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Review

Climate Change, Socio-Economic Status, and Life Expectancy

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Abstract: The relationship between climate change, socio-economic status, and life expectancy is complex and interlinked. Climate change exacerbates environmental conditions that disproportionately affect disadvantaged communities, often due to lower socio-economic status. Poorer populations are generally more vulnerable to extreme weather events, such as heatwaves and floods, because they have fewer resources for adaptation and recovery. For instance, they might live in less durable housing, have limited access to healthcare, and face higher exposure to environmental hazards. This increased vulnerability can lead to higher morbidity and mortality rates, thereby reducing life expectancy. Additionally, socio-economic status impacts an individual's ability to mitigate or adapt to climate-related changes. Those with lower incomes may struggle more with the health impacts of climate change, as they might lack the financial means to afford preventive measures, such as air conditioning or healthcare services. Overall, climate change can deepen existing inequalities by disproportionately affecting those who are already marginalized, contributing to a decline in life expectancy for these vulnerable groups.

Keywords: climate change; heat; life expectancy; poverty; racism

1. Introduction

Climate change has caused a 1.1 °C rise in the global average temperature compared to pre-industrial levels, with projections suggesting increases of 2.5 to 2.9 °C by the century's end if significant reductions in greenhouse gas emissions are not made. The summer of 2023 was exceptionally hot, marking the highest temperatures in the Northern Hemisphere since 1850, and likely the hottest in the past 2000 years, according to evidence from tree rings showing natural climate variations. The majority of this warming is linked to greenhouse gas emissions from burning fossil fuels. The Intergovernmental Panel on Climate Change has definitively reported that human activities, particularly fossil fuel combustion, are driving the warming of the oceans, land, and atmosphere. They also assert that extreme weather patterns are already being observed and recent heatwaves are directly linked to climate change. However, other factors such as El Niño, an underwater volcanic eruption, and a reduction in sulphur dioxide aerosol pollution from container ships contributed to the extreme heat of 2023. According to data derived from tree rings, the average temperature from June to August 2023 was 2.20 degrees Celsius warmer compared to the summer average between the year 1 and 1890. Compared to the summer average between 1850 and 1900, the summer of 2023 was 2.07 degrees Celsius warmer. Trees grow with a distinctive pattern of rings: light in spring and early summer, and dark in late summer and autumn. Each pair of rings represents a year, and differences between the rings provide clues about environmental conditions. Trees tend to grow more and form wider rings during warm and humid years. Most of the data used in the study came from dead trees and historical wood samples. These data suggest that the Earth natural temperature was cooler than the baseline used by scientists to discuss climate targets, such as limiting global warming to 1.5 degrees Celsius above pre-industrial levels. It is important to keep in mind that over long periods of time, like 2000 years, there have been various volcanic eruptions. Large eruptions, at least on land, can cool the Earth by spraying sulphur dioxide aerosols into the atmosphere. Over the past 2000 years, there have been about 20 or 30 eruptions that have lowered average temperatures [1–3].

According to the WHO, more than 166,000 people died due to heatwaves between 1998 and 2017 [4]. This makes heat one of the most lethal weather-related hazards, alongside cold spells, floods, lightning, and hurricanes. However, its effects are often underappreciated, as death certificates typically cite causes like heart failure without indicating that the individual had been exposed to extreme heat. A recent study showed that more than one-third of heat-related deaths between 1991 and 2018 in 43 countries are attributable to anthropogenic greenhouse gas emissions. Models examining scenarios with varying degrees of warming all predict devastating increases in heat-related mortality and morbidity, with regional variations [5,6].

In the United States, the yearly occurrence of heatwaves, extended periods of abnormally high temperatures relative to a region's seasonal average, has doubled since the 1980s, and the heatwave season is now over three times longer than in the 1960s. While some fluctuations occur naturally, overall, heatwaves have grown in both frequency and duration, while severe cold waves have diminished. Compound events, such as droughts or wildfires coinciding with heatwaves, have become more frequent, and this trend is projected to keep increasing. The frequency and magnitude of extremely intense wildfires have more than doubled, with increases largely concentrated in the boreal and temperate coniferous forests of the Northern Hemisphere. In addition to recording the highest global temperature, 2023 also saw the most intense wildfires [7,8].

