Scientific Research Publishing

Open Journal of Business and Management, 2025, 13(1), 596-627
https://www.scirp.org/journal/ojbm
ISSN Online: 2329-3292
ISSN Print: 2329-3284

A Review on Sustainable Socioeconomic Indicators and the Immediate Need for Resilient Interventions in Navigating Future Climate Challenges on Developing Economies

Clemence Abadata, Tian Ze

Department of Business Administration, Business School of Hohai University, Jiangning Campus, Nanjing, China
Email: clemenceabadata@qq.com, tiane21@126.com

How to cite this paper: Abadata, C., & Ze, T. (2025). A Review on Sustainable Socioeconomic Indicators and the Immediate Need for Resilient Interventions in Navigating Future Climate Challenges on Developing Economies. *Open Journal of Business and Management, 13,* 596-627.
https://doi.org/10.4236/ojbm.2025.131033

Received: December 8, 2024
Accepted: January 27, 2025
Published: January 30, 2025

Abstract

A review on sustainable socioeconomic indicators and the immediate need for resilient interventions in navigating future climate challenges on developing economies looks at future trends by examining forthcoming trends in the interplay between socioeconomic factors and projected climate change challenges as documented in existing literature. The study discusses on prediction of what might happen in the coming decades and the need for climate-resilient interventions. However, there is a significant body of literature on some sectors like climate impacts on GDP per capita and crop yield in developing countries and there are some sectors like energy security and water that have received less scholarly attention. Across various sectors, the developing countries will suffer the most and it'll be worse later on if there is no intervention. In addition, the paper highlights the necessity of a structural shift across five important economic sectors that shows how by adopting bold climate policies may result in profits.

Keywords

Socioeconomic, Climate Change, Developing Countries, Africa, Agriculture, Energy Security

1. Introduction

One of the most important global issues of our day is climate change, which is drastically changing the environment of the economy and international business practices. Increasingly obvious signs of climate change include rising sea levels,

harsh weather, and altered farming practices. These effects are having a significant impact on the world economy. Alarming tendencies have been shown in recent studies, such as an increase in extreme weather occurrences, higher temperatures, and changed rainfall patterns (Valenzuela & Anderson, 2011). The average surface temperature of the Earth increased dramatically between 2011 and 2020, tracking a long-term trend of global warming mostly caused by human activity, such as the burning of fossil fuels and extensive deforestation.

The average worldwide temperature this decade was about 1.2 degrees Celsius (2.2 degrees Fahrenheit) higher than pre-industrial levels, in accordance with the findings of the Intergovernmental Panel on Climate Change and the World Meteorological Organization. Moreover, extreme weather events are expected to happen 2.8 times more frequently every 10 years compared to their historical frequency of once every decade between 1850 and 1900. If global warming hits 1.5˚C, this frequency could increase to 4.1 times each decade. Prolonged droughts and destructive floods are two examples of climate-induced disasters that can occur according to IPCC (IPCC, 2022) and WMO (Word Meteorological Organization, 2022).

Significant years included 2016 and 2020, both of which ranked among the hottest on record, with 2020 co-holding the distinction of the warmest year ever documented globally alongside 2016. A combination of natural climatic variability and human-induced climate change, particularly strong El Niño occurrences, contributed to the temperature rises throughout these years according to NASA (NASA, 2021). Increased frequency and intensity of heatwaves, droughts, and heavy rainfall events are a result of rising temperatures, and these phenomena have detrimental effects on ecosystems, agriculture, and human health IPCC (IPCC, 2022). Furthermore, there has been a significant increase in ocean warming, which has an impact on marine ecosystems and raises sea levels because of thermal expansion.

Temperatures have clearly been rising during the decade from 2011 to 2020, which emphasizes the urgent need for comprehensive climate action to reduce future warming and its effects. The need to create adaptable methods that can handle the complex effects of climate change on businesses and societies grows as the globe struggles to solve these issues.

As global temperatures rise, the repercussions of climate change are expected to be distributed unevenly over the globe, perhaps advantageous for certain regions while inflicting significant detriment on others. The disproportionate impact on developing nations, who often possess a constrained capacity to adapt to the adverse consequences of climate change, is a particularly alarming trend according to Tol (Tol, 2018) and Stern (Stern, 2007). Due to multiple factors, poorer nations are more susceptible to the adverse effects of global warming. Numerous countries rely heavily on climate-sensitive sectors such as forestry, tourism, and agriculture due to their naturally milder climates compared to industrialized nations. As crop yields diminish in nations such as Africa owing to escalating

temperatures, it will become increasingly challenging to generate sufficient food for domestic use. Food insecurity and economic challenges are projected to intensify due to the expected reduction in the volume of their primary exports.

Numerous studies have examined the potential impacts of climate change on diverse social, environmental, and political factors across different contexts. Therefore, this study will conduct a comprehensive desk review to ascertain the extent, trends, and evidence patterns obtained to date, particularly from the viewpoint of developing economies. The literature will be analyzed for trends and patterns. This research will focus on the established patterns and trends of consequences described in the existing literature, as the underlying assumptions of models predicting the implications of climate change might vary significantly between studies.

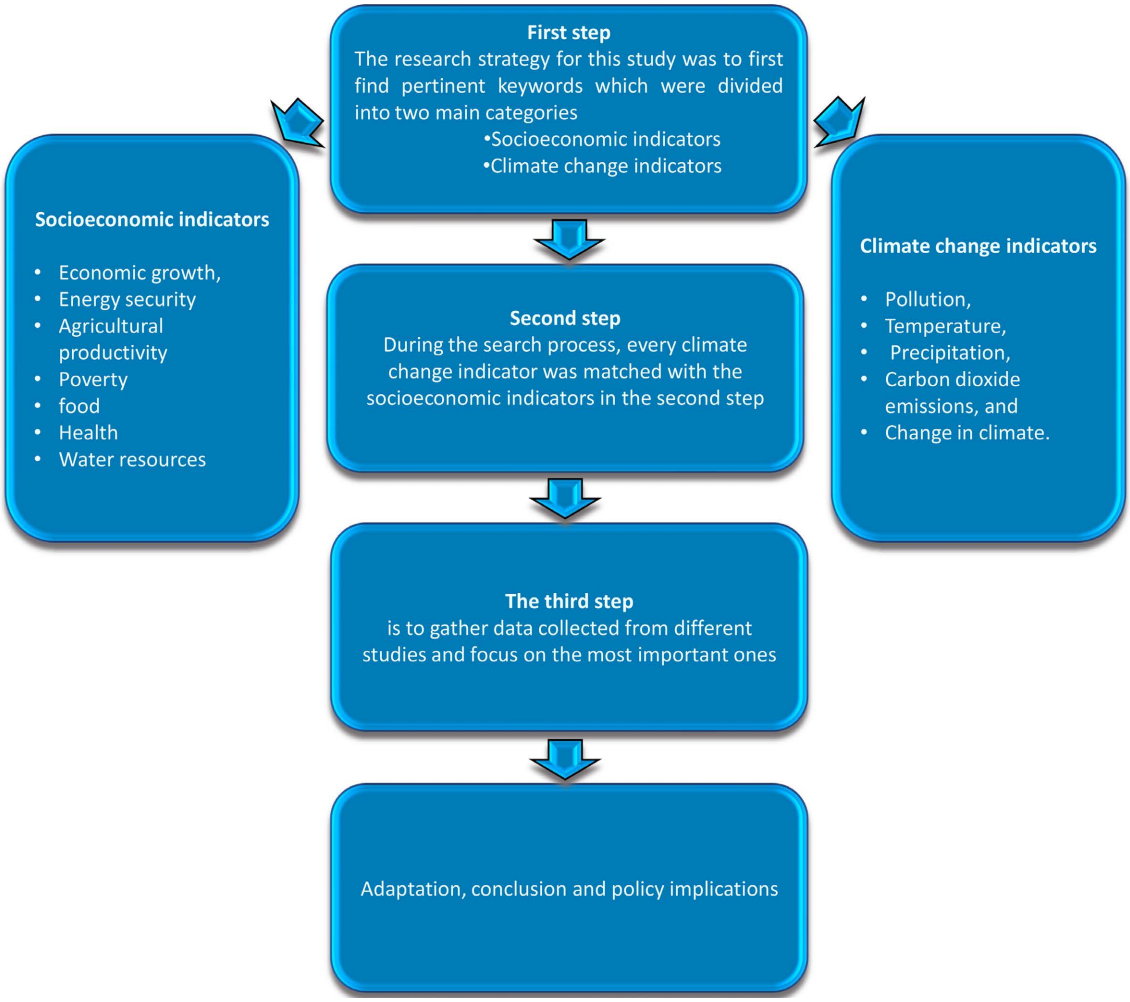
The primary objective of this study is to tackle the challenges posed by climate change in the future by emphasizing the essential requirement for resilience and understanding the underlying socioeconomic dynamics. This will be achieved through a comprehensive review of the studies about the impacts of climate change on various socioeconomic factors in the forthcoming decades, focusing on developing countries.

2. Methods, Strategy and Data

The first step in the research strategy for this study was to find pertinent keywords, which were divided into two main categories: socioeconomic factors and indicators of climate change. Each category had different keywords as it is shown in Figure 1. The second step was to match every climate change indicator with the socioeconomic indicators from different literatures. The third step was to Find the most pertinent research required sifting through the collected data. The objective of this methodical approach is to guarantee a thorough comprehension of the interaction between socioeconomic variables and climate change in developing nations, thereby aiding in the creation of efficacious resilience and adaptation tactics. The literatures were examined broadly, without limitation in terms of period or context.

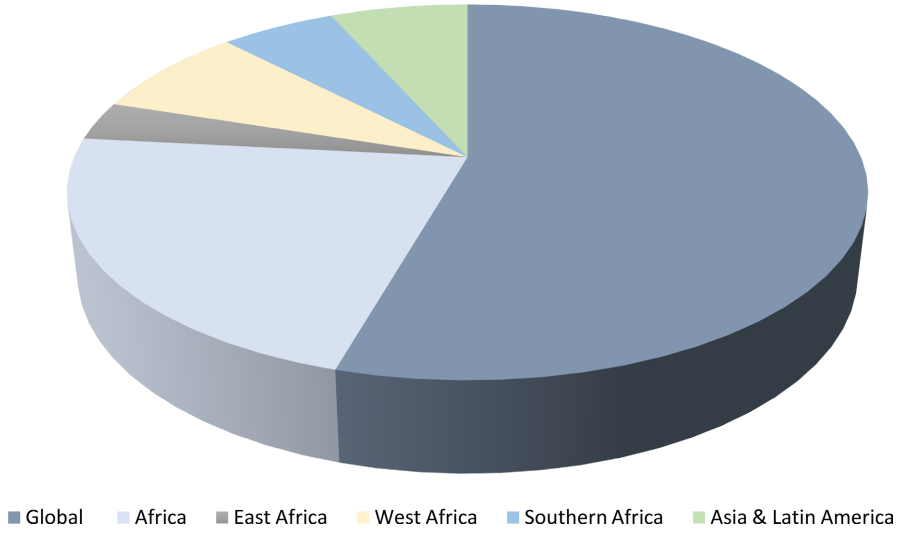
Quantitative assessments of the effects of climate change were prioritized over qualitative studies, though they were not completely disregarded and studies that used mixed-methods or quantitative approaches were given preference. After carefully merging and separating the data from various sources to remove duplicates, the study examined the bibliographies of the studies that it had found to add to the previously collected data. Figure 2 shows the allocation of different studies based on data sources and Figure 3 shows the studies by focused countries.

Figure 4 shows how the papers were distributed according to sectors. It is clear that, in comparison to other sectors, the agricultural sector has received greater attention in studies of the impact of climate change. More specifically, the effects of climate change on agricultural productivity were the subject of 35% of the examined studies. While some of this research focused on the effects of climate change on agricultural value, the majority looked at how it may affect food



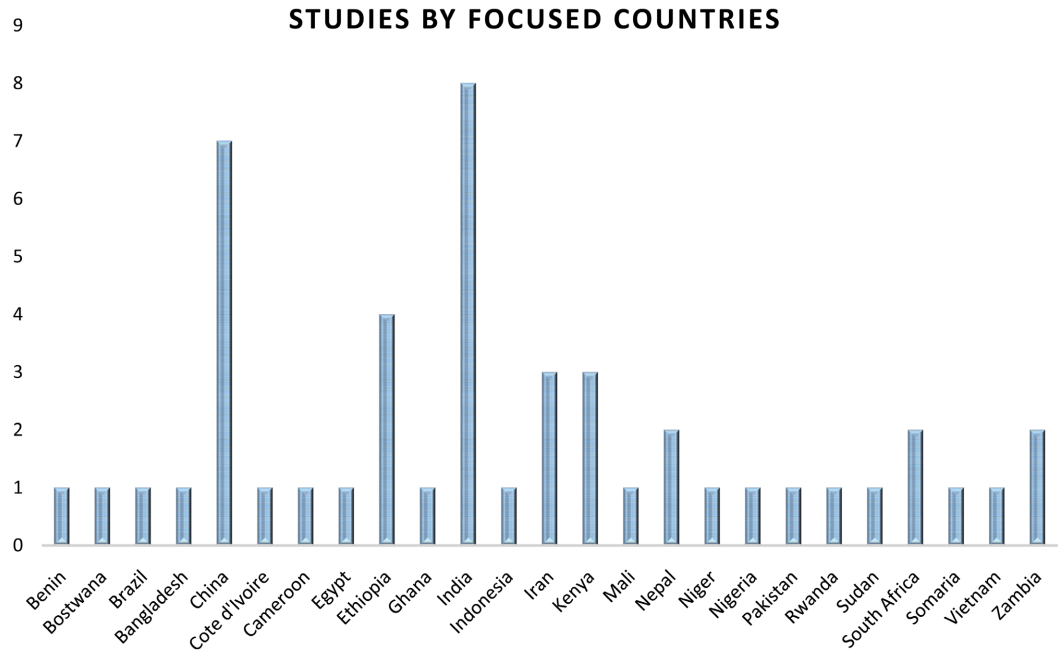
Source: Author's own illustration.

