sensitive nature of violent events can lead to underreporting, potentially skewing the data toward less severe or frequent incidents. This underreporting might obscure the full extent of the impact in the regions. Future research should explore interdisciplinary approaches, collaborate with policymakers and prioritize vulnerable communities. Longitudinal studies can further clarify causal relationships.

The findings on climate change and its association with increased violence necessitate proactive policy interventions. Strengthening data collection infrastructure, particularly in vulnerable regions, alongside standardized reporting practices for violent incidents, is crucial for informed decision-making. Tailored early warning systems for climate-specific events can empower communities to anticipate and prepare for potential disruptions that might exacerbate violence. Investments in programs fostering social support networks, livelihood diversification and resource management training can further bolster community resilience against climate-induced stressors, potentially mitigating violence.

Notes

1. NOAA National Centers for Environmental Information (2023). State of the Climate: Global Climate Report for 2022. Accessed January 18, 2023, from www.ncei.noaa.gov/access/monitoring/monthly-report/global/202213

2. For more detail, see the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI), Monthly Global Climate Report for December 2020 which was made available online in January 2021. The information presented derives from past reports issued by the National Centers for Environmental Information (NCEI) and public reports by National Hydrometeorological Services (NHMSs), akin to the U.S. National Weather Service. The retrieval of this information occurred on November 24, 2023, from the web link: www.ncei.noaa.gov/access/monitoring/monthly-report/global/202013
3. The WHO mortality database is a collection of data from member states' death registrations that also includes cause-of-death information. Key health indicators, such as life expectancy, are best obtained from death registration data, while cause-specific mortality data, such as maternal mortality and suicide mortality, are best obtained from death registration data with cause-of-death information.

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