2. Heat Exposure and Diseases

Exposure to heat has a profound impact on human health, both immediately and over the long term. It also indirectly influences health through environmental consequences, including declines in crop quality and yield, as well as water availability. The greatest health risk comes from extreme heat exposure, though the effects of temperatures above historical norms are also well acknowledged [2].

The range of heat-related diseases includes heat stroke, heat exhaustion, heat syncope, heat oedema, heat cramps, and heat rash. Heat stress can also be deadly by worsening pre-existing conditions such as cardiovascular or respiratory diseases. Children, older people, and individuals with chronic health issues are the most at risk. However, even young, healthy adults can succumb to extreme heat. Many fatalities occur during intense heatwaves, particularly when night time temperatures remain high. Some of the most lethal heatwaves have taken place in temperate regions unexpectedly hit by extreme heat. In 2003, a heatwave in France led to at least 14,000 deaths. However, these acute diseases, along with the acute effects of heat such as sunburn and severe burns from contact with hot surfaces, represent only a fraction of the overall health burden attributable to heat. Substantial epidemiological evidence links both prolonged periods of extreme temperatures (i.e., heatwaves) and single days of high temperature to a wide range of adverse health outcomes, as cardiovascular, kidney, and respiratory diseases as well as mental disorders and adverse birth outcomes [2,9].

Even moderate heat can affect the heart. External temperatures of just 34 °C in humid conditions can cause a constant increase in heart rate, even before body temperature rises. Identifying the combination of temperature and humidity can be useful for developing protective strategies. Cottle et al. [10] conducted a study where 51 young healthy participants engaged in light physical activity in an environmental simulation chamber (where temperature and/or humidity were increased every 5 min), while monitoring body temperature and heart rates. The increase in heart rate under humid conditions began at around 34 °C, while in dry air, the threshold was approximately 41 °C. Cardiovascular stress started about 20 min before the increase in core body temperature. Henderson et al. [11] demonstrated that heat affects the heart even at rest. At 50 °C with 50% humidity, the resting heart rate was on average 64% higher than that measured at 28 °C. The human body regulates temperature through sweating and increased blood flow, raising heart rate. For healthy young individuals, this effort might be harmless, but for older people or those with heart pathologies, it could be lethal. A 2022 meta-analysis [12] showed that an increase in temperature of just 1 °C is associated with a 2.1% increase in the risk of death from cardiovascular diseases.

The links between extreme heat exposure and rising emergency room visits and hospital admissions are well-established. For instance, a large study of adults across the United States found that days in the 95th percentile of local warm-season temperatures were linked to a 7.8% increase in the relative risk of emergency visits for any cause (resulting in 24 additional visits per 100,000 people at risk per day), with notable increases in visits for heat-related diseases, kidney diseases, and mental health disorders. An analysis of approximately 50 million summer hospitalizations revealed higher admission rates (including those for all causes, respiratory conditions, coronary cardiovascular diseases, diabetes, fluid and electrolyte imbalances, and kidney failure) as the daily maximum heat index rose across different U.S. regions. Mortality also climbs with heat and heatwaves. It's estimated that high temperatures, including multiple heatwaves, from late May to early September 2022 in Europe contributed to 61,672 heat-related deaths. A study of deaths and emergency hospitalizations in Houston, Texas, between 2004 and 2013 showed that those over 65 were dying from hot days at higher rates than officially recorded. Extreme heat remains one of the most underestimated natural threats [13–16].

Variations from historical temperature norms greatly affect the body's ability to tolerate and adapt to heat. Both high absolute temperatures (e.g., 37 °C) and unusually high temperatures (e.g., the 99th percentile compared to historical averages) contribute to increased mortality during heatwaves. Even moderately hot days can be harmful without reaching extreme temperatures. The health impact of a specific temperature may vary depending on the level of adaptation, such as when high temperatures occur in regions where they are uncommon, or when they occur either later or earlier in the season than usual [17–19].

Research connecting heat levels to hospitalizations has demonstrated that the heat index threshold at which hospitalization risk increases differs by region. In cooler areas, hospitalization rates begin to rise at heat index levels lower than those prompting heat advisories. Some studies indicate that humidity might affect the link between temperature and mortality, although findings have been inconsistent [3,20].