Figure 1. Steps in the research strategy.



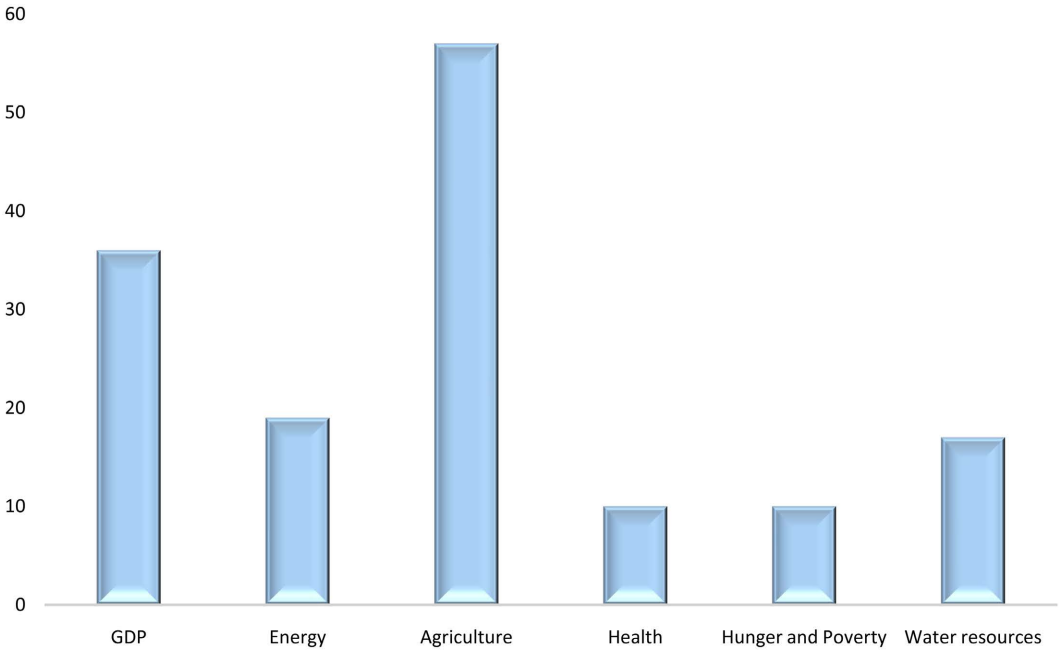
Source: author's own illustration.

Figure 2. Allocation of research studies based on data sources.



Source: Author's own illustration.

Figure 3. Studies by focused countries.



Source: Author's illustration.

Figure 4. Allocation of studies by sectors.

security. Future climate change studies are likely to place a heavy emphasis on agriculture because developing economies being primarily dependent on the primary sector, are naturally more vulnerable to the repercussions of climate change. 28% fall into the second-largest category of the examined studies assessing economy-wide impacts, utilizing GDP or other economy-wide welfare measures. A respectable quantity

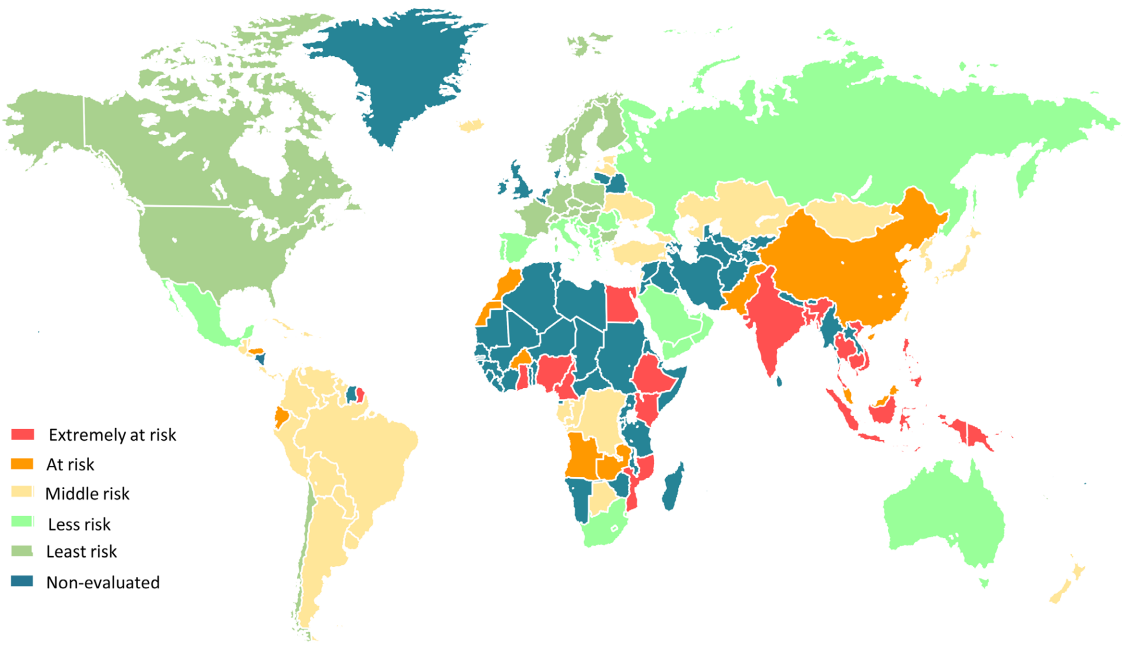
of data is also offered by the water and energy sectors, which account for 10% and 12% of the examined research that looks into the effects of climate change, respectively. On the other hand, only 15% of the examined papers discussed how poverty, hunger, undernourishment, and health are affected by climate change.

3. Effects of Climate Change on Developing Countries

3.1. Effects of Climate Change on Income and Economic Growth

Research consistently shows that developing countries are disproportionately affected by climate change, facing significant threats to their economic stability and advancement. The United Nations Framework Convention on Climate Change (UNFCCC) indicates that places like Sub-Saharan Africa may experience GDP reductions of up to 10% by 2050 as a result of climate-related effects, hence intensifying pre-existing disparities (UNFCC, 2018). A case study in Bangladesh illustrates the threats of increasing sea levels and heightened floods, jeopardizing agricultural output and the livelihoods of millions, hence resulting in economic instability (Hossain et al., 2019).

The Organization for Economic Co-operation and Development (OECD) forecasts that, in the absence of significant mitigation measures, climate change may diminish world GDP by 2.5% to 7.5% by 2100 (Rob Dellink et al., 2014). This prediction considers multiple effects, such as diminished labor productivity, heightened healthcare expenses, and infrastructure damage. A study by Burke (Burke et al., 2018) published in Nature indicates that the economic repercussions of climate change may be more severe, with projected GDP declines of up to 23% in specific regions by 2100. **Figure 5** shows how global warming impacts



Source: Author's illustration based on data from standard and poor's.

Figure 5. Global warming impacts developing economies the most.

developing economies the most especially heavy rainfalls, floods, high temperature and storm surges.

Several studies have either supported or challenged the initial estimates of the monetary costs of global warming on world GDP, which were published in the early 1990s. Covington and Thamotheram's (Covington & Thamotheram, 2015) research is based on the "climate damage functions," which quantify the financial risks associated with climate change. Damage to the economy from climate change is the yearly loss in output relative to output in an economy that does not experience warming, multiplied by a fixed level of warming. These climatic damage functions show the expected output losses under various warming scenarios; larger yearly losses in economic output are predicted by all models as a consequence of increasing warming. On the other hand, how damages change with a stronger warming is still a matter of contention among the projected climate damage functions. **Table 1** provides a concise overview of various estimated harm functions; the names of the people whose work these functions represent are shown in the table. We'll take a quick look at each climate damage function, with a focus on the 4˚C threshold which, according to the World Bank, will be 40% exceeded by 2100 if emissions continue on their "medium business as usual pathway.

Table 1. Damage estimates from climate change based on estimates from Diets and Stern (Dietz, 2014), Weitzman (Weitzman, 2012), and Nordhaus (Nordhaus, 2013) for a given temperature level.

Warming	Nordhaus review	Diets and Stem review	Weitzman review
1˚	0%	0%	0%
2˚	1%	2%	1%
3˚	2%	14%	3%
4˚	4%	50%	9%
5˚	7%	81%	25%

Source: Covington and Thamotheram (Covington & Thamotheram, 2015).

As the earth continues to warm, it is anticipated that the effects of climate change will be felt differently in different parts of the world, creating winners and losers. Generally speaking, developing countries are likely to be the ones most negatively impacted by the effects of global warming. In comparison to developed countries, many of these countries already have naturally warmer climates, and they also depend more heavily on industries that are sensitive to the climate, such forestry, tourism, and agriculture.

It is predicted that crop yields in regions like Africa will decline with rising temperatures, making it harder to provide enough food for local use. Major agricultural exports are also expected to decline in volume. If industrialized nations are able to find new sources of agricultural output to offset their own decreases in agricultural output possibly from their own domestic economies where land may

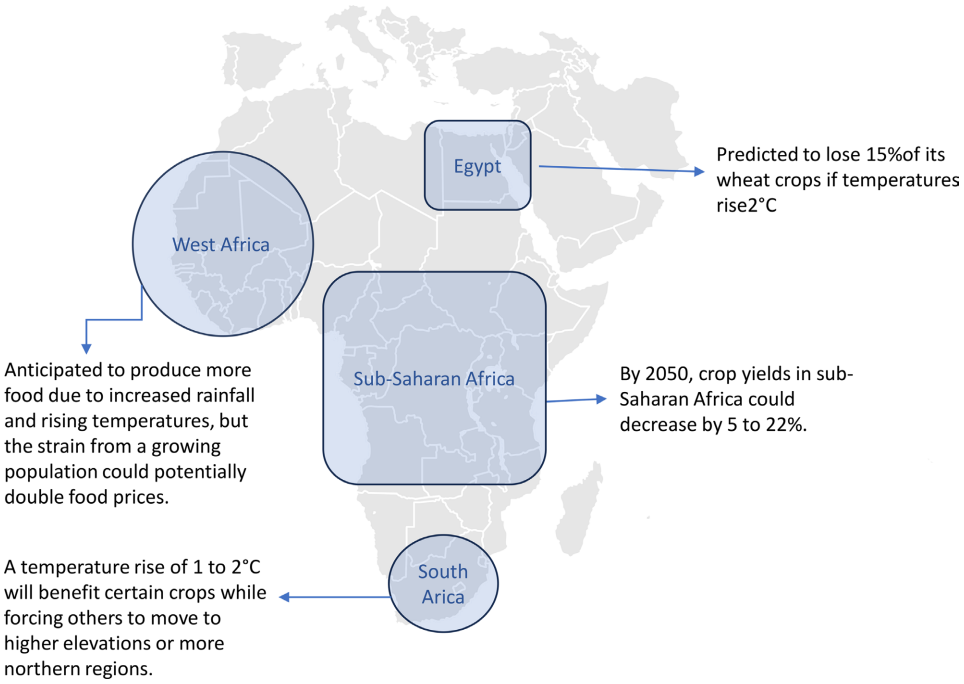
become more conducive to food production, the issue may get worse.

Furthermore, due to a lack of finance and resources for research, developing nations may find it difficult to produce crops resistant to drought. The budgets of these regions' governments will be further strained by the rising frequency and intensity of catastrophic weather events. Local governments have a heavy financial burden in the wake of natural catastrophes, having to set aside large sums of money for cleanup efforts and medical expenses related to severe weather. Significant revenue decreases may also be experienced by nations that primarily depend on tourism or fishing rights according to IMF (International Monetary Fund (IMF), 2008). **Figure 6** shows how climate change will worst hit Africa.

There are two ramifications for the emerging countries. First, the flow of resources in the form of aid and cash for economic development to poor countries is probably going to decline as rich countries struggle with increasing strains on their internal budgets. Second, in order to pay for the expenses related to extreme weather occurrences, the governments of these countries will have to take funds away from initiatives that will be beneficial and promote growth. Such reallocations may make future growth prospects less likely.

Moreover, developing nations usually have a lower capacity for reconstruction following natural disasters. Many emerging economies are left in a constant state of rebuilding as the time needed for recovery may exceed the frequency of such incidents (Hallegatte, 2010).

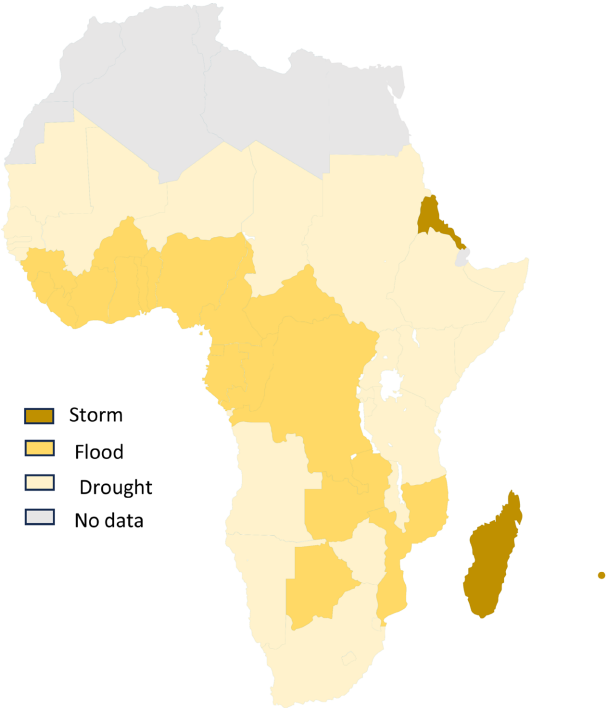
Numerous approaches, each with unique advantages and disadvantages, have been used in the literature to evaluate the economic impact of climate change. For



Source: Author's illustration based on data from FAO, Met office.

