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Global Climate Change, Mental Health, and Socio-Economic Stressors: Toward Sustainable Interventions across Regions

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Abstract: Global climate change's pervasive impacts extend beyond the environment, significantly affecting mental health across diverse regions. This study offers a comprehensive multi-regional analysis spanning Asia, Africa, Oceania, Europe, and the Americas, addressing three critical gaps in existing research: (i) the necessity of a global scope given climate change's widespread impact, (ii) the under-researched mental health dimension compared to general health effects, and (iii) the integration of climate and mental health data. Using data from 1970 to 2020, we found a strong correlation between climate change and rising mental disorders globally. Regional patterns emerged, with Asia, Africa, and Oceania showing broader associations with various mental health issues, while Europe and the Americas saw increases in anxiety and depression. This study contributes to a more comprehensive understanding of the interconnectedness between climate change, mental health, and sustainability. By addressing the mental health impacts of climate change, we can identify sustainable solutions that promote both environmental well-being and human well-being. Our findings highlight the urgent need for global action to mitigate climate change's mental health effects and provide insights for tailored interventions and public health strategies. Additionally, socio-economic factors like unemployment, urbanisation, GDP growth, and globalisation are incorporated to explore the intricate interplay between climate change, mental health, and societal contexts, offering a clearer understanding of the mechanisms at play.

Keywords: climate change; temperature; greenhouse gases; sustainability; mental health; mental disorder; unemployment; urbanisation

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Citation: Nie, P.; Zhao, K.; Ma, D.; Liu, H.; Amin, S.; Yasin, I. Global Climate Change, Mental Health, and Socio-Economic Stressors: Toward Sustainable Interventions across Regions. *Sustainability* **2024**, *16*, 8693. https://doi.org/10.3390/su16198693

Academic Editor: David Lopez-Carr

Received: 24 August 2024
Revised: 27 September 2024
Accepted: 1 October 2024
Published: 9 October 2024

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1. Introduction

Climate change represents just one facet within a complex web of interconnected environmental, physical, social, and ecological factors that collectively influence mental health regardless of the age group. As the body of evidence linking cognitive and behavioural outcomes to climate change continues to grow, decisive actions are imperative to address the evolving climate conditions and the resulting mental health effects [1–3]. According to the Environmental Performance Index (EPI-2022), which is constructed with weightings of 38% for climate change, 20% for environmental health, and 43% for ecosystem vitality, climate change holds a significant share. (For more details, see Wolf, et al. [4]). Within the 38% allocated to climate change, CO_2, GHG emissions, CH_4, and N_2O collectively contribute to 85% of the climate effect. Projections indicate that climate change will significantly impact our planet and its inhabitants in the forthcoming years [5–8]. Thus, adapting to and mitigating these effects becomes paramount for physical and mental well-being. Advocacy from interdisciplinary researchers and healthcare professionals is crucial for

promoting research, education, and policy to assist communities worldwide in effectively mitigating the consequences of climate change [2,9].

The earth is experiencing a discernible trend of warming temperatures, marked by a consistent increase in global average temperatures over recent decades [10]. Human activities, notably the burning of fossil fuels and deforestation, contribute to the accumulation of greenhouse gases in the atmosphere, intensifying the greenhouse effect and trapping heat [11,12]. The consequences of Earth's warming are profound, impacting ecosystems, weather extremes, and sea levels, with widespread implications for biodiversity, agriculture, and human societies [13,14].

Figure 1 indicates that Earth's temperature has increased at an average rate of 0.14° Fahrenheit (0.08° Celsius) per decade since 1880, resulting in a total rise of approximately 2 °F. Notably, warming has accelerated since 1981, with a rate of 0.32 °F (0.18 °C) per decade. According to the NOAA's temperature data, 2022 ranked the sixth warmest year on record. (NOAA National Centers for Environmental Information (2023). State of the Climate: Global Climate Report for 2022. from https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202213, accessed on 14 May 2024.) 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). Notably, the ten warmest years in history have occurred since 2010.

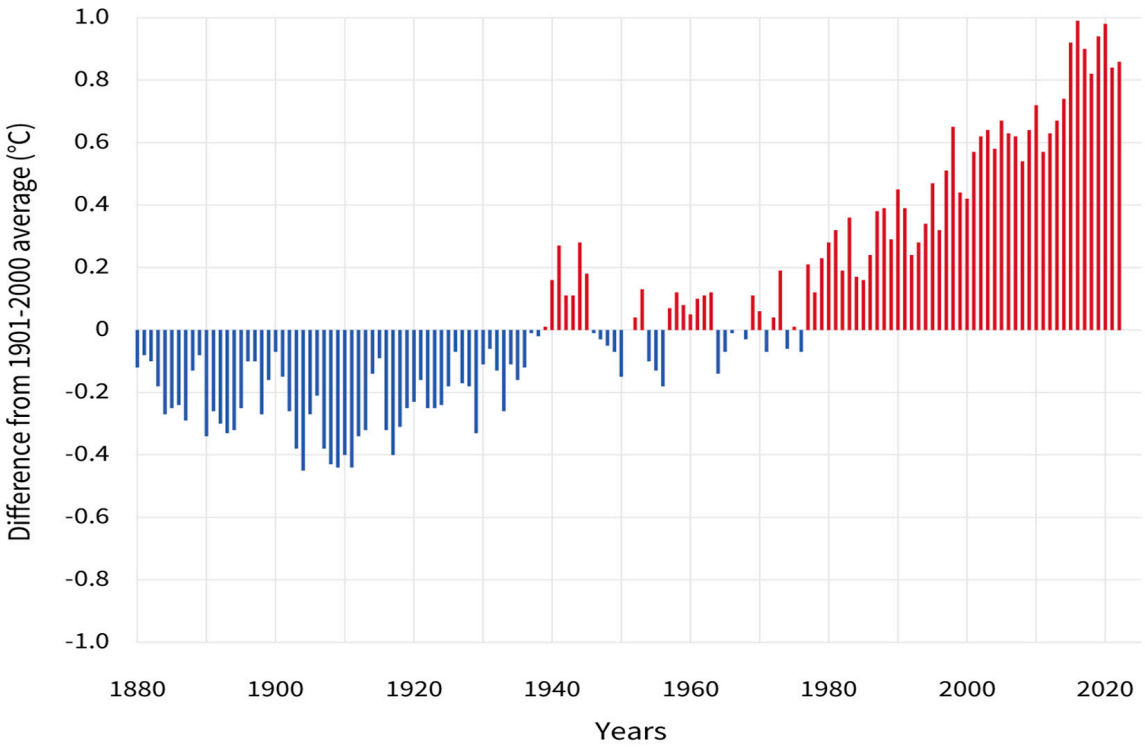


Figure 1. The global average surface temperature in the 1880–2022 period. Source: A visual representation of Earth's annual surface temperature relative to the 20th-century average is provided for the period from 1880 to 2022. The blue bars represent years with cooler-than-average temperatures, while the red bars depict years with warmer-than-average temperatures. Blue bars represent years with cooler-than-average temperatures, while red bars denote years with warmer-than-average conditions. The data originate from the National Centers for Environmental Information (NCEI) and are presented as a graph on NOAA Climate.gov (https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature, accessed on 14 May 2024).

The 2023 Global Climate Report (https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202313, accessed on 14 May 2024) paints a stark picture: record-breaking temperatures engulf continents, from Europe and Asia to North and South

America, even spanning vast oceans. No land area had even a whisper of record cold. The annual temperature of North America was 2.01 °C (3.62 °F) higher than the normal temperature in the 1910–2000 period, marking the hottest year on record. This alarming escalation echoes across continents: it was South America's second warmest year, and Asia shattered records as 2023 was the 27th year in a row with above-average temperatures. The last ten hottest years in Asia have occurred since 2007, and Europe's average annual temperature has risen by 0.15 °C per decade since 1910, but this rate has tripled to 0.47 °C per decade since 1982. Africa and Oceania follow suit, with the top 10 warmest years post-2005 and consecutive years being above average. This alarming consistency necessitates immediate global action.

The far-reaching repercussions of anthropogenic global warming are now indisputable. Once believed a threat, climate change has already inflicted significant damage on the planet, with ongoing and future transformations affecting crucial aspects of our world, including the mental well-being of individuals regardless of age. While significant effects on physical health are apparent, leading to approximately 12.6 million preventable deaths annually due to environmental factors [15], the current literature highlights the adverse effects of anthropogenic climate change on mental health. Research indicates that exposure to extreme weather events, a direct result of climate change, can negatively impact mental health, leading to detrimental effects on quality of life. Estimates indicate that between 25% and 50% of individuals undergoing such extreme weather phenomena may develop symptoms akin to a trauma response, including anxiety, depression, avoidance, guilt, rumination, hypervigilance, schizophrenia, and nightmares [16]. While research indicates that some of these symptoms may improve over time, a notable proportion of individuals go on to develop diagnosable mental health disorders [2].

While the available evidence on the relationship between climate change and mental health is not exhaustive, it is adequate to suggest that climate change can have adverse effects on mental well-being. Particularly robust evidence indicates a correlation between high temperatures and mental health outcomes. Elevated temperatures and heatwaves, for instance, have shown associations with an increased incidence of suicide. Moreover, hot temperatures have consistently been linked to a rise in violent crime, which, in turn, may have detrimental effects on mental health. High temperatures can also contribute to diminished sleep quality and impaired work capacity, resulting in economic losses that, in a cyclical manner, negatively impact mental health [3].

The heightened frequency and intensity of erratic weather patterns can contribute to a broad spectrum of mental and emotional health issues [17], encompassing stress, anxiety, depression, violence, and even suicide [2]. Rising annual surface temperatures are intricately linked to mental health deterioration due to intensified heat waves, causing physical discomfort and health risks [18,19]. The combustion of fossil fuels for energy consumption in buildings, such as air-conditioning, can contribute to elevated temperatures through the urban heat island effect, subsequently impacting mental health [20]. Recent research explores the gradual and less noticeable effects of climate change, such as rising temperatures, drought, and air pollution. Additionally, it examines the long-term consequences of climate-change-related disasters on community health. These environmental changes are believed to contribute to economic losses and pose significant threats to physical well-being [9,21]. Concerns about the future, environmental degradation, and societal consequences add to the psychological burden. Addressing these challenges requires a comprehensive approach, combining climate change mitigation and mental health interventions, to cultivate resilience in the face of evolving environmental conditions [11,22].