Despite the role of air conditioning and other factors in acclimatization, we are nearing the physiological and societal limits of adaptation. Key challenges include the ability of current electrical systems to cope with sustained air conditioning demand and the expenses involved in expanding infrastructure to meet these needs. This becomes especially critical when heatwaves span vast regions. The increasing occurrence of heat domes, a meteorological phenomenon in which an area of high-pressure forms in the atmosphere, trapping warm air below, has caused high temperatures and heatwaves in many regions in recent years. The growing frequency of water shortages due to extended periods of extreme heat presents additional challenges in ensuring sufficient cooling and hydration [21,22].

Health risks related to temperature are highly heterogeneous across locations and populations. Notable variations in heat-related risks have been observed globally, with significant evidence of acclimatization. Health risks associated with high temperatures are greater in hotter regions and are reduced in line with historical average temperatures. In certain countries, but not in others, the risks linked to extreme heat have significantly decreased in recent decades. This decrease in risk is only partially accounted for by the rise in air conditioning use [2,23].

Using mortality and temperature data, along with previous research on the impact of heat on mortality, it is estimated that from 2003–2012 to 2013–2022, heat-related deaths increased by an average of 17 per 100,000 people annually across Europe. The rise in heat-related mortality was more pronounced in women compared to men. Gender differences can be attributed to variations in heat dissipation and sweating rates. Women may also face a higher risk of heat stress post-ovulation, as they typically experience elevated body temperatures during this period. Additionally, the gender gap is partly due to women generally having a longer life expectancy than men, with older individuals being more susceptible to heat stress. Older adults are also more likely to live alone, increasing their risk. Warmer temperatures are enabling disease-carrying parasites to spread into new areas and are boosting tick populations. One pathogen becoming more prevalent due to climate change is the single-celled parasite *Leishmania infantum*. This parasite is transmitted to humans through bites from female sandflies that are infected. Warmer and more humid conditions in Europe have allowed sandflies and their parasites to move northward into new regions. Rising temperatures provide better conditions for sandfly survival and reproduction and may also speed up the parasite's lifecycle within the sandflies. Warmer conditions have also made Europe more suitable for the tick *Ixodes ricinus*, which transmits various diseases, including Lyme disease and tick-borne encephalitis, through bites. Compared to 1951–1960, the period from 2013–2022 has seen a more hospitable climate for *I. ricinus* in Europe, as indicated by the increased number of months per year with optimal temperatures for its juvenile life stage [24,25]. Furthermore, these climatic shifts can affect the behaviour of pathogen-transmitting ticks and their preference for a host. In a study designed to assess how temperature influences host selection in *Rhipicephalus sanguineus*, a potential vector of rickettsioses, researchers found that rising temperatures increase the probability of adult ticks feeding on humans. Within the temperate subspecies of *Rhipicephalus sanguineus*, higher temperatures resulted in a stronger tendency to choose humans rather than dogs [26].

3. Exposure to Heat and Diseases in High-Risk Individuals and Populations

People with lower education and poorer socioeconomic status are more likely to experience early onset of diseases, loss of functionality, and physical disability. Hayward et al. [27] reported that individuals with a low socioeconomic status experience disease onset and mortality 5–10 years earlier than those with higher socioeconomic status. The average number of biological risk factors indicating physiological dysregulation is also higher for poorer and less educated individuals.

Low socioeconomic status is considered a health risk factor, similar to smoking, alcohol consumption, obesity, hypertension, and environmental pollution, and it reduces life expectancy, i.e., the statistical measure indicating the average number of years a person can expect to live based on prevailing mortality conditions in a given population and time period. Low socioeconomic status is an inexorable factor that can lead to early disease and death. The health effects are visible at all stages of life, but particularly in the early years. Being born into poverty reduces life expectancy, with a greater impact in terms of years of life lost compared to hypertension, obesity, and alcohol consumption, but less than that of physical inactivity [28,29].

In Italy, one of the longest-living countries in the world, there is a significant life expectancy gap between the North and the South. The average life expectancy in the North is 81.6 years for males and 85.6 years for females, while in the South, it is 80 and 84 years, respectively. Even more striking are the healthy life expectancy figures, with 66.5 years in Bolzano province (North) compared to 52.8 years in Basilicata region (South). The reduction in mortality over the past fifteen years has been greater in the North (27%) compared to the South (20%). This difference is reflected in the lower disposable income per capita of households in the South (€16.1 k annually) compared to those in the Centre-North (€23.6 k annually). In the South, economic resources and healthcare services are also scarce: per capita healthcare spending varies significantly, being 25% higher than the national average in Bolzano province (North) and 10% lower in Calabria region (South) [30,31].