Figure 6. Climate change will have the worst impact food in Africa.

example, to determine the physical implications of climate change, Nordhaus (Nordhaus, 1994) and Tol (Tol, 1995) used an enumerative technique based on studies from natural science. Results from this technology are naturally easily interpretable and physically realistic. However, there are serious issues with extrapolating these results. Problems include extrapolating recent past values into far-off futures, extrapolating from a small number of locales to the global scale, and applying economic values from different contexts to climate concerns. The estimated economic effects of climate change may be impacted by the significant error that these extrapolations most certainly contain according to Brouwer and Spaninks (Brouwer & Spaninks, 1999). **Figure 7** shows that the most of people across Sub-Saharan African countries were affected by natural hazards 2000-2020.



Source: Author's illustration based on the data from EM-DAT, CRED/UCLouvain.

Figure 7. The most of people across Sub-Saharan African countries being affected by natural hazards from 2000-2020.

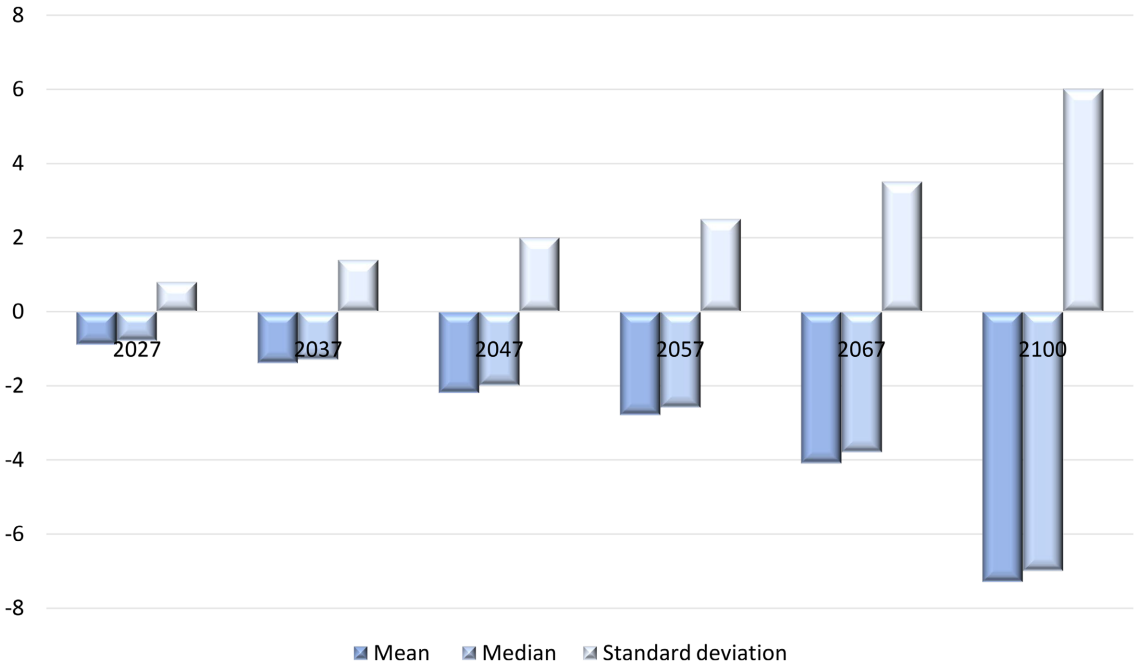
In line with earlier studies, Kompas et al. (Kompas et al., 2018) found that the effects of climate change on economic growth in Africa vary by subregion, warming degree, and time period. Their research showed that the regions of Africa most at risk from climate change were in the west and east.

Figure 8 shows the projected long-term effects of climate change on Africa's mean, median and standard deviation GDP at a 3˚C global warming threshold. In contrast to a world without climate change, Dinar et al. (Dinar et al., 2012) projected that by 2100, Africa's GDP would have dropped by 6% to 100% based on a plethora of climate models specific to the continent. It was anticipated that climate change would only benefit a handful of countries. The results are diverse due to

the fact that the researchers' climate models predict varying temperatures. The University of Illinois at Urbana-Champaign predicts that the polar regions would experience mild warming and the equator will see catastrophic warming in the worst of circumstances. On the other hand, more positive models such as GENESIS, which incorporates a dynamic sea ice model developed by Pollard and Thompson, have projected a greater increase in temperature in temperate and polar regions, with only a small increase near the equator.

Researchers are generally in agreement that climate change may have a negative effect on Africa's economic progress. It is commonly known that, in comparison to a world without warming, a considerable proportion of people may become even more impoverished as a result of climate change. **Table 2** presents a summary of several researches looking at how climate change affects economic output in Africa. The forecasts are based on average temperatures from the preindustrial era and **Figure 9** presents the Impact of climate change on social and economic.

While the entire African continent is expected to be negatively impacted by climate change, not every region will be affected equally. **Figure 10** illustrates Variability in the effects of climate change at 3˚C across time on GDP per capita by subregion in Africa over time, based on a 3˚C global warming scenario (Kompas et al., 2018). On the other hand, specific effect patterns are observed in the regions of western and eastern Africa, which are predicted to be the most severely affected. It is projected that for the next 20 years, GDP per capita in Western Africa will significantly fall. About forty years from now, eastern Africa is predicted to experience its worst economic losses.



Source: author's illustration using original projection data from Kompas et al. (Kompas et al., 2018).

Figure 8. Climate change's predicted effects on GDP over time at 3-degree Celsius for Africa.

Table 2. Climate change's expected effects on Africa's economy.

Forecast year	Degree of warming	% change in GDP
2100 According to Tol	2.5˚C	−8.7
2050 According to Baarsch et al.	2.6˚C to 8.5˚C	−4.0 to −8.0
2100 According to Mendelsohn, Schlesinger, and Williams	2.5˚C	−0.5
2100 According to Hope	2.5˚C	−2.6
2100 According to Nordhaus and Boyer	2.5˚C	−3.9
2100 According to Plambeck and hope	2.5˚C	−8.6
2100 According to Mendelsohn, Morrison et al.	2.5˚C	−3.6
2100 According to Nordhaus and yang	2.5˚C	−2.1
2050 According to Tol	1.0˚C	−4.1
2100 According to Kompas et al.	1.0˚C	−2.2
	2.0˚C	−4.9
	3.0˚C	−8.1
	4.0˚C	−11.8

Source: author's illustration based on data from different literatures (Baarsch et al., 2020; Hope, 2006; Kompas et al., 2018; Mendelsohn, Morrison, Schlesinger, & Andronova, 2000; Mendelsohn, Schlesinger, & Williams, 2000; Nordhaus & Boyer, 2000; Nordhaus & Yang, 1996; Plambeck & Hope, 1996; Tol, 2002).

Even within African subregions, there are notable differences in the effects of climate change. Assuming a 3˚C increase in global temperatures, Interestingly, the risk linked with exposure to climate change differs by country, even in the most affected subregions, such western and eastern Africa.

By the year 2100, it is projected that the nations of Togo, Ghana, Burkina Faso, Nigeria, and Côte d'Ivoire in western Africa will be the most negatively affected. In a similar vein, major issues brought on by climate change are anticipated for Malawi, Mauritius, Kenya, and Mozambique in eastern Africa during the same time frame. There are variations in how different African countries are exposed to different degrees of global warming as below figure illustrates. There are several ways in which climate change can negatively impact economic growth. The study examines the effects of climate change on important industries, such as agriculture, water resources, health, and energy security, in the subsection that follows

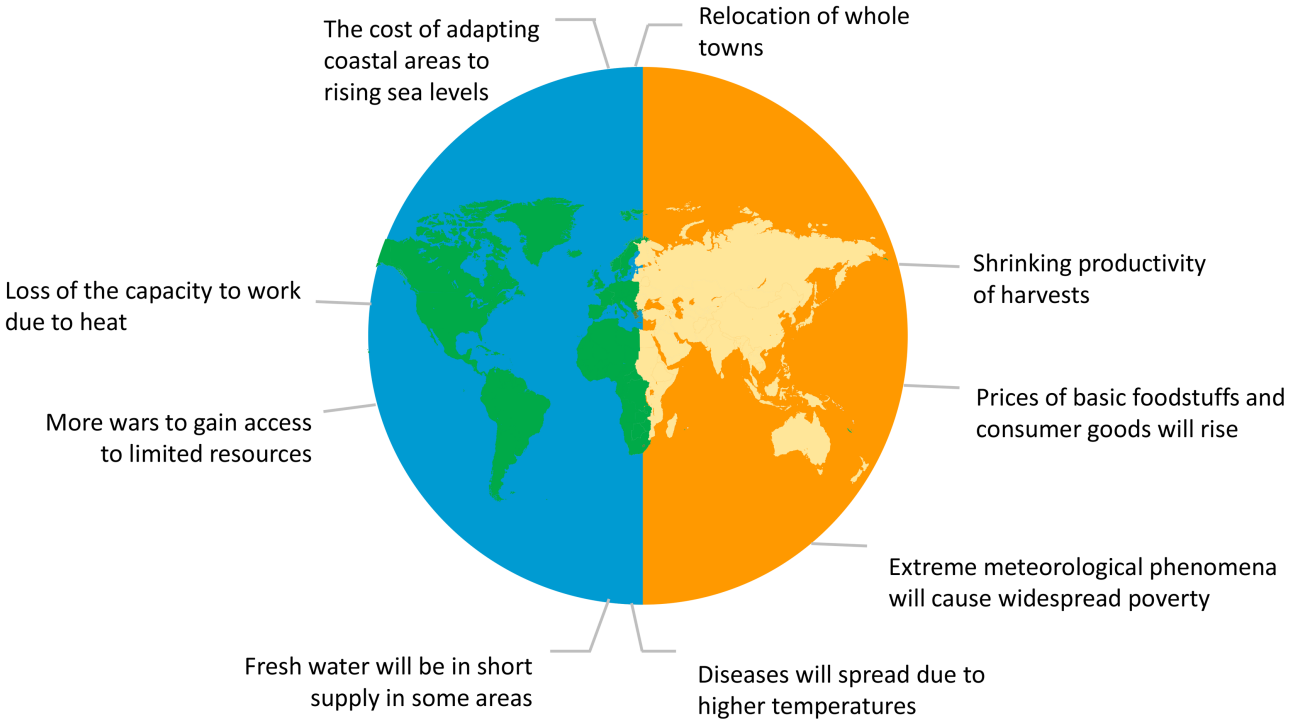
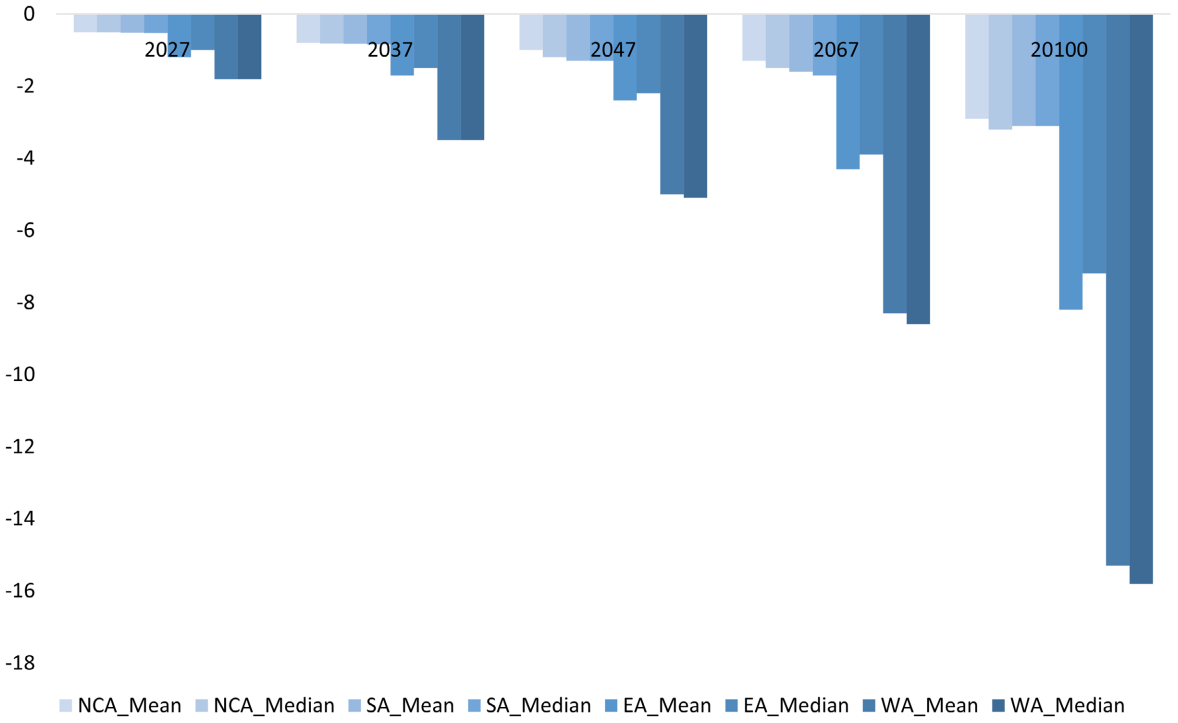