Additionally, extreme weather events like heatwaves can worsen existing mental health conditions, such as schizophrenia and psychosis. These effects can be seen in people of all ages, from children to the elderly [16]. Only a limited number of studies have specifically explored the effects of climate on mental health. Global surface temperatures have steadily increased, raising concerns for planetary and environmental human health. These highlight the potential value of considering climatological variables in assessing

and understanding mental illness. In our study, we thoroughly examine the relationship between these changes in surface temperature, greenhouse gas emissions, and mental health, specifically addressing overall mental disorders, anxiety disorders, depressive disorder, bipolar disorder, and schizophrenia.

Our study diverges from past research by adopting a global perspective, incorporating insights from several continents, including Asia, Africa, Oceania, Europe, and America. This approach allows us to present a comprehensive and all-encompassing view. By utilising this extensive framework, we may recognise distinct geographical patterns and evaluate the prevalence of specific trends, enhancing our comprehension of the relationship between climate and mental health. In addition, we liberate ourselves from the constraints of solely relying on temperature and emissions data, acknowledging the complex interplay between the environment and society. We incorporate vital socio-economic aspects such as unemployment, urbanisation, and GDP growth to unveil the intricate web of elements that impact mental well-being in a shifting climate. Finally, we transcend the prevalent combination of anxiety and depression, which have always been the exclusive subjects of previous studies. Instead, we explore a more comprehensive range of mental health outcomes, including anxiety, depression, bipolar disorder, and schizophrenia. This comprehensive approach enables us to fully understand the extent of climate change's influence on mental perceptions worldwide.

Our work provides evidence-based techniques to mitigate the psychological impact of climate change. It offers customised interventions for various regions, enabling policymakers to go beyond generic solutions. By addressing research deficiencies and highlighting geographical disparities, we establish a foundation for more investigation and enhance the readiness of local communities. This multifaceted strategy promotes mental fortitude, protecting both ecosystems and the vulnerable minds within them. Rising Temperatures, Fragile Minds is not merely an academic investigation but a compelling plea for immediate action. It presents a worldwide narrative interwoven with optimism and determination in the face of the escalating threat of climate change. Hence, this study specifically contributes to building a more sustainable future by examining the intricate relationship between climate change, mental health, and sustainability.

To reveal the connection between climate and mental health, our research is organised as follows: In the next section, the Literature Review Section, we survey the existing body of research and develop a robust theoretical framework to direct our investigation. Following that, we clarify the data and statistical techniques utilised in the Description of Methods and Data Sources Section before presenting the significant discoveries revealed by our analysis in the Empirical Findings Section. Ultimately, we convert these valuable observations into practical suggestions for policymakers and communities in the Conclusion and Policy Implications Section, creating a path towards a future where mental well-being persists in the face of climate change.

2. Literature Review

Climate change represents a pervasive global challenge beyond its well-documented environmental implications, affecting diverse facets of human life, including mental health. A growing body of literature emphasises the intricate relationship between climate change and mental health outcomes, urging a comprehensive exploration of this complex interplay. Global prevalence rates underscore the substantial burden of mental health issues, with studies highlighting the significant contribution of mental and behavioural disorders to the worldwide burden of disease [23].

Clayton [24] examines climate change's current and potential effects on mental health. The author reviews a growing body of research, indicating that extreme weather events linked to climate change can lead to increased rates of depression and post-traumatic stress disorder. Additionally, gradual changes in climatic conditions, such as rising temperatures and reduced air quality, harm mental health. The essay also highlights a significant proportion of the population experiencing unhealthy levels of anxiety related to

their perception of climate change. The authors of [25] emphasised the compounding impact of climate-related disruptions on existing social injustices, with marginalised 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 post-traumatic stress (Organisation, WHO 2022). Palinkas and Wong [26] explored the mental health impacts of climate change, focusing on acute events (e.g., hurricanes), long-term changes (e.g., droughts), and existential threats (e.g., rising sea levels). They highlighted both direct (e.g., heat stress) and indirect (e.g., economic loss and displacement) effects on mental well-being. Mitchell, et al. [27] utilised 11 waves of HILDA survey data (16,629 observations) and applied fixed effects linear regression to assess the impact of multiple disasters on mental health.

Obradovich, et al. [28] found that higher temperatures in the US were linked to an increased risk of mental health problems. For example, a 1 °C increase in temperature over five years was associated with a 2% increase in adverse mental health events. Additionally, heat can suppress thyroid hormones, leading to functional hypothyroidism, which may manifest as decreased energy, dysphoria, and cognitive impairment. Crane, Li, Subramanian, Rovit and Liu [16] conducted an integrative review to explore the implications of anthropogenic climate change on mental health. Evidence suggests that climate change has adverse effects on mental health, leading to amplified rates of psychiatric spots such as depression, anxiety, and post-traumatic stress disorder, as well as elevated measures of suicide, aggression, and crime. Potential mechanisms involve neuroinflammatory responses to stress, maladaptive serotonergic receptors, and adverse impacts on individual and community well-being. Hayes, et al. [29] examined climate change's current and projected impacts on mental health. The authors argued that while attributing mental health outcomes to specific climate change risks is challenging, empirical research opportunities abound. They emphasised the accelerating risks and impacts on mental health, disproportionately affecting marginalised communities. Their discussion concludes with recommendations for coordinated interventions rooted in active hope to address the mental health consequences of climate change.

Ebi, et al. [30] discussed the impact of extreme weather and climate events on human health and mental well-being. The authors emphasised the need for climate-resilient health systems to mitigate health risks associated with extreme events. Pihkala [31] explored the growing research interest in eco-anxiety and climate anxiety, analysing perspectives across disciplines and utilising insights from anxiety theory and empirical studies. The study emphasises factors such as uncertainty and uncontrollability, delving into non-clinical and pathological eco-anxiety alongside related terms like ecological grief and solastalgia. Woodhall-Melnik and Grogan [32] found that climate change has increased the frequency and severity of natural disasters, leading to damage that can negatively impact mental health. Willox, et al. [33] suggested 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.

Vergunst and Berry [34] emphasised the additive, interactive, and cumulative nature of climate-change-related threats, increasing the risk of psychopathology from conception onward. The authors argue that monitoring, measuring, and mitigating these risks are matters of social justice and crucial long-term investments in developmental and mental health sciences. Heeren, et al. [35] investigated the associations among cognitive–emotional features of climate, anxiety, daily life, functional impairments, the experience of climate change, pro-environmental behaviours, 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. An overview of the literature is provided in Table 1.

Table 1. An overview of the literature.

Authors	Sample/Regions	Outcome Measures	Main Themes
Di Giorgi, et al. [36]	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.
Dang, et al. [37]	Cross-sectional 2017–2019 N = 7780 Vietnam	Extreme heat events, characterised by their intensity and duration, were associated with increased admissions for psychiatric illness	Extreme heat events were associated with a significant increase in psychiatric hospitalisations, particularly for psychotic disorders and substance use.
Florido Ngu, et al. [38]	Ecological 60 countries worldwide	Heatwaves, relative humidity, temperature Suicide rate	In countries affected by heatwaves, a 3.5% increase in suicide rates was observed for each additional heatwave. Additionally, about half of these countries experienced a notable rise in suicide rates due to changes in relative humidity.
Lee [39]	Ecological 2003–2013 N = 166,579 Korea	Heatwaves, temperature (daily mean), total solar radiation, humidity, and admissions related to mental health	The strongest association between mental health conditions (anxiety, schizophrenia, dementia, and depression) and elevated temperatures was observed within 0–4 days of exposure. Approximately 14.6% of emergency mental health admissions were linked to extreme heat, with anxiety being the most significant risk at 31.6%, especially impacting the elderly (19.1%).
Hansen, Bi, Nitschke, Ryan, Pisaniello and Tucker [19]	Ecological N = 171,614 1993–2006 Australia	Mortality caused by mental, behavioural, and cognitive disorders due to temperature extremes	Extreme heat events present a significant threat to the health and well-being of individuals with mental illness.
Yoo, et al. [40]	Ecological 2009–2016 N = 2.8 million USA	Heatwaves, ED visits for specific mental disorders	Exposure to temperatures of 27.07 °C and above raised emergency visits for mental disorders, including substance use, mood disorders, anxiety, schizophrenia, and dementia.
Basu, Gavin, Pearson, Ebisu and Malig [18]	Ecological 2005–2013 N = 219,942 USA	Temp (daily mean, maximum, minimum) ED visits related to mental health, external-cause injuries	A 5.6 °C rise in the same-day apparent temperature during the warm season is linked to 4.8%, 5.8%, and 7.9% increased risks of mental health visits, self-injury/suicide, and intentional injury/homicide, respectively.
Bundo, et al. [41]	Ecological 1973–2017 N = 89,996 Switzerland	Temperature and hospitalisations due to psychiatric issues	A 10 °C increase in the daily mean temperature results in a 4.0% rise in hospitalisation risk for mental disorders, even after adjusting for air pollution and weather factors, with schizophrenia and developmental disorders showing the highest risk.
Burke, et al. [42]	Ecological US: 1968–2004 Mexico: 1990–2010	Temp (monthly mean), suicide rates	A 1 °C rise in the monthly mean temperature correlates with a 0.6% increase in US suicide rates and a 2.1% rise in Mexico rates, which is consistent across hot and cool areas. Unlike all-cause mortality, suicide rates climb with higher temperatures and drop with colder ones and are unaffected by income or air-conditioning use.