In a period of low economic growth in Europe, health inequalities are a priority for experts. However, a recent study showed that in Western Europe, the economic conditions related to the crisis did not increase health inequalities, thanks to a more effective welfare system compared to the United States. The "Lifepath" research consortium, funded by Horizon 2020, studied the effects of socioeconomic inequalities on ageing. The objectives included the impact of inequalities on health and the underlying biological mechanisms. Data from 1.7 million participants in Europe, the United States, and Australia showed that socioeconomic conditions predict mortality and functional decline as well as known risk factors. Disadvantaged conditions affect biological systems from childhood, suggesting that improving socioeconomic conditions is as crucial as addressing known risk factors [32].

Low levels of education and socioeconomic status negatively impact health and life expectancy through a pro-inflammatory state. Diseases such as cardiovascular disorders, dementia, and cancer, which are leading causes of mortality, have an inflammatory component. Socially disadvantaged individuals and populations are disproportionately exposed to environments that can be characterized as pro-inflammatory. This includes exposure to infectious agents in overcrowded conditions, poor housing quality, or insufficient access to sanitation services. Health-damaging behaviours, more prevalent among socioeconomically disadvantaged groups with low levels of education, may expose individuals to pro-inflammatory and oxidative factors such as tobacco smoke and dietary behaviours (junk food) that lead to visceral obesity, also responsible for a pro-inflammatory state. Cumulative social disadvantage can lead individuals to experience adverse psychological conditions, resulting in a heightened stress response with increased basal inflammatory state [33].

A disadvantaged socioeconomic status indeed increases basal inflammation. A meta-analysis associated low socioeconomic status with elevated levels of C-reactive protein (CRP), a marker of systemic inflammation. Another meta-analysis showed an inverse relationship between childhood socioeconomic status and CRP levels in adulthood. Health inequalities may result from exposure to pro-inflammatory environments, negative health behaviours, and psychological stress. A recent European study confirmed that a disadvantaged socioeconomic position increases inflammation. Behavioural factors and body mass index only partially explain this relationship. Low educational level is associated with higher CRP levels, suggesting that education is a risk factor for elevated inflammation. Exposures to xenobiotics, infections, oral health conditions, and psychosocial stress can influence inflammation. Understanding the effects of social disadvantage on inflammation from childhood to adulthood is crucial to clarifying the biological mechanisms underlying socioeconomic health inequalities. These studies highlights the significant role of social factors on health, beyond behaviours and lifestyle [33–36].

Immunosenescence is the gradual decline of the immune system associated with ageing. This phenomenon reduces the effectiveness of immune responses, making older individuals more susceptible to infections, autoimmune diseases, and cancer [33,37]. Noppert et al. [38] analysed the relationship between sociodemographic factors and key indicators of immunosenescence in a large cohort. They found evidence that a low level of education and belonging to minority ethnic groups are associated with higher levels of immunosenescence. Although age has traditionally been considered the primary factor in immune differences, the magnitude of the differences observed based on sociodemographic factors suggests that the social environment also plays a significant role in the ageing of the human immune system.

Poverty is a known risk factor for diseases, but racial disparities in exposure to environmental pollutants are even more significant and persist even when controlling for income. African Americans with annual incomes between $50,000 and $60,000, considered middle class, are exposed to much higher levels of industrial chemicals, air pollution, toxic heavy metals, and pathogens compared to very poor white individuals earning $10,000 annually. This disparity is evident in both urban and rural settings. While pathogens can affect everyone, marginalized ethnic minority groups face greater exposure to environmental pollution and have less access to healthcare. This combination creates physical and social vulnerabilities that make people of color less capable of resisting and recovering from infections like the coronavirus. This issue extends beyond the United States. During the height of the COVID-19 pandemic, the National Intensive Care Audit and Research Centre in the UK found that 35% of intensive care patients with COVID-19 were Black, Asian, or from other minority ethnic groups, nearly three times their proportion in the UK population. Contributing factors include overcrowded living conditions and work environments. While only 2% of white individuals in the UK live in overcrowded conditions, 30% of Bangladeshis, 16% of Pakistanis, and 15% of Black African families do. Minority ethnic groups are also more likely to reside in “deprived” areas near sources of industrial pollution. Increased exposure to air pollution is consistently linked to reduced life expectancy, worsening heart disease, inducing hypertension, and weakening immune systems. One study even found a connection between air pollution exposure and a higher likelihood of dying from COVID-19. Limited access to healthy, nutritious food compounds the problem, as such neighbourhoods often have numerous outlets selling junk food, alcohol, and tobacco, contributing to obesity and nutritional deficiencies. For instance, nutrients like vitamin C, calcium, and iron can prevent lead absorption, a toxic metal. Access to green spaces and exercise facilities similarly plays a role in mitigating the effects of environmental pollution [4,39,40].