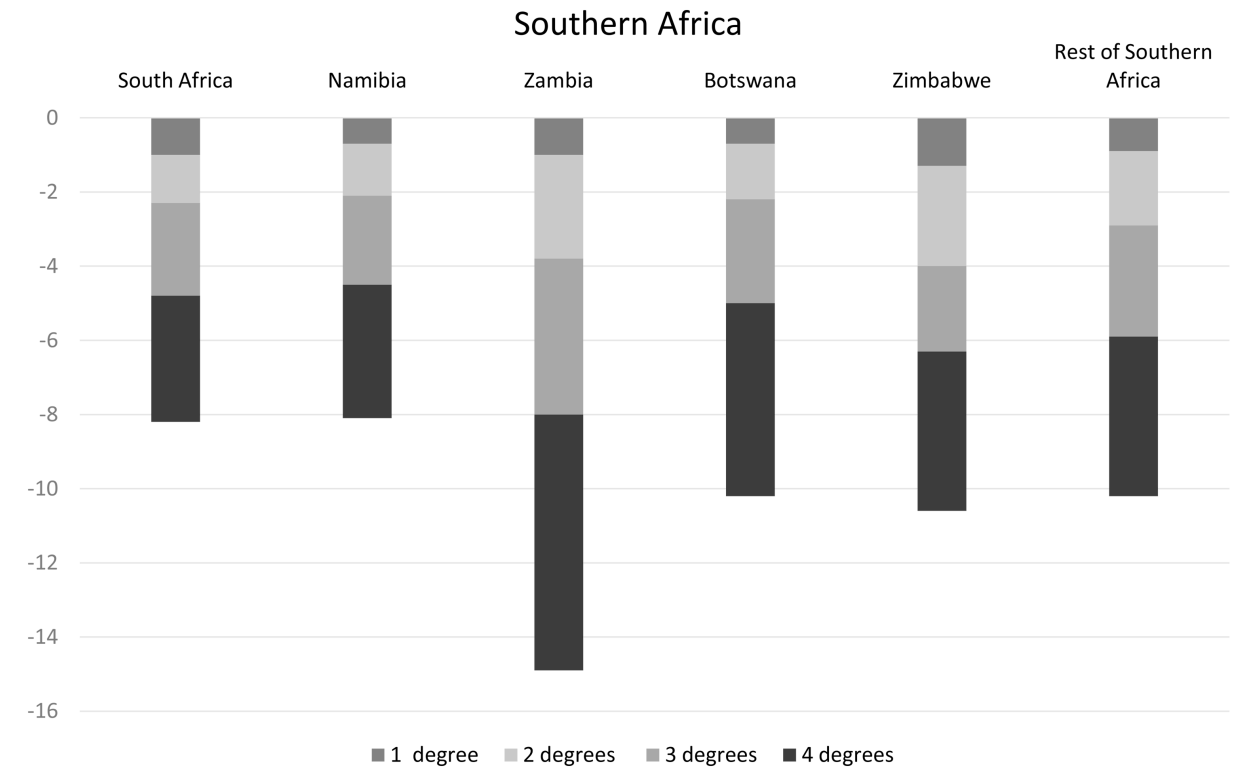
Figure 9. Impact of climate change on social and economic.



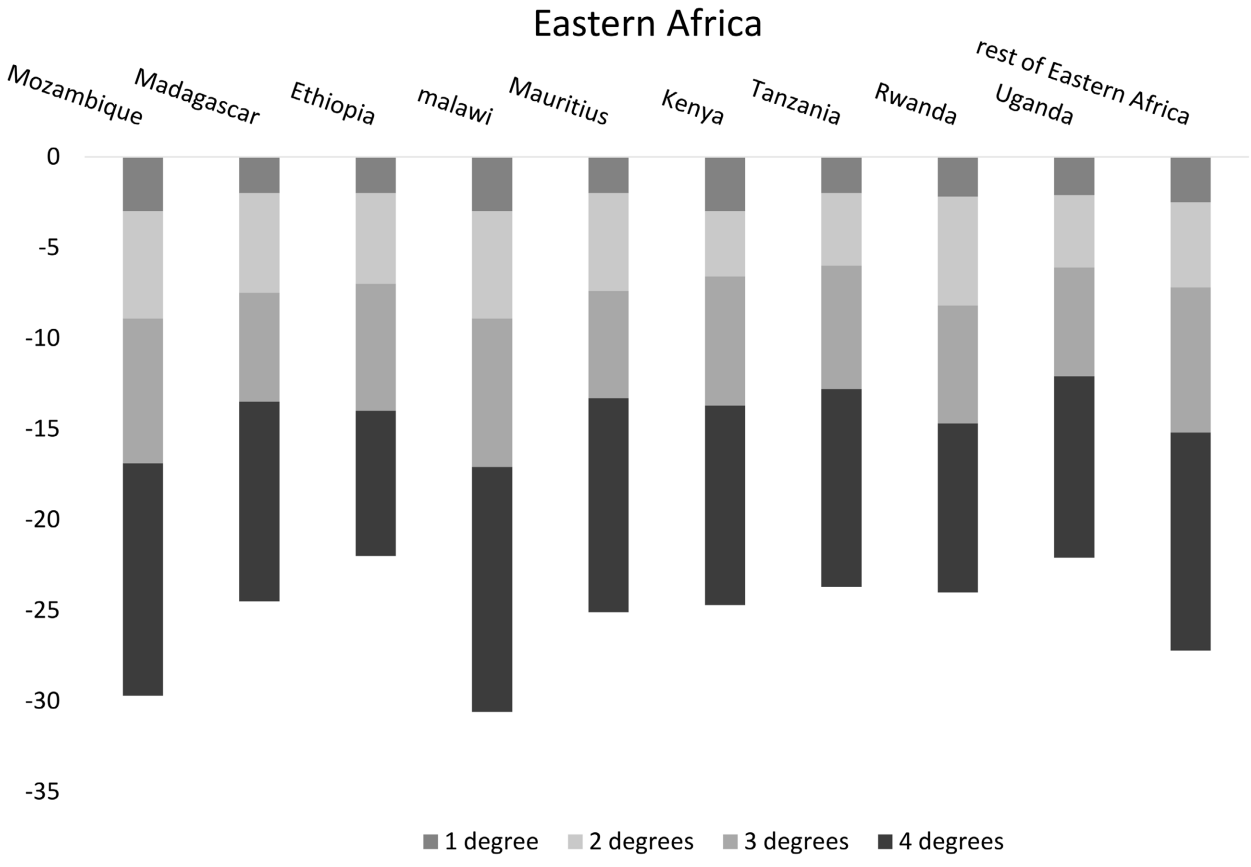
Source: Authors' illustration using data from Kompas et al. (Kompas et al., 2018).

Figure 10. Variability in the effects of climate change at 3˚C across time.

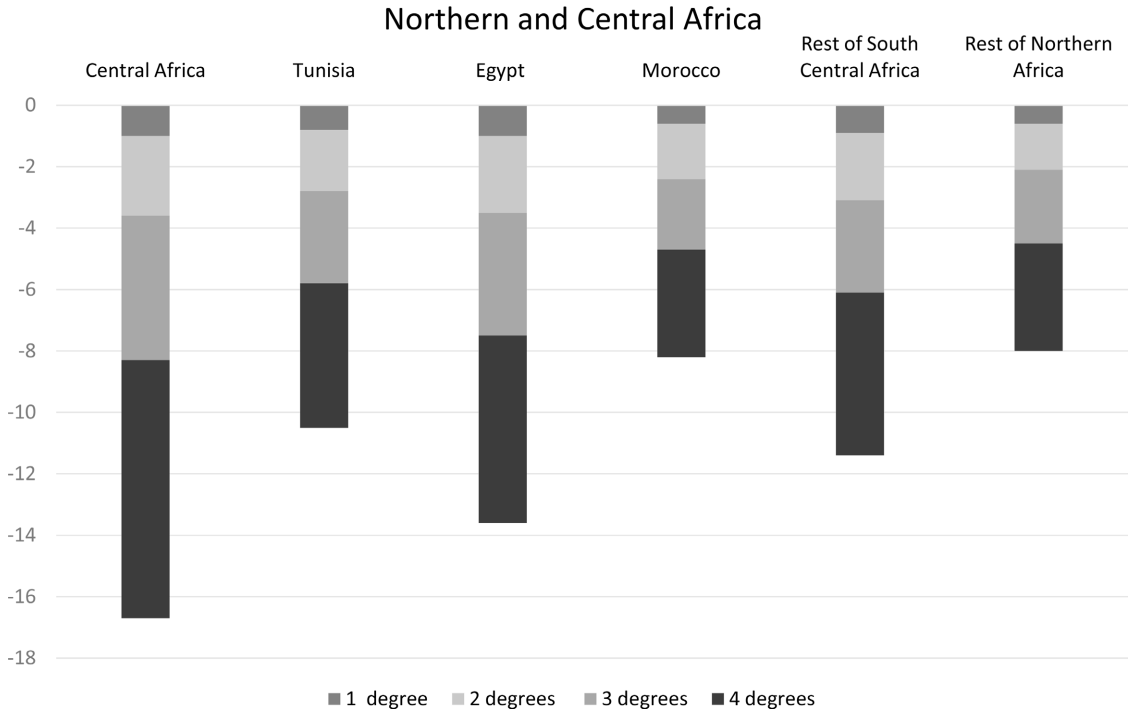
in this review. Figure 11 presents the effect of different temperature extremes on Africa's GDP at the subregional level.


Southern Africa
South Africa
Namibia
Zambia
Botswana
Zimbabwe
Rest of Southern Africa
0
-2
-4
-6
-8
-10
-12
-14
-16
1 degree
2 degrees
3 degrees
4 degrees

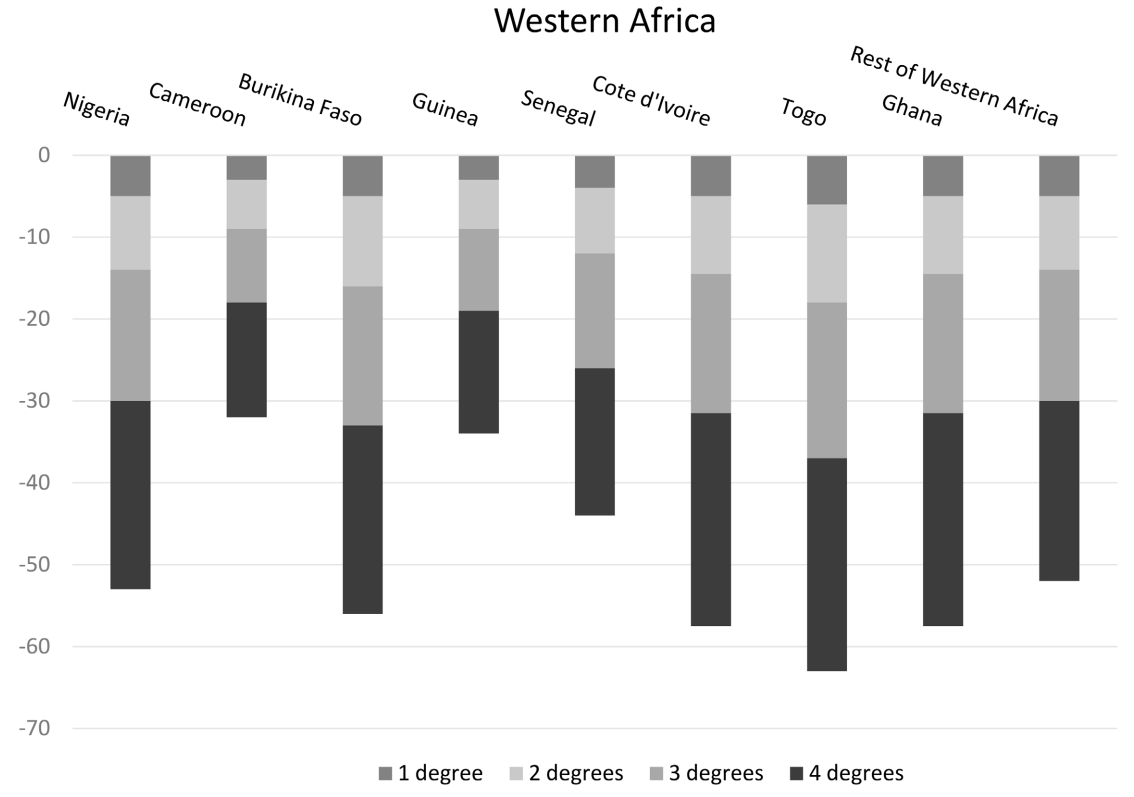
(a)


Eastern Africa
Mozambique
Madagascar
Ethiopia
malawi
Mauritius
Kenya
Tanzania
Rwanda
Uganda
rest of Eastern Africa
0
-5
-10
-15
-20
-25
-30
-35
1 degree
2 degrees
3 degrees
4 degrees

(b)



(c)



(d)

Source: Author's illustration using data from Kompas et al (Kompas et al., 2018).

Figure 11. The effect of different temperature extremes on Africa's GDP at the subregional level. (a) Describes southern Africa, (b) Describes eastern Africa, (c) Describes northern and central Africa, (d) Describes western Africa.

3.2. Effects of Climate Change on Energy Security

Numerous studies indicate the impact of climate change on energy supply and demand in emerging nations. Mei et al. (Mei et al., 2020) examined China's energy economy. They forecasted that, relative to a scenario devoid of climate change, electricity demand in China will surge by 58.6% within just 30 years. Tahir and Al-Ghamdi (Tahir & Al-Ghamdi, 2023) observed that climatic change increases the demand for energy in structures. This additional requirement exacerbates energy demand due to climate change. Campagna and Fioriti (Campagna & Fioriti, 2022) and Li et al. (Li, Yang, & Lam, 2012) reached analogous conclusions. Li et al. indicated that the impacts will be more pronounced during the summer and mild winter months.

Transitioning to renewable energy sources may result in increased energy bills, perhaps exacerbating inflation. As extreme weather patterns become increasingly prevalent, greater energy will be required to heat buildings during prolonged winters or to cool them during sweltering summers. Increasing temperatures may impair the efficiency of existing power facilities. This can influence both the availability of energy and our consumption requirements. In the short to medium term, inflation associated with energy expenses may increase further if governments advocate for greener energy alternatives, particularly if they impose additional fees on fossil fuel power generation. Given that a significant portion of global production depends on energy, elevated costs are expected to exacerbate inflation throughout the economy.