Table 1. *Cont.*

Authors	Sample/Regions	Outcome Measures	Main Themes
Carleton [43]	Ecological 1956–2000 India	Temp (daily mean), suicide rates	A 1 °C rise in the 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 being observed during the non-growing season.
Middleton, et al. [44]	Ecological 2012–2018 N = 5373 Canada	Temp (daily mean), mental health-related visits, including suicide related-visits	Mental health visits rose notably when the two-week average daily temperature exceeded −5 °C compared to temperatures below this threshold.
Mullins and White [45]	Ecological N(ED) = 8294 N(suicides) = 2,096,460 N(self-reported mental health) = 4,120,514 USA	Temp (daily mean), humidity daily precipitation, daily sunlight ED visits related to mental health, suicide rates, self-reported mental health	Elevated temperatures resulted in more ED visits for mental illness, suicides, and reports of poor mental health days. The temperature effect persists over time, with no adaptation, regardless of the baseline climate, air-conditioning, or mental health service access.
Page, et al. [46]	Cross-sectional 1998–2007 N = 22,562 UK	Temp (daily mean) Dementia, diagnosis of psychosis, or substance use	People with psychosis, dementia, or substance misuse faced a 4.9% higher death risk for every 1 °C rise above the 93rd percentile of the annual temperature. The greatest mortality risk was seen in younger individuals primarily diagnosed with substance use disorder.
Tiihonen, et al. [47]	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.
Vida, et al. [48]	Ecological 1995–2007 N = 347,552 Canada	Temp (daily mean, relative humidity), ED visits related to mental health	ED visits increased with a rising mean temperature, notably in metropolitan and suburban areas. The incidence ratio risk rose with higher temperatures, particularly at 22.5 °C and 25 °C. Visits also increased with humidity, especially in the younger age group.
Xue, et al. [49]	Difference-in-difference study 2010–2014 N = 21,543 China	Temp (long-term level of temp, temp variability) Self-reported mental health scores, Depression Scale test	A 1 °C increase in temperature variability within a year was correlated with a 15% risk of decreased mental health scores and strongly linked to higher probabilities of feeling nervous, upset, hopeless, and meaningless.

Note: ED = emergency department, RR = relative risk; UK = United Kingdom; US = United States of America.

Despite there being a growing body of research exploring the relationship between climate change and mental health, several significant gaps remain in our understanding of this complex issue. Numerous research attempts have concentrated on mental health conditions, like depression and anxiety, but a more thorough analysis of the wider spectrum of mental health consequences is required. Furthermore, although there has been some research on the direct and indirect effects of climate change on mental health, a more thorough and empirical understanding is still lacking. Moreover, the possibility of there being regional differences in how climate change affects mental health has not been thoroughly investigated. To create effective interventions and strategies to lessen the detrimental effects of climate change on mental health globally, it is imperative that these research gaps be filled. This study aims to address these significant gaps in the literature by providing a more thorough analysis of the relationship between climate change and mental

health in various continent-specific analyses, i.e., Asian, European, American, African, and Oceanian countries.

3. Theoretical Framework and Model Specification

This framework helps illuminate the complex pathways through which climate change affects mental health, recognising the environment as a crucial determinant of well-being and the long-term consequences of exposure to environmental stressors. The climate, influenced by human behaviour, is undergoing significant changes and has recently gained increased attention [50]. The environmental and ecological issues of the 1960s spurred academic interest in how environmental problems impact human health, primarily driven by biological scientists' early research in this field [51]. In the late 1960s and early 1970s, a few behavioural scientists became interested in these effects. Early research efforts in the new field of human-environment studies focused on two broad topics: design and user satisfaction and human responses to pollution and overpopulation [52].

In some respects, the emergence of human-environment studies represented a convergence of two relatively distinct intellectual paradigms: (i) environmental sciences, which focus primarily on the conditions of the biosphere, and (ii) the study of human behaviour, conducted by psychologists and other social scientists. Human–environment studies examine the interplay between humans and their environment, focusing on how environmental changes influence human behaviour and vice versa.

Biological models of the human-environment interface derive from animal models and emphasise the interactions between environmental constituents and the organism's physiological response. Although the physical perspective has undoubtedly made enormous contributions to understanding the human-environment interface, it has significant 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 natural models on the direct environmental impact on human health. Dubos [53] was among the first biologists to note the role of cognitive mediators between physical stimuli and human responses. Humans interact with the symbolic, cognitively constructed world much more than other animals.

Both bio and ecological approaches face methodological critiques. Environmental stress researchers need to scrutinise their implicit stress models. Insufficient attention has been paid to their empirical and conceptual implications. While alternative explanations exist, arousal, overload, and system models dominate environmental stress research [51]. Beyond standard stress models, smaller schools of thought have significantly shaped environmental stress research. Rooted in psychology and physiology, they delve deeper into how specific environment-individual aspects trigger stress responses and link them to distinct outcomes [51].

The Environmental Stressor Model provides a theoretical framework for understanding how exposure to environmental changes, including those associated with climate change, can act as stressors that impact mental health. Climate change throws mental health a curveball. Extreme events directly jolt us, while slow shifts like ecosystem losses whisper anxieties of change. The Environmental Stressor Model captures this interplay, placing the environment alongside individual and community influences [20,51].

The expanding body of research on climate change and mental health provides increasing evidence that extreme weather events, intensified and complicated under a changing climate, can trigger various mental health conditions. These include depressive disorder, anxiety, depression, complicated grief, survivor guilt, vicarious trauma, recovery, fatigue, substance abuse, and suicidal ideation [42]. Rising temperatures, waves, and resource disruptions create multiple hazards. Financial and social problems arise from agricultural issues, land use fragmentation, and infrastructure failure. Displacement and violence threaten stability. Despite this gloomy canvas, resilience flickers. Environmental disas-

ters cause despair but inspire charity, compassion, and post-traumatic growth as societies recover, reminding us that hope perseveres even in chaos [25,30].

An updated review of recent evidence on the mental health implications of climate change is possible due to the rapid expansion of research in the broader health and climate change field coupled with increasing public concern about climate change trends and risks. Despite the increasing awareness of the health implications of climate change, mental health is often absent from the global discourse. This reflects a broader trend where mental health, in general, has been neglected compared to physical health. Globally, the prevalence of mental health issues is exceptionally high, even without considering the additional mental health consequences of a changing climate [23].

The mental health consequences of climate change manifest through various pathways, as illustrated in Figure 2. Individuals may undergo one or multiple paths simultaneously. Direct exposure to extreme weather events linked to climate, such as floods and wildfires, not only induces physical harm but also significantly affects mental well-being, giving rise to conditions like anxiety, depression, and post-traumatic stress [50]. Addressing the mental health impacts of climate change is vital, particularly for those already disadvantaged by social, economic, and environmental factors. The mental health effects of climate change involve direct exposure to extreme weather events and the emotional toll of environmental transformations, like disappearing rivers or shifting seasons, contributing to a sense of loss termed 'solastalgia'. This underscores the urgency for comprehensive mental health support amid the evolving challenges of climate change [54]. The theoretical framework leads us to examine the relationship between climate change and mental health at a regional level across continents. We adopted the standard specification proposed by Sui, et al. [55] for an empirical analysis, which is represented by the following equation:

$$MH = f(CC, UN, GLOB, GDPG, URB) \quad (1)$$

where

MH denotes mental health, which is used as a proxy of mental disorders (MDs)—i.e., depressive disorder (DD), anxiety disorder (AD), bipolar disorder (BD), and schizophrenia (S);

CC denotes climate change, where CC has been measured by annual surface temperature change (TEMP) and total greenhouse gas emissions (TGHG);

UN is defined as the unemployment rate;

GLOB represents globalisation;

GDPG is the (gross domestic product) annual income growth rate;

URB is the population in urban areas.

Equation (1) can be represented in panel form in the following manner:

$$\mathrm{MH} = \alpha + \zeta \mathrm{CC}_{it} + \Psi UN_{it} + GLOB_{it} + \mu GDPG_{it} + £URB_{it} + €$$ (2)

We further explore the intricate relationship between climate change (CC) and mental health by disaggregating CC into two distinct measures for temperature and greenhouse gas emissions:

$$\mathrm{MH} = \alpha + \lambda \mathrm{TEMP}_{it} + \Psi UN_{it} + GLOB_{it} + \mu GDPG_{it} + £URB_{it} + €$$ (3)

$$\mathrm{MH} = \alpha + \text{Ⱶ}\mathrm{TGHG}_{it} + \Psi UN_{it} + GLOB_{it} + \mu GDPG_{it} + £URB_{it} + €$$ (4)

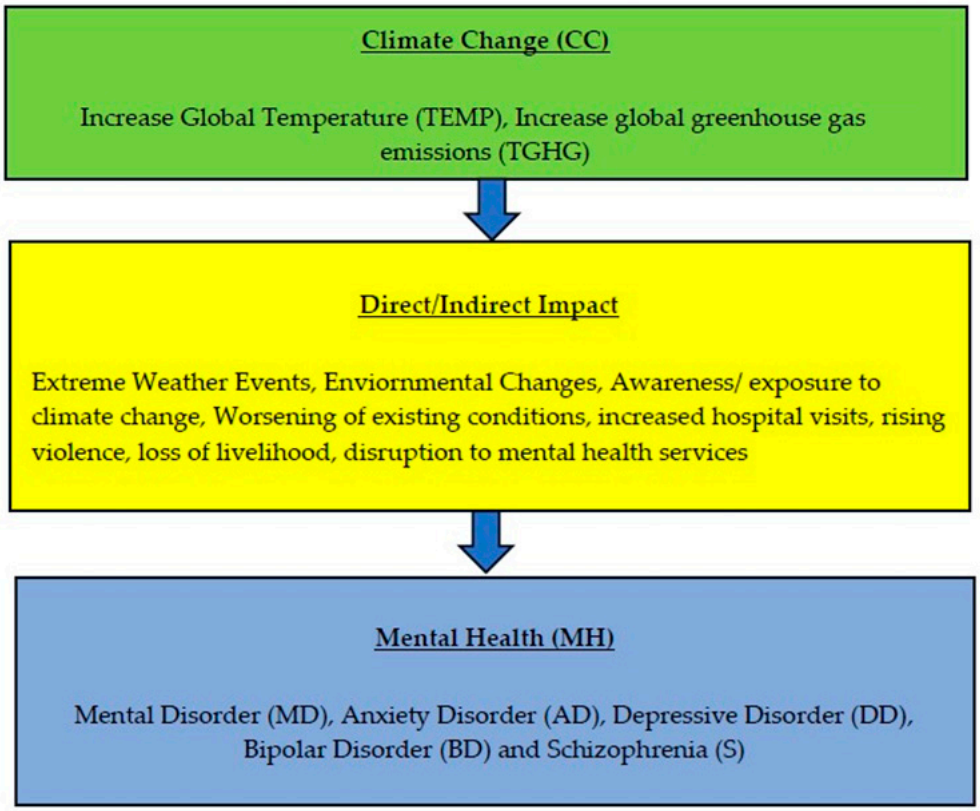


Figure 2. Relationship between climate change (CC) and mental health (MH). Source: Designed by the author(s). Adapted in part from World Health Organization (WHO), Mental Health and Climate Change: Policy Brief (3 June 2022) and Emily Hough and Nathaniel Counts, "How Climate Change Affects our Mental Health, and What We Can Do About It" Commonwealth Fund, 29 March 2023.