Regarding heat vulnerability, belonging to a marginalized ethnic group or having a low socioeconomic status is a major risk factor, but several other elements also heighten the risk of adverse health outcomes. These factors include extreme age, pre-existing health conditions, the use of specific medications, and social isolation. Individuals with heart disease, cerebrovascular conditions, respiratory or kidney diseases, diabetes mellitus, or dementia are more susceptible to heat-related health issues. Additionally, those taking medications like diuretics, antihypertensives, other cardiovascular drugs, certain psychotropic medications, or antihistamines are at increased risk. Older adults, whose ability to regulate body temperature is often diminished, are more likely to have underlying health problems, use medications that affect heat dissipation, face mobility challenges that can limit access to hydration or cooling, or live in older homes without air conditioning [2].

As temperatures rise and heatwaves become more frequent due to global warming, urban residents face particularly high risks. Materials like asphalt and concrete, which absorb and radiate heat, make cities significantly hotter than suburban or rural areas. To mitigate the risk of heat-related diseases, urban planners, meteorologists, climate scientists, and other experts are focusing on identifying the most at-risk neighbourhoods. A key aspect of this effort is recognizing how extreme heat disproportionately affects low-income and, in the United States, African American communities. Discriminatory urban policies have led to African American neighbourhoods being at greater risk for heat-related health issues and fatalities compared to white neighbourhoods. Recent research has increasingly highlighted the environmental injustices that have left some residents exposed to excessive heat on expansive asphalt, while other areas enjoy green parks, large lawns, and tall trees. These disparities also affect urban residents in many other countries, but the U.S. provides some of the most documented examples of how discriminatory practices link to heat-related risks. Many cities are now striving to address heat equity through urban planning efforts, such as planting trees and painting roofs white in traditionally under-resourced areas. Nonetheless, these climate adaptation strategies have much progress to make in reversing the effects of decades of targeted neglect of the most vulnerable populations [4].

In numerous cities globally, the most at-risk residents are those who face the highest danger. For example, in Qatar, many migrant construction workers have succumbed to heart failure induced by heatstroke. Research on over 1300 Nepali workers who died between 2009 and 2017 indicated that up to 200 of these deaths might have been prevented with better heat protection measures. Similarly, a 2016 survey of 505 residents in Bangkok during the hot season revealed that individuals with lower incomes were more prone to experiencing heat stress than those with higher incomes [41,42].

In one of the largest studies conducted so far to examine differential heat exposure in the United States, Hsu et al. [43] integrated satellite data on urban heat with census information detailing the demographics of residents in the 175 cities studied. In 97% of these cities, African American communities experienced average temperatures that were one degree Celsius higher compared to predominantly non-Hispanic white areas. Additionally, heat exposure is linked to income levels; individuals living below the poverty line, regardless of their ethnicity, faced higher temperatures compared to those living above the poverty threshold.

Ethnicity continues to be the primary factor influencing urban heat exposure in the United States, with roots extending back over 150 years. Following the abolition of slavery in 1865, housing policies nationwide were systematically crafted to prevent African Americans from residing in certain neighbourhoods. A significant contributor to today's disparate heat exposure was a federal loan approval program established by Congress in 1933 to assist people with mortgage payments during the Great Depression. The agency responsible for these loans created detailed maps of neighbourhoods in 239 U.S. cities, rating them from A (deemed the safest for bank investments) to D (considered the riskiest). Neighbourhoods with large ethnic minority or immigrant populations were almost invariably classified as D and shaded in red on city maps. This practice, known as "redlining," influenced nearly every aspect of urban life, including the allocation of schools, parks, and community facilities. On average, temperatures in the redlined areas of 108 U.S. cities are 2.6 °C higher than those in non-redlined areas. This difference is attributed to impervious surfaces and limited tree cover, as well as potentially to discriminatory urban planning practices, such as placing large highways and industrial facilities (which absorb heat) in communities of color [4,44].