However, there is a positive aspect. A swift shift to renewable energy could prevent significant increases in energy bills in the future. Fant et al. (Fant et al., 2016) assert that hydropower resources in southern Africa are unlikely to experience significant alterations as a result of climate change. However, some regional studies present contradictory perspectives regarding the impact of climate change on hydropower output. For instance, van Vliet et al. (Van Vliet et al., 2016) forecast a 5.2% increase in hydropower potential in high-latitude regions, but Hamudu & Killingtveit (Hamududu & Killingtveit, 2012) propose a minimal variation of only 1%.

This discussion clearly indicates that the demand side of the energy industry is jeopardized due to climate change endangering energy security in developing nations. Although there is widespread consensus on certain energy sources, others require further research and debate, resulting in ambiguity regarding supply. The impacts may differ by location and source; some experience more significant changes than others. However, the majority of research suggests minimal effects on supply. Maintaining global warming at 2˚C might significantly mitigate energy poverty, particularly in developing economies such as those in Africa, which frequently experience the most severe impacts of climate change. Energy poverty is an escalating concern in the region as well. It is intricately linked to various socio-economic concerns, including income levels, education, gender equality, and health.

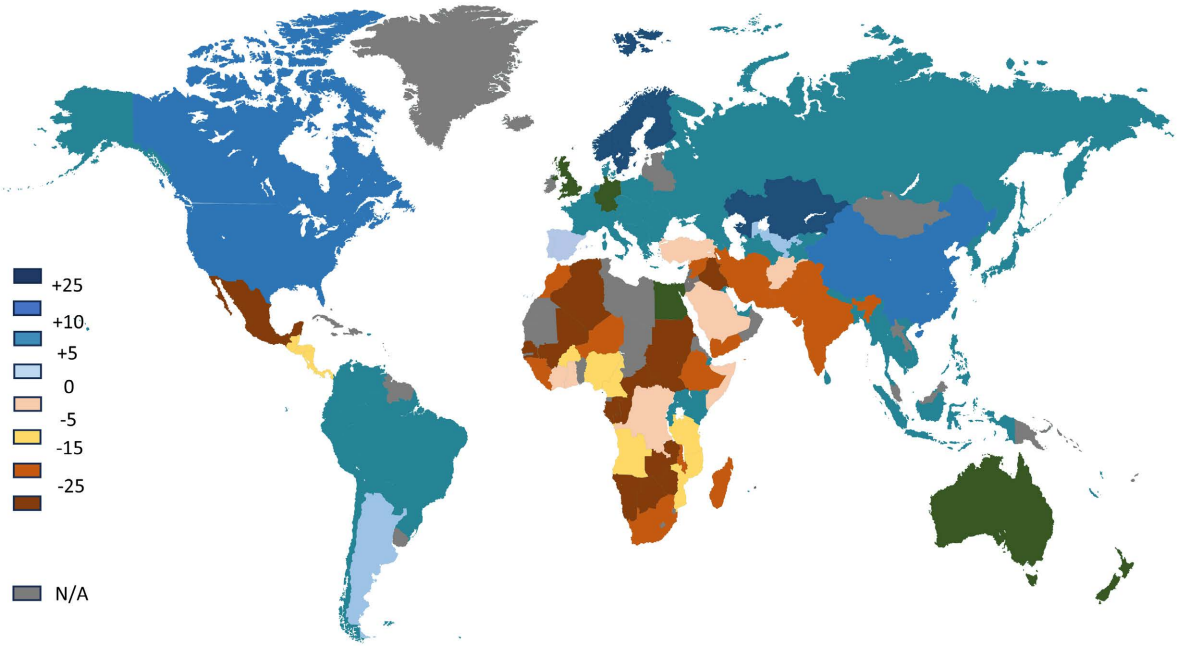
3.3. Impact of Climate Change on Agricultural Productivity

Temperature and precipitation patterns have a substantial impact on the primary

sector, which is the main driver of developing economies. Consequently, agricultural activities may be negatively impacted by any erratic or drastic changes in these climate indicators. Even if mitigation measures are started right now, it is anticipated that cropland and labor productivity, as well as food security, will be impacted by climate change for several decades. According to Schmidhuber and Tubiello (Schmidhuber & Tubiello, 2007), climate change can impact food production in three ways: the first one: indirectly by reducing the amount of land available for agriculture; second: indirectly by affecting the demand for agricultural products, income distribution, and overall economic growth; and the third: directly by modifying agroecological conditions. Nonetheless, other scientists contend that the impact of climate change on agriculture in developing nations may inadvertently advantage farming households. As a result of diminished agricultural output caused by population growth, these households may see a gain in income when food prices escalate (Valenzuela & Anderson, 2011).

Lobell et al. (Schlenker & Lobell, 2010) performed a meta-analysis published in the journal Science, illustrating the agricultural sector's vulnerability to climate change. It shows that increasing temperatures and changing precipitation patterns can result in lower crop yields, which can then cause food insecurity and higher prices. According to the IPCC (IPCC, 2014), by 2050, climate change might lower agricultural productivity worldwide by 10% to 25%, with developing nations most likely to suffer the most.

Expressed as a percentage change from 2003 values, the map below in **Figure 12** shows the expected consequences of climate change on agricultural productivity globally in the 2080s. The European Environment Agency referenced Cline's



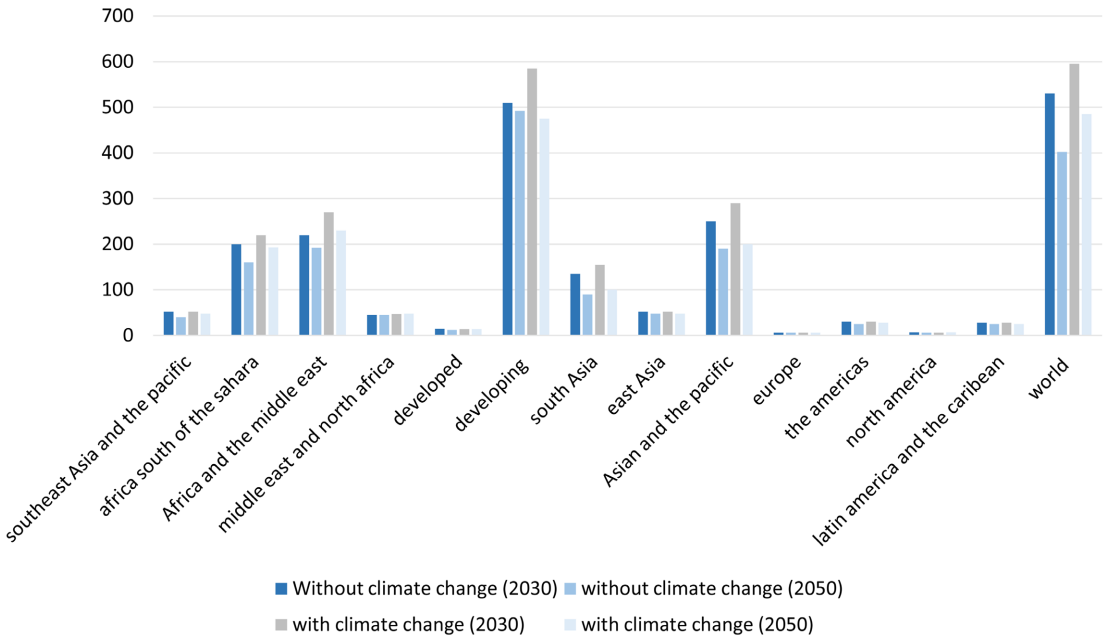
Source: author's illustration based on the analysis draws from Cline's research.

Figure 12. Projected impact of climate change on agricultural productivity between 2003 to 2080s.

research from 2007 for its analysis, which observes that although world agricultural production may initially increase before 2030, the long-term perspective indicates that global warming would probably have negative effects. More specifically, higher latitude areas should benefit from climate change, while many African countries and Latin America are likely to experience significant hurdles in terms of agricultural productivity.

3.3.1. Poverty, Food Insecurity, and Malnutrition

Hundreds of millions of people are at risk of acute hunger, severe malnutrition, and economic losses as a result of climate change's direct effect on agricultural output in developing nations, where agriculture is a crucial economic sector. Schmidhuber and Tubiello (Schmidhuber & Tubiello, 2007) found that compared to a world without climate change, the number of undernourished individuals could rise by 5% - 26% by 2080. Climate change has the potential to affect food production in three ways, according to Schmidt and Tubiello (Schmidhuber & Tubiello, 2007): 1) directly through altering agroecological conditions; 2) indirectly through influencing the demand for agricultural products, income distribution, and overall economic growth; and 3) indirectly through lowering the amount of land available for agriculture. However, other experts argue that the way climate change affects agriculture in developing countries can unintentionally benefit farming households. These households may experience an increase in income when food costs rise due to the decreased agricultural output brought on by population growth (Valenzuela & Anderson, 2011). The purpose of this part is to identify patterns and trends associated with the expected implications of climate change on land use and food security by reviewing prior research. Therefore,



Source: author's construction using data from Weibe et al.

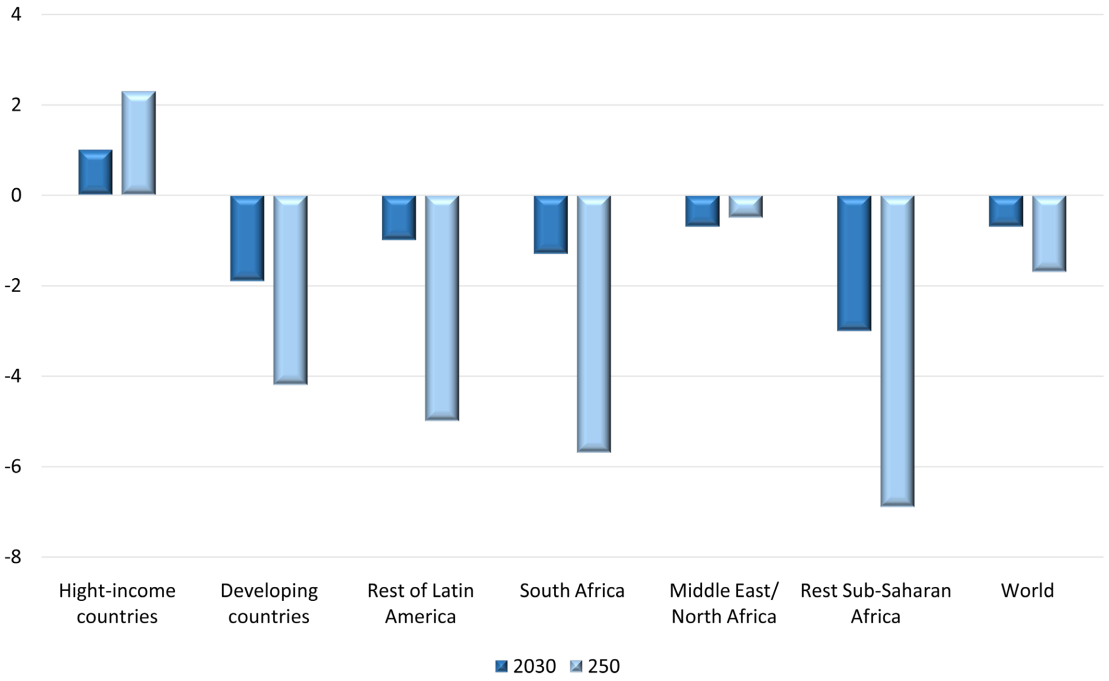
Figure 13. Climate change's expected effect on the world's hungry population.

Figure 13 shows expected effect of climate change on the world's hungry population.

In order to evaluate the influence of climate change on the prevalence of undernourishment, Molotoks et al. (Molotoks et al., 2021) compared increases to baseline circumstances in two global impact scenarios: the lowest, SSP1-RCP2.6, and the highest, SSP3-RCP6. Their results show that undernourishment as a result of climate change more than tripled in both scenarios, with an average of 13 percent during the research period. Certain regions have been identified as being especially vulnerable to high levels of undernourishment associated with climate change, including sections of South Asia, Africa, and Latin America. While there is variation in regions such as South Asia and Latin America, a higher number of African countries are anticipated to have high prevalence rates in the scenario with the lowest global impact. The largest difference between the two scenarios is evident in Southern Africa, where the population undernourished is expected to increase by more than 30% from a "moderately low" impact in the lowest scenario to a "very high" impact in the highest scenario.

To sum up, this discussion draws attention to the significant potential impact of climate change on the incidence of hunger, undernourishment, and household income. Although the study's conclusions are compelling, they also highlight geographical and temporal variations. It is anticipated that emerging nations will have greater rates of undernourishment, hunger, and poorer wages than industrialized nations.

Using worldwide data, Figure 14 shows the impact of climate change on agriculture between the year of 2030 and 2050 which shows that high-income



Source: author's illustration based on data from Center for Global Development.