4. Description of Statistical Methods and Data Sources

This section describes the approaches and methods employed in the empirical analysis of this study. Understanding the specific impact of climate change on mental health is not straightforward and lacks a simple theory to rely on. It is worth exploring broad hypotheses to shed light on the consequences for mental health. It is important to note that the impacts of climate change are not homogeneous, and some individuals may experience more severe effects than others. Our database contains geographical variations regarding environmental damage. This study utilises data from regional levels across continents, i.e., Asian, European, American, African, and Oceanian countries (in total, 201 countries worldwide), covering the period from 1970 to 2020. However, the availability of data on annual surface temperature changes and greenhouse gas emissions spans the entire period, while data on various mental health disorders are only available from 1990 to 2020. This limited data availability constrains our ability to conduct more detailed analyses mainly due to the small sample size.

While existing data on mental health often focus on a few specific disorders, the Institute for Health Metrics and Evaluation (IHME) provides estimates for a wider range of mental health conditions across all age groups. These estimates are based on various data sources and assumptions and are currently one of the few sources available for a global-level analysis of mental health prevalence and burden.

This study uses a panel dataset to examine the association between climate change and mental health in 201 nations. Fixed-effects and random-effects models are more successful in handling panel data and accounting for possible country heterogeneity. For the purpose of choosing between fixed-effects random-effects models, the Hausman test was utilised in this study. A fixed-effects static-panel estimator is a better estimator than all of the models as per the outcomes of the Hausman test). A fixed-effects model, on the other hand, would

be excellent in this scenario because it can account for unobserved countries and time-fixed effects [56]. Time-invariant variables with time-invariant effects are organised in or partially in fixed-effect models [57].

The basic model is

$$Y_{it} = \alpha_i + X'_{it}\beta + a_t + v_{it}$$

where α_i (i = 1…N) is the unknown intercept for each entity (n entity-specific intercepts that are also known as the individual impact of individual heterogeneity, and it indicates the unobservable variable that accounts for the fundamental differences between various nations, which are denoted by (i)); Y_{it} is the dependent variable (DV); and mental health disorders, i.e., MD, AD, DD, BD, and S, are denoted by i = entity and t = time (for t = 1…T, i = 1…N). X'_{it} represents the independent variables (IVs); the main explanatory IVs are TEMP and TGHG, while the other control variables are UN, GLOB, GDPG, and URB. β is the coefficient for those IVs, a_t is the unobserved individual effect that is independent of time, and v_{it} is the error term (unobserved time-variant factor). Descriptions of the variables and their expected signs can be seen in Table 2.

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

Variable Type	**Symbols**	**Variable Description/Definition**		**Database**
Dependent Variables				
Mental disorder	MD.	The percentage of people with mental health disorders within the total population. This includes conditions such as anxiety, depression, schizophrenia, substance abuse, bipolar disorder, and eating disorders, according to the IHME.		Institute of Health Metrics and Evaluation (IHME) Global Burden of Disease (GBD) World Health Organization (WHO) https://ourworldindata.org/mental-health [online resource] (accessed on 14 May 2024)
Depressive disorder	DD.	Depressive disorders vary in severity, ranging from mild to moderate persistent depression (dysthymia) to severe major depressive disorder (MDD).		
Anxiety disorder	AD.	Phobias, social anxiety, obsessive compulsive disorder (OCD), post-traumatic stress disorder (PTSD), and generalised anxiety disorders are all examples of anxiety disorders.		
Bipolar disorder	BD.	Bipolar disorder is a condition in which a person's mood and activity levels are affected by a wide range of factors, ranging from low energy and activity (mania) to hypomania (hypomania) or depression (depression).		
Schizophrenia	S.	Thought echoes, thought insertions or withdrawal, and thought broadcasting characterise schizophrenia. It can cause hallucinations; delusions of control, influence, or passivity; or hallucinations of body parts moving or reacting abnormally.		
Independent Variable (IV)	Symbols	Variable description/definition	Exptd. Sign	Database
Annual surface temperature change	TEMP	Temperature change concerning a baseline climatology (degree Celsius), i.e., surface temperature change.	+	FAOSTAT Climate Change https://www.fao.org/faostat/en/#data/ET (accessed on 14 May 2024)

Table 2. *Cont.*

Variable Type Dependent Variables	Symbols	Variable Description/Definition		Database
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, CH4 (methane), N_2O (nitrous oxide), and F-gases (fluorinated gases, including HFCs, PFCs, and SF6). The measurement comprehensively assesses 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: https://www.climatewatchdata.org/ghg-emissions, accessed on 14 May 2024)
Unemployment	UN.	% of the unemployed population (out of the total population).	+/−	WDI
GDP growth	GDPG	Annual gross domestic product growth.	+/−	WDI
globalisation index	GLOB	The economic, social, and political aspects of globalisation measure the KOF globalisation index.	+/−	KOF GLOBALISATION INDEX
Urbanisation	URB	% of the urbanisation population (out of the total population).	+/−	WDI

5. Empirical Findings

This study comprehensively analysed diverse variables, encompassing environmental, economic, social, and mental health aspects. Multiple regional datasets covering numerous observations and featuring variables such as the annual surface temperature change, total greenhouse gas emissions, globalisation index, unemployment, urbanisation, and gross domestic product growth provide a rich foundation for understanding the complex interplay between these factors.

Table 3 summarises the vital data points. The annual temperature change averages 0.595 degrees Celsius, ranging from −2.06 to 3.05. The mean total greenhouse gas emissions are 43.26 units, ranging from −85.27 to 2519.0. Mental health data, based on 5610 observations, include the prevalence of various disorders: anxiety (AD), depression (DD), bipolar (BD), and schizophrenia (S). Descriptive statistics confirm that this is a well-organised dataset suitable for further analysis.

Table 3. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
TEMP	8913	0.5956357	0.6233388	−2.062	3.058
TGHG	3817	43.26419	155.6238	−85.27789	2519.02
GLOB	8980	49.71704	16.60668	14	91
UN	5307	8.201684	6.402226	0.1	38.8
URB	10,042	52.28379	24.67649	2.845	100
GDPG	8311	3.691531	6.176869	−64.0471	149.973
MD	5670	13.38747	1.986117	9.467642	19.35467
AD	5610	4.323728	1.22719	1.974823	9.015948
DD	5610	3.968681	0.9209553	1.640902	7.688213
BD	5610	0.6936509	0.2494127	0.1894145	1.676204
S	5610	0.2784279	0.0470665	0.191621	0.5060182

The correlations presented in Table 4 tell a nuanced story. Temperature rise (TEMP) is modestly linked to higher mental health issues, suggesting multifaceted influences. Similarly, greenhouse gas emissions (TGHG) hint at a potential link with mental health challenges. Specifically, the global share of the population with mental health disorders has increased from 12.9% 1990 to 13.6% in 2021 (IHME), as shown in Figure 3, coinciding with rising global temperatures and greenhouse gas emissions. Urbanisation (URB) and unemployment (UN) also show positive correlations with most mental health indicators, highlighting the intricate interplay between economic factors and well-being.

Table 4. Spearman correlation.

	MD	AD	DD	BD	S	TEMP	TGHG	UN	GLOB	GDPG	URB
MD	1.0000										
AD	0.8223	1.0000									
DD	0.4708	0.0762	1.0000								
BD	0.6809	0.6618	0.1346	1.0000							
S	0.1236	0.3215	−0.4699	0.2869	1.0000						
TEMP	0.3440	0.2265	0.2509	0.1823	0.0569	1.0000					
TGHG	0.1111	0.0327	0.2242	0.0466	0.2742	0.0102	1.0000				
UN	0.1023	0.1001	0.0643	0.2642	0.0719	0.1066	−0.1548	1.0000			
GLOB	0.3336	0.4778	−0.1256	0.5359	0.6670	0.2693	−0.1009	0.2188	1.0000		
GDPG	−0.0995	−0.1297	−0.0096	−0.2073	−0.0868	−0.0029	0.1121	−0.1274	−0.1188	1.0000	
URB	0.4062	0.5081	−0.0425	0.6629	0.5688	0.1771	−0.1726	0.2913	0.7128	−0.1576	1.0000

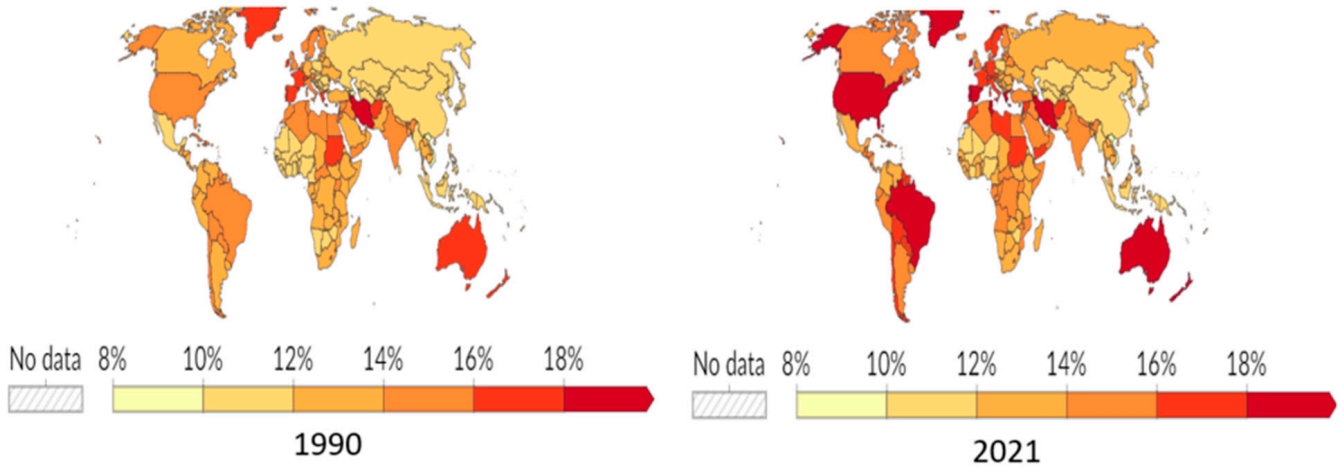


Figure 3. Share of population with mental health disorders in 1990–2021 period. Source: IHME, Global Burden of Disease (2024), https://ourworldindata.org/mental-health, accessed on 14 May 2024.