Marginalized ethnic groups and low-income communities face a heightened risk of adverse health effects at certain ambient temperatures due to these and additional factors. These include restricted access to healthcare, higher rates of occupational exposures (such as working in non-air-conditioned factories or outdoor environments), and a greater prevalence of chronic medical conditions like hypertension, diabetes, and kidney disease [2,4].

4. Conclusions

Climate change is increasing overall temperatures as well as the frequency, duration, and intensity of heatwaves, leading to multiple adverse health outcomes. These effects are inequitable, with certain individuals and communities disproportionately affected. Despite the importance of this issue, to the best of our knowledge, no epidemiological studies have investigated the effect of heat exposure on life expectancy across various exposed populations or its role in the likelihood of achieving e, similar to a study conducted in the United States that clearly demonstrated the negative impact of air pollution on longevity, measured as reaching the age of 85 or older. In that national analysis of approximately 28 million individuals aged 55 and older in 3034 counties, higher levels of PM2.5 air pollution were associated with lower probabilities of longevity, even after adjusting for smoking, obesity, demographic and socioeconomic variables, migration rates, and regional differences. Counties with relatively low pollution levels, lower smoking and obesity rates, and higher median income showed the highest rates of longevity. The negative association was also observed with PM2.5 concentrations below the annual limits set by the U.S. Environmental Protection Agency (12 $\mu g/m^3$). Smoking, obesity, and poverty also showed negative associations with longevity. Although further studies in other nations are needed, particulate pollution is pervasive, and according to these findings, reducing PM2.5 and improving other sources of inequality can increase the likelihood of exceptional ageing [45]. It is very likely that, among disadvantaged populations, heat exposure contributes to reduced longevity rates and life expectancy, but as previously mentioned, there are no specific studies yet. In this review, we discussed life expectancy, which is a global indicator of lifespan that combines all ages into a single index. It would have been better to consider the differential impact of climate on mortality risks by age groups and the two sexes, but unfortunately, most studies primarily focus on life expectancy. Moreover, it is also important to consider that climate change has a significant impact on migration flows worldwide, both at the internal level in large countries and at the international level, which alters the demographic structure of the population exposed to climate change.

Intervention strategies and policies targeting specific locations and populations are crucial to minimizing the negative health effects of heat. Improved reporting of heat-related injuries and deaths, including the use of International Classification of Diseases codes that recognize indirect health effects, is needed. Currently, there is no universally accepted definition of heat-related death. In addition to addressing climate change by transitioning away from fossil fuels, various protective measures can reduce the burden of heat-related diseases. During heatwaves, individuals should limit exposure, wear light-coloured clothing, stay hydrated, use sunscreen, and employ cooling devices. However, some interventions, like air conditioning, may have negative environmental consequences. Population-level interventions, such as public education on health risks and protective strategies, are essential. Public health organizations and medical professionals play key roles in informing communities and policymakers. Public health policies on heat exposure should be adapted to local conditions and account for compound events like extreme heat and air pollution [2].

Climate models forecast worsening conditions. Not only are average summer temperatures rising, but heatwaves are also becoming more frequent, intense, and prolonged. Approximately 37% of heat-related fatalities in 43 countries are attributable to human-induced climate change. An empirical analysis, providing a solid lower estimate of the persistence of economic impacts based on recent data from over 1600 regions globally over the past 40 years, indicates that the global economy could face a 19% reduction in income over the next 26 years, regardless of future mitigation efforts (compared to a baseline without climate impacts, with a probable range of 11–29% considering physical and empirical climate uncertainties). These damages are already six times greater than the mitigation costs required to limit global warming to 2 °C in the short term, and the divergence will be pronounced depending on mitigation choices. When factoring in additional climate elements, estimates rise by about 50%, leading to increased regional variability [5,46].

Finally, we provide some concrete ideas and suggestions for future research aimed at disentangling the combined effects OF climate change and various human development: (i) Conduct case studies in different regions to compare areas with varying levels of economic and social development in order to understand how these differences influence vulnerability and adaptation to climate change, (ii) Conduct longitudinal studies tracking communities over time to observe how health, education, and economic opportunities shape the impacts of climate change.

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