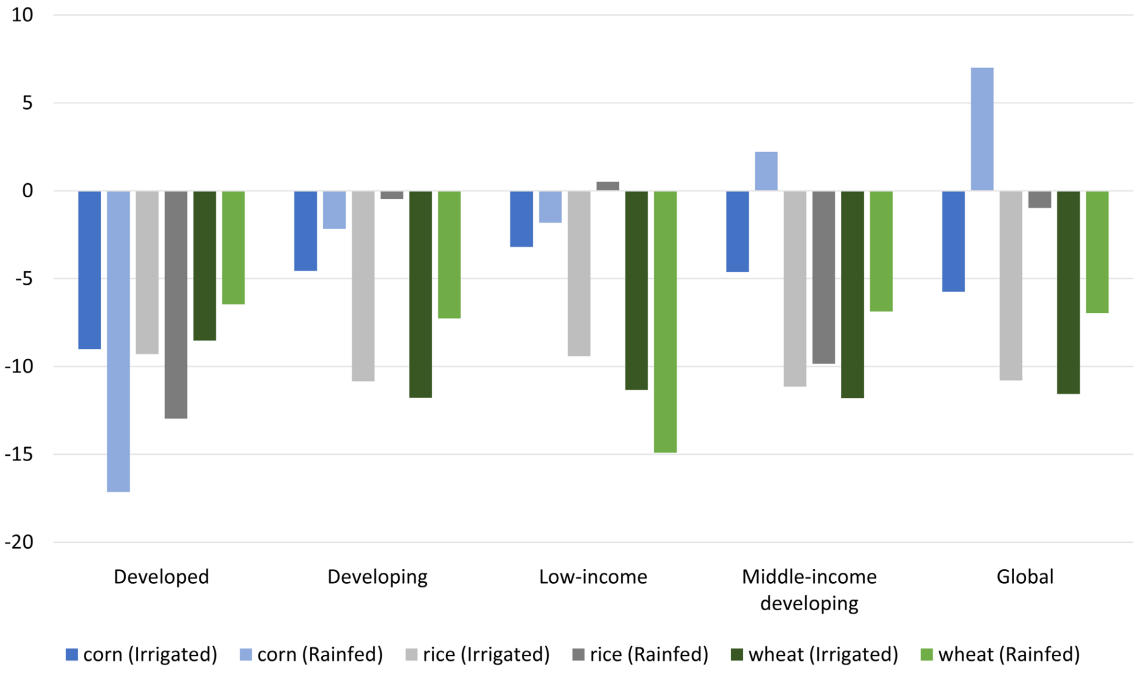
Figure 14. Impact of climate change on agriculture between 2030 and 2050.

countries may benefit from climate change shocks, while developing countries are predicted to see a negative response in agricultural production. It also indicates that although the effect of climate change on agricultural productivity may be small in the short run, it will increase dramatically over the next several decades.

This decline in agricultural output is predicted to result in an increase in global agricultural prices. It is expected that regardless matter how optimistic or pessimistic the scenario is, global food prices will rise significantly by 2050 compared to 2020. Specifically, prices for cereal grains, sugarcane, sugar beet, and wheat are expected to increase by 38 to 43 percent, contingent upon the emissions scenario considered.

3.3.2. Agricultural Land and Food Safety

Agricultural output is expected to undergo changes in response to climate change in different regions from 2010 to 2050, as shown in **Figure 15**. These numbers show the average effect that two different global warming scenarios (1.4˚C and 2.8˚C) are projected to have by the year 2050. In affluent nations, irrigated crops produce far higher yields of wheat, rice, and maize than rainfed crops. In contrast, middle-class and developing nations are expected to experience poorer crop yields from irrigated varieties. Unlike in high-income nations, low-income nations may feel the effects of climate change more acutely on irrigated rice and maize varieties. It is expected, however, that rainfed wheat crops in low-income nations will be more severely affected than irrigated crops. The findings from the simulations conducted by Nelson et al. show that depending on the location, the impact of climate change on crops that are grown using rainwater or irrigation could differ



Source: author's illustration using presented by Nelson et al. (Nelson et al., 2010).

Figure 15. Change in projected yield (in percentage terms) due to climate change from 2010 to 2050.

greatly. Change in projected yield (in percentage terms) due to climate change from 2010 to 2050.

According to research by Berhane (Berhane, 2018), considerable yield decreases in low-latitude regions are predicted as a result of climate change. Using a baseline value of 0.6˚Cover preindustrial levels Li et al. (Li, Pan, Xiong, Xie, & Ali, 2022) simulated the future effects of climate change on world maize production under scenarios of 1.5˚C and 2˚C of global warming. The findings demonstrate how yield variations depend on the rate of warming, the length of time elapsed, and the location; maize yields are predicted to rise by 0.18 percent at 1.5˚C and fall by 10.8 percent at 2˚C. The mid-latitudes of Africa and North America, Asia, and South America's middle and lower latitudes are where the majority of the losses are located.

These results imply that, in comparison to high-income nations, developing economies are likely to see a more noticeable impact from climate change on agricultural yields. Since the primary sector is a major source of income for many developing economies, the effects of climate change may have a substantial influence on the lives of those who work in agriculture. The projected impacts of climate change on key agricultural yields are outlined in **Table 3**, with a focus on Africa.

The first finding from the studies in the above table show a great deal of variability in their scope, which makes it difficult to compare the outcomes across various nations and areas. This unpredictability also draws attention to a critical knowledge gap about the effects of global and regional climate change on certain crops. There is a problem with policy since there is so little thorough evidence, especially on a global and regional scale.

The above table shows that while a small number of researches address other crops, the bulk focus on maize, sorghum, rice, and millet. Studies carried out in Asia and Africa have predominantly documented adverse effects of climate change on rice yields; however, there is inconclusive information about crops such as sorghum, maize, and millet. Notably, it seems that the negative effects on rice yields are more severe in Pakistan, Thailand, India, and Nigeria. As opposed to Africa, the results point to a somewhat detrimental effect of climate change on maize yields in Asia.

In contrast, maize is less hardy in Sudan, Ghana, Nigeria, Mali, Cameroon, Botswana, and Benin than it does in areas like Rwanda, Kenya, and Burundi. Sorghum exhibits a similar pattern, being more resilient in Nigeria but more fragile in Sudan, Ethiopia, Mali, Cameroon, and Botswana states. These results suggest that some crops can persist in particular areas even in the face of unfavorable climate change conditions. Forecasting the effects of climate change and creating practical adaptation plans may benefit from an understanding of the spatial dynamics associated with agroecological differences. The temporal and regional variability linked to the effects of climate change implies that hazards are probably variable in terms of time, crops, irrigation techniques, and geographic

Table 3. The projected impacts of climate change on key agricultural.

Country/region	Predicted year and the researcher	Crop (% change in yield)				Degree of warming (˚C)
		Wheat	Rice	Corn/maize	Millet	
Nigeria	2035 to 2085	2 to 4	−22	−11	4.1	2 to 4
Nepal	2030 to 2050	1.6 to 2.8	−0.8 to −7.2	−2.4 to −8.4		1.7 to 2.8
India	2046 to 2050	4.5 to 8.6				4.5 to 8.6
Sudan	2050	3.6		−59.5		3.6
Pakistan	2050	3.3	−20.5			3.3
Mekong river delta	2050	1	−35			1
Legal amazon	2049	1.4	−7.5	−7.9		1.4
Tanzania				−3.2 to −8		
Uganda				−2.2 to −8.6		
Rwanda	2030 to 2050			10.8 to 14.9		
Kenya				15 to 17.7		
Burundi				9.1		
Ethiopia	2050			−21.8		
Thailand	2030 to 2090	3.5 to 12.5	−9.37 to −33.7			3.5 to 12.5
Mali	2030			−11.2 to −13.5	−6.3 to −11.5	
Botswana				1 to 36		
Benin	2020 to 2025		−2.5	−4		
Sub-Saharan Africa	2046 to 2065			−22	−17	
Africa	2040 to 2069				48 to 55	
Ghana	2050			−14.18		
Cameroon	2080	2.5 to 3.5		−8.2 to −14.6		2.5 to 3.5

Source: author's illustration using data from literature (Adejuwon, 2006; Adom, 2024; Chalise et al., 2017; Pipitpukdee et al., 2020; Thornton et al., 2010).

areas. Due to the fact that the most susceptible regions in Africa are found in the west and east, it is imperative that the highest-risk areas in each region be given priority.

3.4. Effects of Climate Change on Health

Cardiovascular disease, Stroke, Concerns regarding our food and water supply. Affirmative! Climate change exacerbates these issues! Health-related expenses associated with climate change are projected to reach between US$2 billion and US$4 billion by 2030. That is a substantial cost for our worldwide community. From now until 2050, climate-related diseases are projected to result in over 250,000 fatalities, particularly impacting developing nations with weaker healthcare systems (WHO, 2021). Although research differs regarding the severity of these impacts, there is a

consensus that the outlook is unfavorable.

A study conducted by Li et al. (Li, Ren, Kinney, Joyner, and Zhang, 2018) examined heat-related fatalities in major cities in China. It is estimated that between 2041 and 2060, around 37,000 more fatalities due to heat may occur annually, according to specific climate scenarios. In dry places such as Kerman, Iran, Aboubakri et al. (Aboubakri et al., 2020) examined the impact of temperature fluctuations on mortality rates due to heat and cold, while also considering adaption mechanisms. Chang et al. (Chang et al., 2022) provided insights into the correlation between elevated temperatures of merely 1˚C and the rise in cardiovascular mortality rates. The hazards of malaria are increasing, as Ermert et al. (Ermert et al., 2012) indicate that the likelihood of outbreaks may rise owing to climate change.

The research indicates that these adverse consequences vary according to time and location, necessitating our attention. The long-term effects appear to surpass the immediate ones, particularly for nations with fragile healthcare systems. The correlation between health and production is significant. Adverse health impacts can impede economic progress, especially in underdeveloped countries. Failure to address climate change effectively could negate advancements in health and jeopardize sustainable development objectives. Collaboratively mitigating global warming to 1.5˚C could prevent millions from illness and premature mortality, which is a goal worth pursuing.

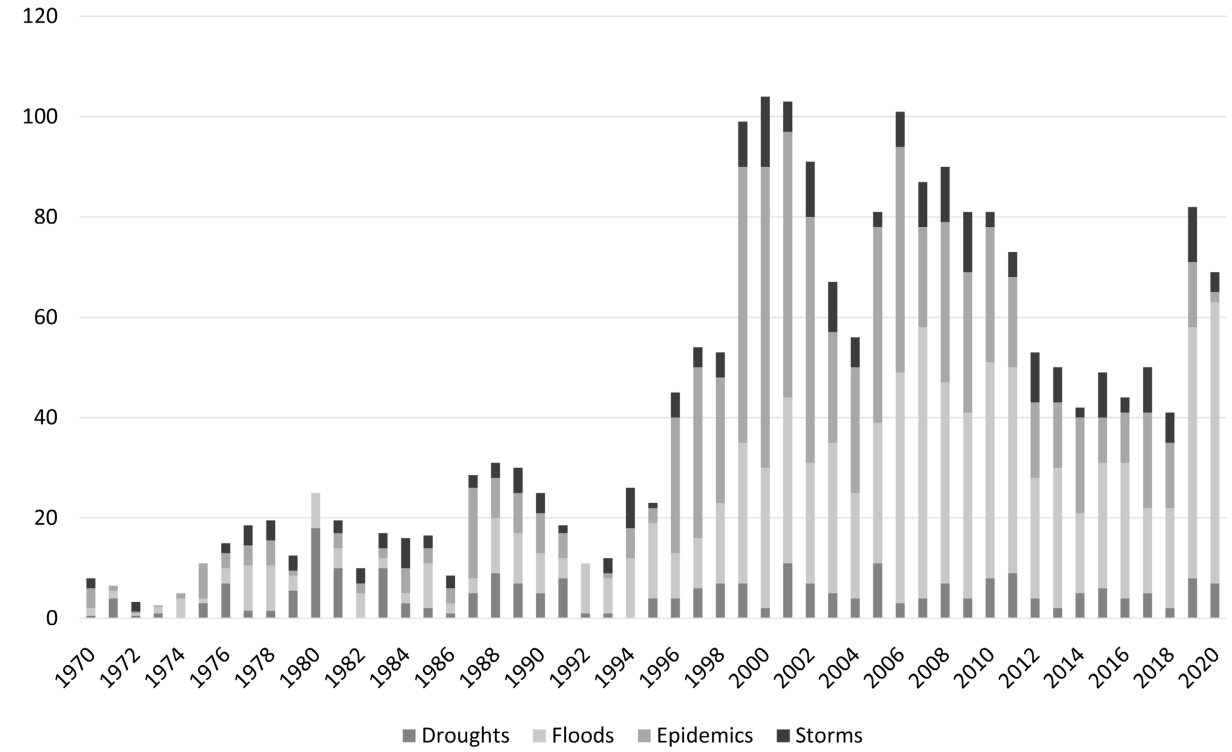
3.5. Effects of Climate Change on Water Resources

The climate is significantly impacting our water resources. It is not a singular issue; rather, it is a confluence of difficulties. For instance, elevated temperatures, alterations in precipitation, and increased severity of weather can lead to both water scarcity and flooding. Certain regions rely on snow for their water supply. Reduced snowfall may present significant issues for them. Currently, around 3.6 billion individuals globally experience significant water scarcity. According to the Word Meteorological Organization (2022), this figure may escalate to 5 billion by 2050.