Meanwhile, the negative correlation between GDP growth and mental health indicators suggests that higher income growth may be associated with a lower prevalence of mental health disorders. It is crucial to interpret these correlations cautiously, recognising that a correlation does not imply causation. These findings underscore the intricate relationships between environmental, socio-economic, and mental health variables, emphasising the need for more nuanced analyses to unravel the underlying complexities.

Table 5 employs a fixed-effects model to investigate the complex relationship between climate-induced psychological distress and various factors across regional continent countries, i.e., Asian, European, American, African, and Oceanian countries. Our findings reveal a positive association between temperature (TEMP) and mental disorders in Asian

(coeff = 0.0429), African (coeff = 0.0170), and Oceanian (coeff = 0.0716) countries, indicating that higher temperatures are linked to increased psychological distress in these regions, which is in line with the findings obtained by Ventriglio [58]. Additionally, the total greenhouse gas emissions (TGHG) show a positive relationship with mental disorders in Asian (coeff = 0.0005), African (coeff = 0.0002), and Oceanian (coeff = 0.0001) countries. Our results support the theory that the potential contribution of climate-induced stress, such as rising temperatures and extreme weather events, can introduce uncertainties and disrupt daily life, leading to heightened stress levels, which are established precursors to mental health disorders [59]. Additionally, the environmental disruptions associated with climate change, such as natural disasters and ecosystem changes, may profoundly affect communities, causing displacement and social upheaval, further impacting mental well-being.

Table 5. Mental disorders and climate change estimation results.

Variables	Dept: Mental Disorders (MDs)									
	Asia		Europe		Americas		Africa		Oceania	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TEMP.	0.0429 ***		0.0018		0.0537		0.0170 **		0.0716 ***	
	(0.0127)		(0.0121)		(0.0299)		(0.0123)		(0.0266)	
TGHG		0.0005 ***		0.0004		−0.0001		0.0002 ***		0.0001 *
		(0.0001)		(0.0007)		(0.0003)		(0.00003)		(0.0002)
UN	0.0213 ***	0.0246 ***	0.0128 ***	0.0131 ***	0.0139 ***	0.0139 **	−0.0024	0.0018	0.0778 ***	0.0858 ***
	(0.0031)	(0.0031)	(0.0021)	(0.0025)	(0.0040)	(0.0055)	(0.0021)	(0.0023)	(0.0061)	(0.0079)
GLOB	−0.0117 ***	−0.0084 ***	−0.0111 ***	−0.0102 ***	0.0090 ***	0.0109 ***	−0.0013	−0.0048 ***	0.0043 **	0.0043 *
	(0.0011)	(0.0011)	(0.0012)	(0.0011)	(0.0022)	(0.0030)	(0.0010)	(0.0011)	(0.0019)	(0.0023)
GDPG	0.0019 **	0.0033 ***	0.0066 ***	0.0057 ***	−0.0001	−0.0002	0.0017***	0.0013 ***	−0.0022	−0.0025
	(0.0009)	(0.0008)	(0.0013)	(0.0013)	(0.0028)	(0.0034)	(0.0006)	(0.0005)	(0.0023)	(0.0025)
URB	0.0127 ***	0.0102 ***	0.0088 ***	0.0094 **	0.0025	0.0086	−0.0028*	0.0025	−0.0005	0.0077
	(0.0019)	(0.0022)	(0.0029)	(0.0039)	(0.0036)	(0.0053)	(0.0013)	(0.0017)	(0.0046)	(0.007)
C	130.85 ***	130.46 ***	140.10 ***	140.10 ***	130.39 ***	120.91 ***	120.85 ***	120.82 ***	130.69 ***	130.36 ***
	(0.0817)	(0.0916)	(0.1904)	(0.2531)	(0.1647)	(0.2483)	(0.0478)	(0.0579)	(0.1815)	(0.2499)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.2927	0.3050	0.1586	0.1357	0.0718	0.0944	0.0325	0.0972	0.4834	0.4594
No. of Observations	1116	792	1064	779	874	617	1320	1035	222	175
Cross-sections	41	38	41	38	31	29	51	50	8	8

Note: (i) Mental disorders are aggregated through various indicators, i.e., anxiety disorder, depressive disorder, bipolar disorder, schizophrenia, excessive drug use, and alcoholic disorder. TGHG is the combined effect of CO_2, CH_4, and N_2O. (ii) * represents 10% significance level, ** represents 5% level of significance, and *** represents 1% significance level.

The uncertainty of climate change is a psychological stressor, fuelling anxiety about its impact on society, economy, and personal well-being. This uncertainty worsens existing mental health issues, fostering unease. Displacement and loss, typical results of climate events, heighten mental health challenges by upending familiar settings. Coping with displacement leads to increased stress, anxiety, and mental strain [10,60]. Greenhouse gases exacerbate climate-related stressors, intensifying extreme weather and disrupting climate patterns, causing floods, droughts, heat waves, and storms. These impose significant stress, while poor air quality from increased gases links to respiratory and potential neurological issues. These complexities illustrate how environmental factors contribute to mental health decline [22].

Africa bears the brunt of climate change's fury, facing disproportionate health impacts and a rise in mental health struggles compared to the past, as Moyo, et al. [61] noted. Across Asia, landmass size and rapid warming double the global pace, raising temperatures like never before. The WMO and IPCC paint a stark picture: Asia's vulnerability exposes it to substantial challenges, with the IPCC's 2022 report highlighting surges in fatalities and illnesses fuelled by heat stress that worsen this concerning trend. Furthermore, the report highlights the link between climate change and mental health disorders like depression and anxiety.

Furthermore, Clissold, et al. [62] discussed Oceania's Anthropocene emotional landscape. Their research shows that rapid and gradual weather occurrences, direct experiences of loss and transformation, a sense of limited control over the future, and injustice have evoked various emotions. These include fear, tension, anxiety, tiredness, sadness, grief, wrath, frustration, helplessness, worry, and empowerment.

Our results indicate that the control variable unemployment (UN) demonstrates a consistently positive impact across all continents, with statistically significant coefficients in Asian, European, American, and Oceanian countries. Unemployment often leads to financial hardship and social isolation, which can cause significant stress and anxiety. This can exacerbate existing mental health conditions or lead to the development of new ones [63]. Interestingly, globalisation (GLOB) exhibits a negative relationship with mental disorders in European (coeff = −0.0084) and American (coeff = −0.0102) nations. Globalisation can create new economic opportunities, leading to increased income and job satisfaction. This can reduce stress and anxiety and improve overall well-being [64].

Moreover, gross domestic product growth (GDPG) is positively associated with mental disorders in Asian (coeff = 0.0019), European (coeff = 0.0033), and American (coeff = 0.0057) countries. Economic growth can lead to increased competition, job insecurity, and longer working hours, which can contribute to stress, anxiety, and depression [65]. Furthermore, economic growth often drives urbanisation, which can lead to social isolation and a loss of community support, both of which have been linked to mental health issues [66]. Lastly, urban population (URB) reveals a positive correlation with mental disorders in Asian, European, and American countries. Urbanisation can lead to social isolation and a sense of alienation, as individuals may struggle to connect with others in a large and impersonal city environment [67]. These continent-specific findings emphasise the multifaceted relationship between climate-related factors and psychological distress, urging a comprehensive approach to address the varied impacts across diverse regions. These results are also similar to the literature and supportive of the theory.

Table 6 shows the intricate relationship between anxiety disorders (ADs) and climate-related factors across diverse continents, including Asian, European, American, African, and Oceanian countries. Our empirical findings show a noteworthy positive association between temperature (TEMP) and anxiety disorders in Asian (coeff = 0.0456), African (coeff = 0.0207), and Oceanian (coeff = 0.0431) countries, underscoring the impact of elevated temperatures on heightened anxiety levels. Concerning total greenhouse gas emissions (TGHG), they exhibit a positive relationship with Oceanian countries (coeff = 0.0002), Asian countries (coeff = 0.00002), and American countries (coeff = 0.0038). These results are supported by studies such as that by Ebi et al. (2021), showing that heat-related mortality in low- and middle-income countries (LMICs) exists due to data scarcity, with over half of the studies focusing on China (56%) and other Asian countries (14%). LMICs, characterised by resource constraints and lower air-conditioning prevalence, often rely on behavioural adaptations and personal cooling measures, such as applying ice or towels, wetting the skin, or using water-saturated clothing and additional ventilation (e.g., fans) for heat mitigation. One reason may be that individuals in developing nations may face heightened vulnerability to these direct environmental impacts. For instance, climate change may alter soil quality, affecting agricultural practises essential for food supply. Ongoing climate change could lead to ecological 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 as independent risk factors for youth depression in developing nations [68].

Our results also indicate that the control variable unemployment (UN) is a consistent contributor to anxiety disorders, with positive and statistically significant coefficients across all continents except Oceanian (coeff = −0.0214, $p < 0.001$) countries. Unemployment often leads to financial hardship and uncertainty about the future. This can create a sense of stress and anxiety [69]. Furthermore, the globalisation variable (GLOB) demonstrates

positive associations with anxiety disorders in Asian (coeff = 0.0031; $p < 0.001$), European (coeff = 0.0021; $p < 0.001$), and American (coeff = 0.0038) nations, implying that increased interconnectedness may contribute to heightened anxiety levels. A sense of financial uncertainty and employment insecurity may result from increasing competition for jobs brought about by globalisation. This could worsen anxiety, stress, and the fear of losing one's job [70].

Table 6. Anxiety disorders and climate change estimation results.