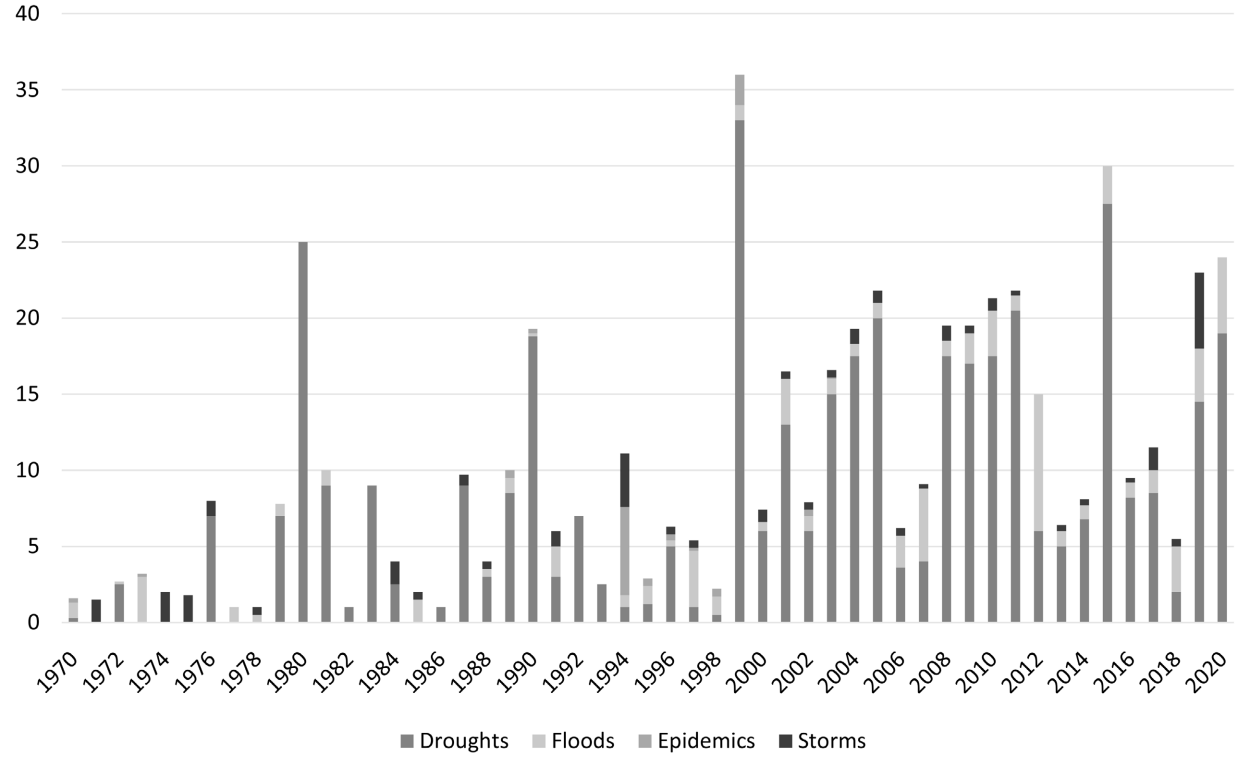
Rainfall patterns are also undergoing alterations. Droughts may affect certain regions, while others may experience excessive rainfall and flooding. **Figure 16** presents Natural disasters in Sub-Saharan Africa from 1970 to 2020**.** This study observed a transformation in the global movement of water. This results in an increase in arid days and severe flooding, along with accelerated glacier melt. In 2021, a greater number of locations had drier-than-average conditions compared to the historical norm of the preceding 30 years (Word Meteorological Organization, 2022).

Another concern is the quality of water. Elevated temperatures can induce algal blooms and promote the proliferation of pathogenic microorganisms. This is detrimental to both our health and the environment. The effects on water complicate agriculture, energy production, and may adversely affect our economy due to the fundamental importance of water.

Hashemi et al. (Hashemi et al., 2015) investigated groundwater variations in



(a)



(b)

Source: CRED and World Bank.

Figure 16. Natural disasters in Sub-Saharan Africa from 1970 to 2020. (a) Describes Sub-Saharan Africa's natural disasters from 1970-2020, (b) Describes quantity of individuals impacted.

Iran's arid regions and found little differences between present and future scenarios for groundwater recharging. In Brazil, De Moura et al. (De Moura et al., 2020) examined a healthy watershed and discovered that sufficient water may still be accessible despite a reduction in minimum flow levels. However, they cautioned that severe climate change could exacerbate water stress, a significant issue under their RCP8.5 scenario in contrast to RCP4.5.

Andersson et al. (Andersson et al., 2006) observed a decline in annual river flow in Africa's Okavango River, with anticipated losses of approximately 13% - 20% from 2050 to 2080. Balcha et al. (Balcha et al., 2023) investigated the potential impacts of climate change on the water balance in the lakes basin of Ethiopia's Central Rift Valley. They saw slight increases in anticipated rainfall, but confirmed that elevated temperatures are undoubtedly forthcoming. Current considerations on irrigation strategies in Asia, particularly in India, highlight concerns related to climate change, as increased precipitation may lead to heightened flooding, while diminished surface runoff could adversely impact irrigation systems. The situation in Africa is complex as well. Groundwater resources are expected to decline in conjunction with surface runoff and precipitation as a result of climate change.

4. Adaptation and Mitigation Strategies

4.1. Economic Benefits of Mitigation

Financial gains from investing in climate mitigation techniques can be significant. By 2030, shifting to a low-carbon economy would boost the global economy by $26 trillion, according to the Global Commission on the Economy and Climate (Global Commission on the Economy and Climate, 2018). Stern's (Stern, 2007) analysis emphasizes the potential benefits of aggressive climate action, including increased energy security, reduced energy prices, and job creation.

4.2. Climate Change Can Be Halted While Boosting the Economy

The business community was first hesitant to address global climate change, but a growing amount of research and efforts indicates that this is a rare chance for both sustainable development and economic success. Adopting bold climate policies may result in profits of USD $26 trillion by 2030 and the creation of 65 million new employment in low-carbon sectors, according to research released in late 2018 by the World Commission on the Economy and Climate (Development, 2018). In order to create a more robust and advantageous growth model, the paper highlights the necessity of a structural shift across five important economic sectors:

1) Smarter Urban Developments: By making cities more compact, linked, and coordinated, the world can potentially save up to $17 billion by 2050 and boost economic growth by providing better access to housing and employment opportunities.

2) Clean Energy Systems: An extra billion people could receive contemporary energy services by decarbonizing the energy system and utilizing decentralized, digital electrification technologies.

3) Smart Water Management: By 2050, the GDP (Gross Domestic Product) might drop by as much as 6% in areas where there is a water scarcity. By using water more wisely, developing technology, and making investments in public infrastructure, this trend can be stopped.

4) Sustainable Land Use: Adopting stricter forestry regulations and switching to more environmentally friendly farming methods might result in yearly economic gains of about USD $2 billion.

5) Circular Industrial Economy: After the initial usage, 95% of the materials worth plastic packaging or USD $120 billion annually are wasted. Policies that encourage the more economical and efficient use of resources could increase world trade while lowering pollution and waste. Within the next two to three years, leaders in the public and commercial sectors are urged by the Global Commission on the Economy and Climate to put these crucial steps into action. To ensure equitable growth and a just transition, this involves putting a price on carbon emissions, making it mandatory for businesses to disclose financial risks related to climate change, stepping up investments in sustainable infrastructure, utilizing private sector innovation, boosting value chain transparency, and putting people first.

According to the United Nations Organization (UNO), there is still time to stop climate change and lessen its disastrous impacts. The organizational and technological capacities of humanity enable us to confront and repair the harm done to the world and to nature.

5. Conclusion and Policy Implications

Economic growth, agricultural production, poverty, food security, health, water resources, and the energy sector are some of the socioeconomic variables that are impacted by climate change. Data used in this study comes from studies that have already been published and used to statistically assess the possible future effects of climate change on these components.

There is a large gap in the literature on a comprehensive analysis of all these indicators, even though researchers have looked at different parts of them independently to understand the consequences of climate change. Because of the widespread belief that emerging economies, particularly those in Africa, will bear the brunt of climate change, that is where the bulk of this paper's attention is directed. Problems like membership fees prevented us from reviewing all relevant work, no matter how hard we tried. Therefore, we acknowledge that this report may not contain all relevant information.

This investigation allows for the deduction of numerous conclusions. It is expected that there will be winners and losers in terms of GDP consequences. The research suggests that while wealthy economies might see short-term gains, these advantages should eventually wane. On the other hand, even in the medium run, the costs are probably going to be more than the advantages for emerging nations, and this tendency is only going to get worse. Furthermore, considerable effects are

detected at the subregional and national levels, underlining the significance of localized analysis in understanding the economic ramifications of climate change, even when the overall expected impact of climate change on global GDP may seem minor.

Economic growth, agricultural production, poverty, food security, health, water resources, and the energy sector are some of the socioeconomic variables that are impacted by climate change. Data used in this study comes from studies that have already been published and used to statistically assess the possible future effects of climate change on these components. There is a large gap in the literature on a comprehensive analysis of all these indicators, even though researchers have looked at different parts of them independently to understand the consequences of climate change. Because of the widespread belief that emerging economies, particularly those in Africa, will bear the brunt of climate change, that is where the bulk of this paper's attention is directed. Problems like membership fees prevented us from reviewing all relevant work, no matter how hard we tried. Therefore, we acknowledge that this report may not contain all relevant information.

Research keeps showing that the agriculture industry is especially susceptible to the effects of climate change. A fall in the value of farmland and a rise in food insecurity are possible outcomes. Although it is widely agreed upon that increasing temperatures would have a negative impact on productivity and crop yields, increased precipitation levels have the potential to improve crop yields in the future. There is ample evidence that climate change affects rice production, indicating that major rice-producing nations would probably experience serious difficulties. On the other hand, results on crops like millet, sorghum, and maize indicate significant variability and no discernible trends, making the effects on these crops less certain. Notably, decreased food yields due to climate change are a problem for both developed and developing countries; however, the hazard seems to be greater in developing economies, particularly in Africa.

According to regional estimates, by 2030 and 2050, agricultural yields could range significantly between regions due to climate change. Crop yield reductions ranging from −0.6 percent to -10.8 percent are predicted for the rest of the world, gains of 1 percent to 14 percent for Latin America, and decreases of −2.9 percent to −18 percent for Africa. In particular, it is predicted that crop output declines in Africa will range from 2.9% to 5% by 2030 and then from 6.8% to 18% beyond 2050. Africa's West and East are seen as being especially susceptible.

The type of crop and its geographic location have a major impact on how climate change affects crop production. For example, different crops in Africa, such as sorghum and maize, show different degrees of resistance to climate change, which emphasizes the significance of spatial dynamics in determining effects on production. Furthermore, because rainfed crops are dependent on steady rainfall, it is expected that they will suffer more than irrigated crops. Crop prices are predicted to rise as a result of this general drop in yields, maybe by a factor of 10% to 100%.

Furthermore, there is ample evidence from studies on how climate change affects agricultural value to suggest that while higher precipitation may improve farmland value, rising temperatures will have the opposite impact. It is anticipated that the value of smaller landholdings will drop more than that of bigger ones. It is also mentioned that long-term effects on agricultural value are anticipated to be more severe than medium-term effects.

There will likely be more people suffering from extreme hunger, undernourishment, and lower income levels as a result of the reduction in agricultural productivity brought on by climate change. A far greater number of people would probably experience extreme hunger if global warming is allowed to go unchecked, with poor nations likely to be more affected than industrialized ones. Africa is expected to be the developing continent most severely affected by hunger-related problems. According to research, the medium- to long-term effects of climate change may put over 200 million people in Africa in danger of acute starvation.

Furthermore, it is predicted that undernourishment will worsen due to the consequences of climate change in the future, especially in areas like Asia, Latin America, and Africa. The economic sustainability of the agriculture industry is also under jeopardy, as predictions indicate that losses from climate change could surpass thirty percent of crop income for developing nations. This scenario carries a considerable risk of plunging a large number of people into poverty because agriculture provides a livelihood for a significant section of the population in emerging nations. Research indicates that, in comparison to non-climate change scenarios, poverty rates in Africa may increase by 20 to 30 percent.

The hydrological cycle is being significantly impacted by climate change, which will alter precipitation patterns, groundwater availability, and streamflow amount and timing. Although these changes are seen around the world, different areas and nations experience them in very different ways. The increasing likelihood of floods is a bigger problem associated with climate change in Asia than any possible effects on irrigation systems. In contrast, water shortage is a major issue in Africa and is expected to become even more severe in the case of severe climate change. More than half a million people may experience water scarcity as a result of these developments.

Particularly in less developed countries with weaker health care systems, climate change has serious consequences for people's physical and mental well-being. Scientists are in agreement that global warming is a factor in the worsening health situation and the increasing mortality toll. The severity of the health effects of climate change is proportional to its duration and severity. It should be noted that the negative health impacts are expected to be more pronounced in extreme climate scenarios in comparison to less extreme ones. It is also expected to have significant long-term implications on health. It is projected that nations with inadequate health infrastructures will bear the brunt of these effects, since the costs to health from climate change will surpass $2 billion by 2030. Finally, climate change poses a significant risk to energy security, especially in developing countries. It is

generally believed that as temperatures rise, energy consumption will also rise, and this effect is most apparent on the demand side. Heating and cooling demands are likely to rise in response to warmer weather, further taxing energy resources in these regions. When it comes to the supply side, though, the data is more complex and varies by both the geography and the specific energy source being considered. Nearly everyone agrees that climate change reduces the efficiency of some renewable energy sources like solar, wind, and thermal power; however, how it will affect others, like hydropower and biofuels, is less obvious. Significantly, solar panels maintain their effectiveness throughout a range of climate conditions, leading many to believe that the impact of climate change on solar energy generation is minimal. In addition, this review has shed light on the potential effects of climate change on a number of socioeconomic indices. Developed and emerging economies alike may feel the pinch in the long run, even while certain areas may benefit and others may lose out in the short term. Climate change consequences on socioeconomic indices are complex and multi-faceted, with conflicting results reported in the literature. This is particularly true in the case of developing nations. It is possible that the varied model assumptions and estimation methodologies used in these studies, along with different starting conditions such as wealth, temperature, sickness burdens, and sectoral outputs, are to blame for this variety.

The negative impacts of climate change are confirmed to be more severe in emerging economies especially in Africa than in industrialized countries across all metrics that were looked at. These regional differences emphasize how important it is to plan initiatives for climate adaptation that take local settings into consideration. These differences also imply that some sectors may require priority attention even in the most impacted regions, like Africa. As a result, it is crucial to concentrate on these high-priority areas that are most susceptible to the effects of climate change when developing plans for adaptation.

Authors' Contributions

Writing, review and editing, Clemence Abadata; supervision, Tian Ze. All authors have read and agreed to the submitted version of the manuscript.