Variables	Dept: Anxiety Disorders (ADs)									
	Asia		Europe		Americas		Africa		Oceania	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TEMP.	0.0456 ***		0.0129		0.0235		0.0207 ***		0.0431 **	
	(0.0069)		(0.0084)		(0.0264)		(0.0049)		(0.0187)	
TGHG		0.00002 **		0.0002		0.0038 **		0.00002 **		0.0002 **
		(0.00005)		(0.0005)		(0.0002)		(0.00001)		(0.0001)
UN	0.0064 ***	0.0040 **	0.0105 ***	0.0065 ***	0.0088 **	0.0106 **	−0.0007	−0.0008	−0.0131 ***	−0.0214 ***
	(0.0017)	(0.0015)	(0.0015)	(0.0018)	(0.0035)	(0.0051)	(0.0008)	(0.0008)	(0.0043)	(0.0048)
GLOB	0.0031 ***	0.0021 ***	0.0042 ***	0.0038 ***	0.0126 ***	0.0138 ***	0.0039 ***	0.0021 ***	0.0058 ***	0.0039 ***
	(0.0006)	(0.0005)	(0.0009)	(0.0009)	(0.0019)	(0.0027)	(0.0004)	(0.0003)	(0.0013)	(0.0014)
GDPG	−0.0014 ***	−0.0001	−0.001 *	−0.0035 ***	−0.0003	0.0008	−0.0001	−0.00008	−0.0019	−0.0024
	(0.0005)	(0.0004)	(0.0009)	(0.0009)	(0.0024)	(0.0031)	(0.0002)	(0.0001)	(0.0016)	(0.0015)
URB	0.0001	0.0019 *	0.0051 **	0.0050 *	0.0021	0.0041	0.0021 ***	0.0026 ***	0.0034	0.0073 *
	(0.0010)	(0.0011)	(0.0020)	(0.0028)	(0.0031)	(0.0049)	(0.0005)	(0.0006)	(0.0032)	(0.0043)
C	30.652 ***	30.529 ***	40.317 ***	50.140 ***	30.862 ***	30.711 ***	30.407 ***	30.482 ***	40.447 ***	40.416 ***
	(0.0453)	(0.0455)	(0.1323)	(0.1801)	(0.1453)	(0.2281)	(0.0192)	(0.0211)	(0.1279)	(0.1521)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.1491	0.0499	0.1065	0.0600	0.1180	0.1167	0.2903	0.1264	0.2748	0.2300
No. of Observations	1133	792	1036	763	874	617	1263	996	222	175
Cross-sections	42	38	39	37	31	29	49	48	8	8

Note: * represents 10% significance level, ** represents 5% level of significance, and *** represents 1% significance level.

Gross domestic product growth (GDPG) exhibits a negative relationship with anxiety disorders in Asian (coeff = −0.0014) and European (coeff = −0.0035) countries, suggesting that higher economic growth may be associated with lower anxiety levels. A higher GDP per capita can lead to improved living standards, including better housing, education, and healthcare. These factors can contribute to a sense of security and well-being, potentially reducing anxiety [71].

Lastly, the urban population (URB) displays positive coefficients for European (coeff = 0.0019) and American (coeff = 0.0050) countries, indicating that increased urban population may contribute to elevated anxiety levels in these regions.

Table 7 presents the association between depressive disorder (DD) and climate-related factors across Asian, European, American, African, and Oceanian countries. Our results reveal that higher temperatures in European nations (coeff = 0.025) are positively correlated with an increased prevalence of depressive disorders. American countries also show a significant positive relationship between temperature and depressive disorders (coeff = 0.0410), indicating that temperature has a notable impact on mental health in this region; these outcomes support the findings obtained by Cianconi, Betrò and Janiri [68]. The total greenhouse gas emissions (TGHG) exhibit a significant positive relationship in European (coeff = 0.0021) and American (coeff = 0.00015) countries, indicating a potential link between elevated emissions and heightened depressive disorders.

In supportive alignment with our findings in 2019, North America, the Caribbean, and Central America witnessed approximately 20% of global disasters, resulting in total damage worth USD 55 billion. Additionally, severe weather, floods, and winter storms in the United States led to significant financial impacts [30]. Bathiany, et al. [72] argued that high-income countries like the USA have contributed heavily to climate change due to greenhouse gas emissions and industrial activity; the burden of morbidity and mortality because of climate change will largely fall upon low-income nations worldwide. Hwong, et al. [73] highlighted the strengths and weaknesses of ex-

isting approaches to researching the effects of climate change on mental health. They argued that the studies mainly come from high-income countries, particularly the USA and Australia, where the effects might not be generalisable to low-income and middle-income settings.

Table 7. Depressive disorders and climate change estimation results.

Variables	Dept: Depressive Disorders (DDs)									
	Asia		Europe		Americas		Africa		Oceania	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TEMP.	0.009		0.025 **		0.0410 ***		−0.0150		0.0057	
	(0.0087)		(0.0105)		(0.0154)		(0.0095)		(0.0139)	
TGHG		0.0003		0.0021 ***		0.00015 **		0.00006		0.0001 *
		(0.00006)		(0.0006)		(0.0002)		(0.00002)		(0.00008)
UN	0.0133 ***	0.0114 ***	−0.0006	0.0055 **	0.0079 ***	0.0071 ***	0.0058 ***	0.0028	0.0289 ***	0.0336 ***
	(0.0021)	(0.0019)	(0.0019)	(0.0022)	(0.0021)	(0.0026)	(0.0016)	(0.0018)	(0.0032)	(0.0029)
GLOB	−0.0039 ***	−0.0049 ***	−0.0108 ***	−0.0110 ***	−0.0024 **	−0.0008	−0.00005	−0.0028 ***	−0.0019 *	−0.0013
	(0.0008)	(0.0007)	(0.0011)	(0.0011)	(0.0011)	(0.0014)	(0.0007)	(0.0008)	(0.0010)	(0.0008)
GDPG	−0.0007	0.00003	0.0036 ***	0.0051 ***	−0.0008	−0.0024	0.0007 *	0.0001	−0.0003	−0.0007
	(0.0006)	(0.0005)	(0.0011)	(0.0011)	(0.0014)	(0.0016)	(0.0004)	(0.0003)	(0.0012)	(0.0009)
URB	0.0028 **	0.0051 ***	0.0038	0.0135 ***	−0.00008	0.0029	−0.0032 ***	−0.0037 ***	−0.0024	−0.0018
	(0.0013)	(0.0014)	(0.0025)	(0.0034)	(0.0018)	(0.0025)	(0.0010)	(0.0014)	(0.0024)	(0.0026)
C	30.633 ***	30.561 ***	40.402 ***	30.735 ***	30.652 ***	30.412 ***	40.930 ***	50.032 ***	30.726 ***	30.679 ***
	(0.0569)	(0.0565)	(0.1652)	(0.2205)	(0.0851)	(0.1187)	(0.0372)	(0.0462)	(0.0952)	(0.0932)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.0638	0.1370	0.1653	0.1528	0.0330	0.0272	0.0367	0.0466	0.2888	0.4767
No. of Observations	1133	792	1036	763	874	617	1263	996	222	175
Cross-sections	42	38	39	37	31	19	49	48	8	8

Note: * represents 10% significance level, ** represents 5% level of significance, and *** represents 1% significance level.

Our findings also indicate that unemployment (UN) consistently contributes to depressive disorders across Asian, European, American, and Oceanian countries. Unemployment can lead to financial hardship and uncertainty about the future. This can create a sense of stress and anxiety, which can contribute to feelings of hopelessness and despair [74]. Globalisation (GLOB) presents a distinctive pattern with negative coefficients across continents, especially in Asian, European, and African countries, suggesting that higher globalisation levels may be associated with lower levels of depressive disorders. Globalisation can create new economic opportunities, leading to increased income and job satisfaction. This can reduce depression, stress, and anxiety and improve overall well-being [75]. The complex interplay of gross domestic product growth (GDPG) and depressive disorders is evident, with significant coefficients being found in European nations. A higher GDP per capita can be associated with increased competition, longer working hours, and higher levels of stress [65]. Urban population (URB) displays positive coefficients for Asian, European, American, and Oceanian countries, indicating a potential connection between increased urbanisation and an elevated prevalence of depressive disorders.

Table 8 delves into the intricate relationship between bipolar disorder (BD) and climate-related factors across diverse continents, encompassing Asian, European, American, African, and Oceanian countries. The analysis uncovers significant insights into the nuanced dynamics of bipolar disorder in different regions. Temperature (TEMP) exhibits a significant positive association with bipolar disorders in Asian (coeff = 0.0009), European (coeff = 0.0005), African (coeff = 0.0007), and Oceanian (coeff = 0.0053) countries, highlighting the impact of temperature on mental health; these results align with those of Triki and Sellami [76]. The total greenhouse gas emissions (TGHG) show significant coefficients for Asian (coeff = −0.0008) and European (coeff = 0.00003) countries, suggesting a potential link between emissions and bipolar disorder.

In support of our findings, a study conducted in Ethiopia, a low-income country heavily reliant on the local environment for essential human and animal needs, revealed that seasonal environmental changes, particularly those related to water security, expose

populations to significant emotional distress [22]. Small island developing states in the Pacific Ocean, considered particularly vulnerable to the impacts of climate change, face heightened fear and worry at personal and community levels due to sea level rise, as reported in low-lying villages in the Solomon Islands in the South Pacific [77]. Research conducted in Tuvalu, another small Pacific Island threatened by sea level rise, highlights individual experiences of distress in the face of climate change, emphasising the importance of providing culturally informed social and mental health services in the region [78]. In Bangladesh, three studies have documented adverse effects on emotional well-being resulting from climate-induced immobility [79].

Table 8. Bipolar disorder and climate change estimation results.

Variables	Dept: Bipolar Disorders (BDs)									
	Asia		Europe		Americas		Africa		Oceania	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TEMP.	0.0009 ***		0.0005 **		0.0015		0.0007 **		0.0053 ***	
	(0.00021)		(0.0002)		(0.0010)		(0.0001)		(0.0020)	
TGHG		0.0008 ***		0.00003 **		0.00001		0.00004 *		0.00004 *
		(0.000018)		(0.00001)		(0.00001)		(0.000025)		(0.00001)
UN	0.00004	0.00006	0.0001 ***	0.00003	0.0005 ***	0.0005 ***	0.00009 ***	0.00007 ***	0.0033 ***	0.0034 ***
	(0.00005)	(0.00005)	(0.00004)	(0.00005)	(0.0001)	(0.0001)	(0.00002)	(0.00001)	(0.0004)	(0.0005)
GLOB	0.00024 ***	0.0002 ***	0.0003 ***	0.0003 ***	0.0009 ***	0.0010 ***	0.0001 ***	0.0001 ***	0.0004 ***	0.0005 ***
	(0.00001)	(0.00002)	(0.00002)	(0.00002)	(0.00008)	(0.0001)	(0.00009)	(0.00008)	(0.0001)	(0.0001)
GDPG	−0.00004 ***	−0.00001	−0.00001	−0.00005 **	−0.0001	0.00001	−0.00006	−0.00006 *	−0.0002	−0.0002
	(0.00001)	(0.00001)	(0.00002)	(0.00002)	(0.0001)	(0.0001)	(0.00005)	(0.00003)	(0.0001)	(0.0001)
URB	0.00009 ***	0.0002 ***	0.0001 **	0.0001	0.00005	−0.00006	0.0002 ***	0.0002 ***	−0.0006 *	−0.0002
	(0.00003)	(0.00003)	(0.00006)	(0.00008)	(0.0001)	(0.0001)	(0.00001)	(0.00001)	(0.0003)	(0.0005)
C	0.5449 ***	0.5204 ***	0.7549 ***	0.7640 ***	0.882 ***	0.8839 ***	0.5693 ***	0.5775 ***	0.5939 ***	0.5636 ***
	(0.0014)	(0.0015)	(0.0040)	(0.0055)	(0.0059)	(0.0086)	(0.0004)	(0.0004)	(0.0138)	(0.0174)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.3591	0.3495	0.2445	0.2132	0.3253	0.2867	0.7298	0.6985	0.2857	0.2770
No. of Observations	1133	793	1036	763	874	617	1263	996	222	175
Cross-sections	42	38	39	37	31	29	49	48	8	8

Note: * represents 10% significance level, ** represents 5% importance, and *** represents 1% significance level.

Our results also indicate that the control variable, unemployment (UN), demonstrates a positive relationship in European, American, African, and Oceanian countries. Globalisation (GLOB), gross domestic product growth (GDPG), and urban population (URB) also exhibit varying relationships across continents.

Table 9 investigates the relationship between schizophrenia (S) and climate-related factors across diverse continents, including Asian, European, American, African, and Oceanian countries. Our results reveal that climate change indicators—temperature (TEMP) and total greenhouse gas emissions (TGHG)—display no statistically significant association with schizophrenia in any continent, i.e., Asian, European, American, African, and Oceanian regions, which supports the findings of Teobaldi, et al. [80]. Unemployment (UN) presents a positive relationship with schizophrenia in Asian, European, American, and Oceanian countries. Unemployment can lead to significant stress and anxiety [74], which can trigger or worsen symptoms of schizophrenia. Globalisation (GLOB) and urban population (URB) show consistent positive associations, while GDP growth shows negative associations with schizophrenia across all continents, highlighting the potential role of economic and global factors in mental health outcomes. Globalisation can lead to increased competition, job insecurity, and rapid cultural changes, which can contribute to stress and anxiety [70] and can trigger or worsen symptoms of schizophrenia. Similarly, urban living can be stressful, with factors such as noise pollution, overcrowding, and fast-paced lifestyles contributing to anxiety and stress [67], which may worsen the conditions of schizophrenia.

Figure 4 depicts a Global Heat Plot utilising hexagons to showcase the relationship between mental disorder prevalence and annual surface temperature changes across Asia (Panel A), Europe (Panel B), the Americas (Panel C), Africa (Panel D), and Ocea-

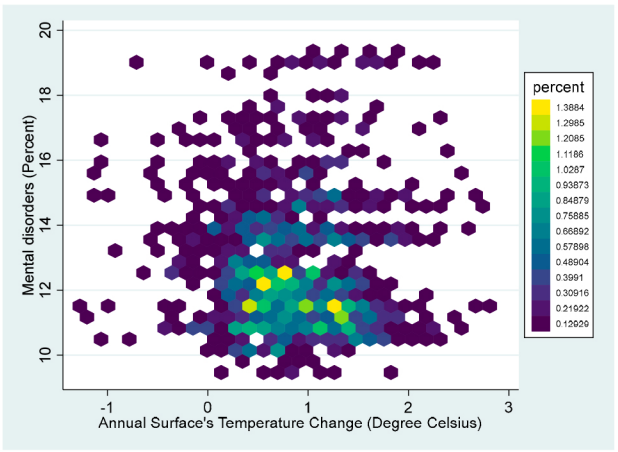
nia (Panel E). The plot's axes correspond to geographical locations on Earth's surface, aiding in identifying regions with differing associations between mental disorders and surface temperature changes. In each plot, hexagons symbolise clusters of data points, where the colour intensity or shading indicates the density of mental disorder cases, or the magnitude of temperature change specific to each continent. A legend accompanying the plot clarifies the colour gradients, with warmer colours like yellow signifying a more robust correlation and cooler colours (blue or green) representing medium and weaker correlations, respectively. Asia demonstrates a stronger correlation between mental disorders and temperature within the ranges of 10–14 and 0–2, respectively. Europe displays a seemingly higher correlation than Asia with ranges of 10–18 and 0–2, respectively. For the Americas, the ranges are 10–14 and 0–2; for Africa, the ranges are 10–14 and 0–2. The correlation hovers around 12 and 0–1 in Oceania, respectively. Similar patterns or trends are noticeable in Asia, Europe, and Africa, as well as between the Americas and Oceania.

Table 9. Schizophrenia and climate change estimation results.

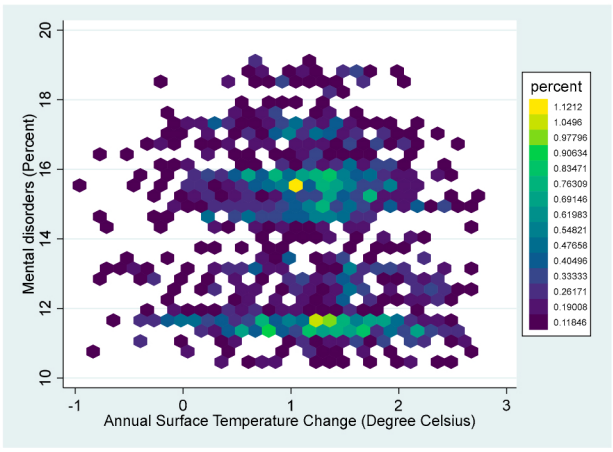
Variables	Dept: Schizophrenia (S)									
	Asia		Europe		Americas		Africa		Oceania	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TEMP.	−0.0002		0.0001		0.0004		0.0002		0.0001	
	(0.0001)		(0.0002)		(0.0003)		(0.0001)		(0.0004)	
TGHG		0.00009		−0.00001		0.00003		0.00008		−0.00006
		(0.00001)		(0.00009)		(0.00002)		(0.00003)		(0.00003)
UN	0.0004 ***	0.0003 ***	0.0001 ***	0.00007 **	0.0003 ***	0.0002 ***	0.00009	−0.00001	0.0002 **	0.0001
	(0.00004)	(0.00003)	(0.00003)	(0.00003)	(0.00004)	(0.00004)	(0.00003)	(0.00002)	(0.0001)	(0.0001)
GLOB	0.0002 ***	0.0001 ***	0.0003 ***	0.0002 ***	0.0003 ***	0.0002 ***	0.00006 ***	0.00004 ***	0.0002 ***	0.0002 ***
	(0.00001)	(0.00001)	(0.00002)	(0.00001)	(0.00002)	(0.00002)	(0.00001)	(0.00001)	(0.00003)	(0.00003)
GDPG	−0.00003 ***	−0.00003 ***	−0.0001 ***	−0.0001 ***	−0.0001 ***	−0.00009 ***	−0.00008 ***	−0.00004 ***	−0.00002	−0.00004
	(0.00001)	(0.00001)	(0.00002)	(0.00001)	(0.00003)	(0.00002)	(0.00009)	(0.00005)	(0.00003)	(0.00003)
URB	0.0003 ***	0.0003 ***	−0.0001 ***	0.00003	0.0001 ***	0.0001 ***	0.0003 ***	0.0002 ***	−0.00006	−0.0002 **
	(0.00002)	(0.00002)	(0.00005)	(0.00005)	(0.00003)	(0.00004)	(0.00001)	(0.00002)	(0.00007)	(0.0001)
C	0.2579 ***	0.2619 ***	0.2915 ***	0.2844 ***	0.2713 ***	0.2720 ***	0.2040 ***	0.2091 ***	0.3164 ***	0.318 ***
	(0.0012)	(0.0010)	(0.0034)	(0.0033)	(0.0017)	(0.0019)	(0.0007)	(0.0007)	(0.0029)	(0.0038)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.5489	0.5730	0.3022	0.3437	0.4824	0.5131	0.5118	0.6127	0.2725	0.2954
No. of Observations	1133	792	1036	763	874	617	1263	996	222	175
Cross-sections	42	38	39	36	31	29	49	48	8	8

Note: ** represents 5% level of significance, and *** represents 1% significance level.

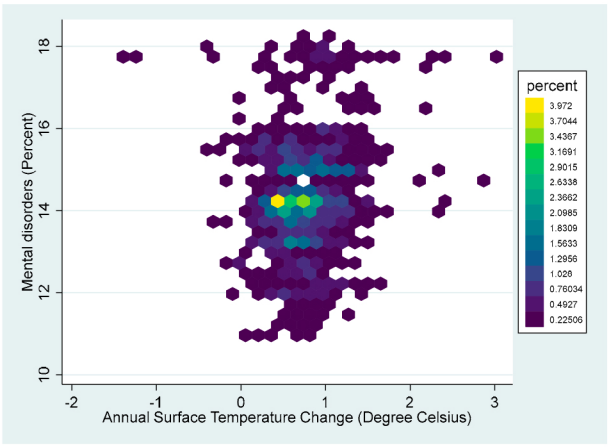
Figure 5 illustrates a Global Heat Plot utilising hexagons to display the correlation between mental disorder prevalence and total greenhouse gas emissions across continents: Asia (Panel A), Europe (Panel B), the Americas (Panel C), Africa (Panel D), and Oceania (Panel E). This might include a correlation between 10 and 16 in mental disorder prevalence and between −100 and 100 in total greenhouse gas emissions. Europe might exhibit a higher correlation, such as in the range of 10–18 in mental disorder prevalence and in the range of −50 to 50 in total emissions. The correlation in the Americas might range from 12 to 16 with emissions around 0, in Africa from 10 to 16 with emissions ranging from −500 to 500, and in Oceania from 10 to 12 with emissions ranging from −100 to 100, respectively. Similar patterns or trends might be observable between specific continents, such as Asia, Europe, Africa, and the Americas. This visualisation allows for a comparative analysis of the relationship between mental disorder prevalence and total greenhouse gas emissions across continents, highlighting potential global correlations or variations in these associations.