Funding

This research is supported or funded by fundamental research funds for central universities of China. grant number B220207035.

Data Availability Statement

The first step in the research strategy for this study was to find pertinent keywords, which were divided into two main categories: socioeconomic factors and indicators of climate change. Each category had different keywords as it is shown in Figure 2. The second step was to match every climate change indicator with the socioeconomic indicators from different literatures. The third step was to Find the most pertinent research required sifting through the collected data. The objective

of this methodical approach is to guarantee a thorough comprehension of the interaction between socioeconomic variables and climate change in developing nations, thereby aiding in the creation of efficacious resilience and adaptation tactics. The literatures were examined broadly, without limitation in terms of period or context.

Acknowledgements

We give thanks and glory to almighty God, for the gift of life and health he has given unto us in our lives. We thank him for the wisdom, love, care and protection. We would also like to thank the anonymous editor and the referees, for their time, comments and suggestions which are very helpful. We would also like to thank the fundamental research funds for the central universities of China for the funding.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Aboubakri, O., Khanjani, N., Jahani, Y., Bakhtiari, B., & Mesgari, E. (2020). Projection of Mortality Attributed to Heat and Cold; the Impact of Climate Change in a Dry Region of Iran, Kerman. *Science of The Total Environment, 728,* Article ID: 138700. https://doi.org/10.1016/j.scitotenv.2020.138700

Adejuwon, J. (2006). Food Crop Production in Nigeria. II. Potential Effects of Climate Change. *Climate Research, 32,* 229-245. https://doi.org/10.3354/cr032229

Adom, P. K. (2024). *The Socioeconomic Impact of Climate Change in Developing Countries in the Next Decades: A Review* (pp. 20-32). Center for Global Development.

Andersson, L., Wilk, J., Todd, M. C., Hughes, D. A., Earle, A., Kniveton, D. et al. (2006). Impact of Climate Change and Development Scenarios on Flow Patterns in the Okavango River. *Journal of Hydrology, 331,* 43-57. https://doi.org/10.1016/j.jhydrol.2006.04.039

Baarsch, F., Granadillos, J. R., Hare, W., Knaus, M., Krapp, M., Schaeffer, M. et al. (2020). The Impact of Climate Change on Incomes and Convergence in Africa. *World Development, 126,* Article ID: 104699. https://doi.org/10.1016/j.worlddev.2019.104699

Balcha, S. K., Awass, A. A., Hulluka, T. A., Bantider, A., & Ayele, G. T. (2023). Assessment of Future Climate Change Impact on Water Balance Components in Central Rift Valley Lakes Basin, Ethiopia. *Journal of Water and Climate Change, 14,* 174-200.

Berhane, A. (2018). Climate Change and Variability Impacts on Agricultural Productivity and Food Security. *Journal of Climatology & Weather Forecasting, 6,* Article No. 240. https://doi.org/10.4172/2332-2594.1000240

Brouwer, R., & Spaninks, F. A. (1999). The Validity of Environmental Benefits Transfer: Further Empirical Testing. *Environmental and Resource Economics, 14,* 95-117. https://doi.org/10.1023/a:1008377604893

Burke, M., Davis, W. M., & Diffenbaugh, N. S. (2018). Large Potential Reduction in Economic Damages under UN Mitigation Targets. *Nature, 557,* 549-553. https://doi.org/10.1038/s41586-018-0071-9

Campagna, L. M., & Fiorito, F. (2022). On the Impact of Climate Change on Building

Energy Consumptions: A Meta-Analysis. *Energies, 15,* Article 354. https://doi.org/10.3390/en15010354

Chalise, S., Naranpanawa, A., Bandara, J. S., & Sarker, T. (2017). A General Equilibrium Assessment of Climate Change-Induced Loss of Agricultural Productivity in Nepal. *Economic Modelling, 62,* 43-50. https://doi.org/10.1016/j.econmod.2017.01.014

Chang, C. C., Hsu, C. S., & Hsu, S. H. (2022). *Integrated Assessment of Climate Change-Driven Temperature Impacts on Health and Labor Force Participation in Taiwan Region.* National Taiwan University.

Covington, H., & Thamotheram, R. (2015). The Case for Forceful Stewardship (Part 1): The Financial Risk from Global Warming. *SSRN Electronic Journal, 1,* 2-19. https://doi.org/10.2139/ssrn.2551478

de Moura, C. N., Neto, S. L. R., Campos, C. G. C., & Sá, E. A. S. (2020). Hydrological Impacts of Climate Change in a Well-Preserved Upland Watershed. *Water Resources Management, 34,* 2255-2267. https://doi.org/10.1007/s11269-019-02450-1

Development, S. (2018). *Report of the World Commission on Environment and Development: Our Common Future.* https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Dietz, S., & Stern, N. (2014). Endogenous Growth, Convexity of Damages and Climate Risk: How Nordhaus' Framework Supports Deep Cuts in Carbon Emissions. *SSRN Electronic Journal, 125,* 6-17. https://doi.org/10.2139/ssrn.2471019

Dinar, E. A. (2012). *Climate Change and Agriculture in Africa: Impact Assessment and Adaptation Strategies.* Routledge, https://doi.org/10.4324/9781849770767.

Ermert, V., Fink, A. H., Morse, A. P., & Paeth, H. (2012). The Impact of Regional Climate Change on Malaria Risk Due to Greenhouse Forcing and Land-Use Changes in Tropical Africa. *Environmental Health Perspectives, 120,* 77-84. https://doi.org/10.1289/ehp.1103681

Fant, C., Schlosser, C. A., & Strzepek, K. (2016). The Impact of Climate Change on Wind and Solar Resources in Southern Africa. *Applied Energy, 161,* 557-565.

Global Commission on the Economy and Climate (2018). *Global Commission Finds Bold Climate Action Could Deliver US$26 Trillion by 2030.* International Institute for Sustainable Development.

Hallegatte, S. (2010). *A Note on the Economic Cost of Climate Change and the Rationale to Limit It Below 2˚C.* World Bank, Policy Research Working Paper 5179.

Hamududu, B., & Killingtveit, A. (2012). Assessing Climate Change Impacts on Global Hydropower. *Energies, 5,* 305-322. https://doi.org/10.3390/en5020305

Hashemi, H., Uvo, C. B., & Berndtsson, R. (2015). Coupled Modeling Approach to Assess Climate Change Impacts on Groundwater Recharge and Adaptation in Arid Areas. *Hydrology and Earth System Sciences, 19,* 4165-4181. https://doi.org/10.5194/hess-19-4165-2015

Hope, C. W. (2006). The Marginal Impacts of CO_2, CH_4 and SF_6 Emissions. *Climate Policy, 6,* 537-544. https://doi.org/10.1080/14693062.2006.9685619

Hossain, M. S., Arshad, M., Qian, L., Zhao, M., Mehmood, Y., & Kächele, H. (2019). Economic Impact of Climate Change on Crop Farming in Bangladesh: An Application of Ricardian Method. *Ecological Economics, 164,* Article ID: 106354. https://doi.org/10.1016/j.ecolecon.2019.106354

International Monetary Fund (IMF) (2008). *The Fiscal Implications of Climate Change.* IMF, Fiscal Affairs Department.

http://www.imf.org/external/np/pp/eng/2008/022208.pdf

IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.

IPCC (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. https://doi.org/10.1017/9781009325844

Kompas, T., Pham, V. H., & Che, T. N. (2018). The Effects of Climate Change on GDP by Country and the Global Economic Gains from Complying with the Paris Climate Accord. *Earth's Future, 6,* 1153-1173. https://doi.org/10.1029/2018ef000922

Li, D. H. W., Yang, L., & Lam, J. C. (2012). Impact of Climate Change on Energy Use in the Built Environment in Different Climate Zones—A Review. *Energy, 42,* 103-112. https://doi.org/10.1016/j.energy.2012.03.044

Li, K., Pan, J., Xiong, W., Xie, W., & Ali, T. (2022). The Impact of 1.5°C and 2.0°C Global Warming on Global Maize Production and Trade. *Scientific Reports, 12,* Article No. 17268. https://doi.org/10.1038/s41598-022-22228-7

Li, Y., Ren, T., Kinney, P. L., Joyner, A., & Zhang, W. (2018). Projecting Future Climate Change Impacts on Heat-Related Mortality in Large Urban Areas in China. *Environmental Research, 163,* 171-185. https://doi.org/10.1016/j.envres.2018.01.047

Mei, H., Li, Y. P., Suo, C., Ma, Y., & Lv, J. (2020). Analyzing the Impact of Climate Change on Energy-Economy-Carbon Nexus System in China. *Applied Energy, 262,* Article ID: 114568. https://doi.org/10.1016/j.apenergy.2020.114568

Mendelsohn, R., Morrison, W., Schlesinger, M. E., & Andronova, N. G. (2000). Country-Specific Market Impacts of Climate Change. *Climatic Change, 45,* 553-569. https://doi.org/10.1023/a:1005598717174

Mendelsohn, R., Schlesinger, M., & Williams, L. (2000). Comparing Impacts across Climate Models. *Integrated Assessment, 1,* 37-48. https://doi.org/10.1023/a:1019111327619

Molotoks, A., Smith, P., & Dawson, T. P. (2021). Impacts of Land Use, Population, and Climate Change on Global Food Security. *Food and Energy Security, 10,* e261. https://doi.org/10.1002/fes3.261

NASA (2021). *Extreme Weather and Climate Change.* https://science.nasa.gov/climate-change/extreme-weather/

Nelson, G. C., Rosegrant, M., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T. B., Ringler, C., Msangi, S., & You, L. (2010). *Food Security, Farming, and Climate Change to 2050: Scenarios, Results, and Policy Options.* International Food Policy Research Institute. https://www.ifpri.org/publication/food-security-farming-and-climate-change-2050

Nordhaus, W. (1994). *Managing the Global Commons: The Economics of Climate Change.* MIT Press.

Nordhaus, W. (2013). *The Climate Casino.* Yale University Press. https://doi.org/10.2307/j.ctt5vkrpp

Nordhaus, W. D., & Boyer, J. (2000). *Warming the World.* The MIT Press. https://doi.org/10.7551/mitpress/7158.001.0001

Nordhaus, W. D., & Yang, Z. (1996). Regional Dynamic General-Equilibrium Model of Alternative Climate Change Strategies. *American Economic Review, 86,* 740-766. http://www.jstor.org/stable/2118303

Pipitpukdee, S., Attavanich, W., & Bejranonda, S. (2020). Climate Change Impacts on

Sugarcane Production in Thailand. *Atmosphere, 11,* Article 408. https://doi.org/10.3390/atmos11040408

Plambeck, E. L., & Hope, C. W. (1996). An Updated Valuation of the Impacts of Global Warming. *Energy Policy, 24,* 780-795.

Rob Dellink, E. L., Jean Château, Francesco Bosello, Ramiro Parrado, Kelly de Bruin (2014). *Consequences of Climate Change Damages for Economic Growth: A Dynamic Quantitative Assessment.* Economics Department Working Papers No. 1135. https://dx.doi.org/10.1787/5jz2bxb8kmf3-en

Schlenker, W., & Lobell, D. B. (2010). Robust Negative Impacts of Climate Change on African Agriculture. *Environmental Research Letters, 5,* Article ID: 014010. https://doi.org/10.1088/1748-9326/5/1/014010

Schmidhuber, J., & Tubiello, F. N. (2007). Global Food Security under Climate Change. *Proceedings of the National Academy of Sciences, 104,* 19703-19708. https://doi.org/10.1073/pnas.0701976104

Stern, N. (2007). *The Economics of Climate Change.* Cambridge University Press. https://doi.org/10.1017/CBO9780511817434.

Tahir, F., & Al-Ghamdi, S. G. (2023). Climatic Change Impacts on the Energy Requirements for the Built Environment Sector. *Energy Reports, 9,* 670-676. https://doi.org/10.1016/j.egyr.2022.11.033

Thornton, P. K., Jones, P. G., Alagarswamy, G., Andresen, J., & Herrero, M. (2010). Adapting to Climate Change: Agricultural System and Household Impacts in East Africa. *Agricultural Systems, 103,* 73-82. https://doi.org/10.1016/j.agsy.2009.09.003

Tol, R. S. J. (1995). The Damage Costs of Climate Change toward More Comprehensive Calculations. *Environmental & Resource Economics, 5,* 353-374. https://doi.org/10.1007/bf00691574

Tol, R. S. J. (2002). Estimates of the Damage Costs of Climate Change. *Environmental and Resource Economics, 21,* 46-75.

Tol, R. S. J. (2018). The Economic Impacts of Climate Change. *Review of Environmental Economics and Policy, 12,* 4-25. https://doi.org/10.1093/reep/rex027

UNFCC (2018). *Climate Action Plan 2050.* https://unfccc.int/files/focus/application/pdf/161114_climate_action_plan_2050.pdf

Valenzuela, E., & Anderson, K. (2011). Climate Change and Food Security to 2050: A Global Economy-Wide Perspective. In *55th Australian Agricultural and Resource Economics Society Conference* (pp. 5-10). National Library of Medicine. https://doi.org/10.22004/ag.econ.100531

van Vliet, M. T. H., van Beek, L. P. H., Eisner, S., Flörke, M., Wada, Y., & Bierkens, M. F. P. (2016). Multi-Model Assessment of Global Hydropower and Cooling Water Discharge Potential under Climate Change. *Global Environmental Change, 40,* 156-170. https://doi.org/10.1016/j.gloenvcha.2016.07.007

Weitzman, M. (2012). GHG Targets as Insurance against Catastrophic Climate Damages. *Journal of Public Economic Theory, 14,* 220-245.

WHO (2021). *Climate Change and Health.* World Health Organization. https://www.who.int/news-room/fact-sheets/detail/climate-change

Word Meteorological Organization (2022). *State of Global Water Resources 2021.* https://library.wmo.int/idurl/4/58262