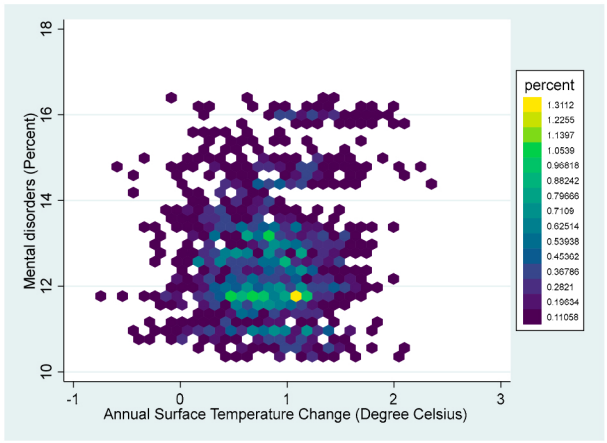
(**A**)
Asia



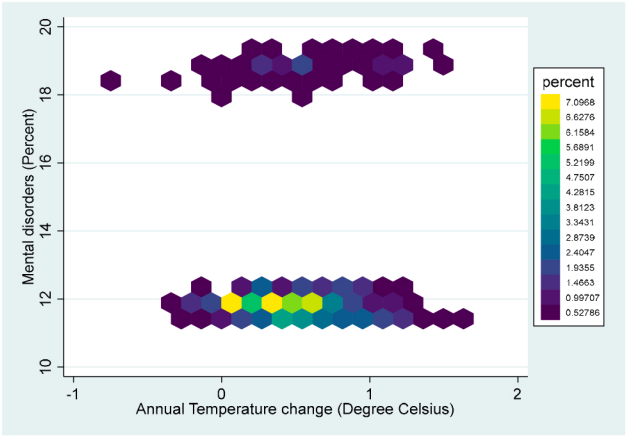
(**B**)
Europe



(**C**)
Americas



(**D**)
Africa



(**E**)
Oceania

Figure 4. Global Heat Plot using hexagons to present correlations between mental disorders and annual surface temperature change.

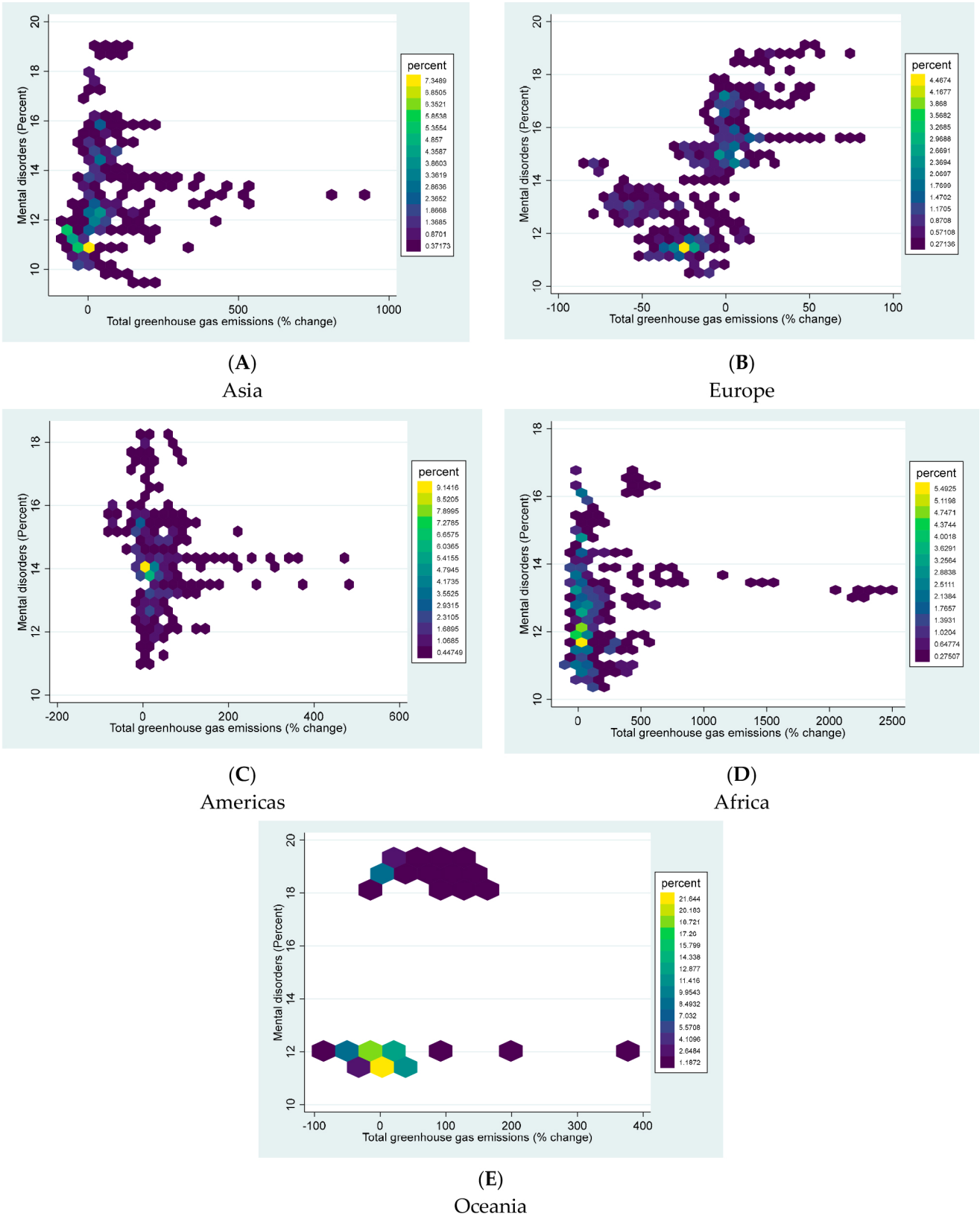


Figure 5. Global Heat Plot using hexagons to present correlations between mental disorders and total greenhouse gas emissions.

6. Conclusions and Policy Implications

This continent-specific analysis reveals distinct patterns in how climate change factors, like temperature shifts and greenhouse gas emissions, impact mental health disorders across diverse populations. Our findings underscore a strong and consistent link between rising temperatures and adverse mental health outcomes across various regions. In Asian, African, and Oceanian countries, rising temperatures exhibited significant associations with mental anxiety and bipolar disorders. European countries showed connections primarily with depressive and bipolar disorders, while American countries predominantly highlighted associations with depressive disorders. The impact of greenhouse gas emissions also varied across continents, with Asian countries showing links with various mental disorders, anxiety, and bipolar disorder, while Europe highlights depressive and bipolar disorders, the Americas mainly exhibit connections with anxiety and depressive disorders, African nations highlight associations with mental and anxiety disorders, and Oceanian countries specifically show connections to anxiety disorders.

Our empirical findings align with the existing literature, emphasising that beyond simple numerical shifts, alterations in climate patterns signify a spectrum of stressors, including extreme weather events and prolonged high temperatures, contributing to heightened psychological stress. These stressors disrupt daily routines, induce uncertainty, and evoke anxiety, highlighting the complex interplay between environmental changes and mental well-being. Regional nuances emerge, with North America facing the devastating aftermath of wildfires and hurricanes, leading to widespread trauma, anxiety, and PTSD. South America grapples with environmental degradation and biodiversity loss due to deforestation, triggering distress, depression, and cultural trauma. Water scarcity from droughts and shortages exacerbates these issues, further deteriorating mental health conditions. Oceania's changing climate ripples globally, with melting ice and rising sea levels contributing to weather extremes that transcend continents, influencing mental health worldwide.

This continental-level analysis underlines the urgent need for global, comprehensive, and region-specific efforts to address climate change's profound impact on mental health. Acknowledging diverse mental well-being dynamics across regions is crucial for crafting effective policies. In regions with widespread mental health issues (Asia, Africa, and Oceania), comprehensive mental health services and climate adaptation strategies are essential. This includes strengthening mental health infrastructure, implementing community-based interventions, and developing climate adaptation plans. In regions with increased anxiety and depression (Europe and the Americas), targeted mental health support and resilience-building programmes are crucial. This involves expanding access to mental health services, promoting mindfulness techniques, and fostering community resilience.

It is recognized that addressing climate change goes beyond environmental concerns; it is integral to global mental well-being. Mitigating climate change's impacts alongside enhancing community resilience is pivotal for safeguarding mental health. Our research fosters an understanding of the link between environmental change and mental well-being, stressing the need for a holistic approach that addresses climate change's root causes, reduces emissions, and fosters community resilience. Recognising the co-benefits of climate action on mental well-being is crucial. Initiatives promoting active transportation and expanding green spaces offer double benefits, reducing emissions and positively impacting mood and mental health by connecting people with nature. Our study reinforces the inseparable link between climate change and mental health, advocating comprehensive strategies that mitigate climate change's impacts on mental health and promote global well-being through tailored policies and fostering community resilience.

Limitations and Future Research Directions

Due to data scarcity, stigma in some regions, and limitations in establishing direct causality, our study primarily identifies correlations between climate change and mental

health. Analysing regional data may mask population variations, and resource constraints limit generalizability. However, these findings highlight crucial research gaps for future investigations into the nuanced relationship between climate change and mental health across diverse populations.

Author Contributions: Conceptualisation, P.N. and I.Y.; methodology, K.Z.; software, I.Y.; validation, D.M., H.L. and S.A.; formal analysis, P.N., I.Y. and H.L.; investigation, K.Z.; writing—original draft preparation, S.A.; writing—review and editing, I.Y and S.A.; visualisation, D.M. All authors have read and agreed to the published version of the manuscript.

Funding: Guangdong Basic and Applied Basic Research Foundation (2022B1515120060) and Research on Issues in the Development of the Digital Economy Industry (PT252022035).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data is freely and publicly available at the provided links. The data presented in this study are available at https://www.fao.org/faostat/en/#data/ET, https://www.climatewatchdata.org/ghg-emissions, https://ourworldindata.org/mental-health, https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html, and https://databank.worldbank.org/ (accessed on 14 May 2024).

Conflicts of Interest: The authors declare no conflicts of interest.

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