Climate security nexus: Climate inequality and food security between Middle East & North African Countries

Dina Mohyee Eldin Mohamed Abdel-Naby
Assistant professor of Economics
School of Business and Economics, Badr University in Cairo- BUC, Egypt
School of Business, Ain Shams University- ASU, Egypt.

Mohamed Abdelraouf
School of Business and Economics, Badr University in Cairo- BUC, Egypt
Faculty of Management & Technology, Arab Academy for Science and Technology and Maritime Transport- AAST, Egypt

Rania Alaa Eldin Ahmed Khedr
Assistant professor of Economics
School of Business and Economics, Badr University in Cairo- BUC, Egypt

Abstract

This paper aims to investigate climate inequality between countries in the Middle East and North Africa (MENA) during 2012–2020. This is done by comparing their unequal contribution to climate change and their unequal impact on food security. MENA countries are classified according to two criteria (per capita emissions and level of income) into two groups (Gulf and other MENA). The study conducts a t-test to determine whether there is a significant difference in the mean values of the variables between the two groups of countries. Then, two panel data regression models are conducted to study the impact of CO2 emissions on food security in the two groups. Results reveal that the Gulf countries have a significantly higher contribution to climate change and a significantly better performance on food security than the other MENA countries. In addition, the regression analysis reveals that for other MENA groups, their own low carbon emissions do not significantly affect their food security, despite their worse performance on food security. On the other hand, the high carbon emissions of Gulf countries are significantly affecting their food security.

Keywords: Climate Inequality, Food Security, CO2 emissions, MENA countries

1. Introduction

The climate issue is currently causing significant disruptions to human society since it profoundly impacts the fundamental aspects of human livelihoods and social structures. The interplay between these climatic fluctuations and their repercussions across diverse societal facets has spawned an intricate tapestry of interactions that warrant meticulous scrutiny and remediation (Nordhaus, 2019).

Due to the increased frequency and intensity of extreme weather events, climate change has reduced food security in some countries. The decline in agricultural productivity directly affects food price volatility, threatening the food security of economically vulnerable people. The impact on agriculture has been particularly strong in mid- and low-latitudes, and malnutrition is expected to worsen worldwide (Bezner Kerr et al., 2022). Climate change also harms food security indirectly. It reduces crop output directly and indirectly through water availability, pests, and illnesses. Climate change also affects food safety during transport and storage (Mbow et al. 2020).

The variety of socio-economic development, topography, and climate in the Middle East and North Africa (MENA) area makes it a climate change flashpoint. Like other regions, MENA is subject to environmental problems and climate change. In the past decade, the region has witnessed more severe weather conditions, high temperatures, little precipitation, and drought (Duenwald et al., 2022). MENA has 11 of the 17 countries with the highest levels of water stress. The MENA area uses nearly 80% of its water for agriculture, compared to 70% globally. Water resources are concentrated for agricultural use, limiting the region's ability to explore alternative uses. Water and arable land shortages may be a threat to domestic production (Cramer et al., 2018).

Many countries, particularly in the MENA region, suffer from food insecurity. Although making up 6% of the world's population, MENA is home to 54.3 million undernourished people (12.2% of the total) (Chancel et al., 2023).

Climate change makes inequality worse. Rich nations with large contributions to climate change often experience less severe climate effects than low- and middle-income nations (UNDP, 2022).

Climate inequality and food security within MENA nations have not been examined adequately, to our knowledge. The contribution of this paper is to help fill this knowledge gap. Thus, this paper aims to examine climate inequality within MENA nations by comparing their unequal climate change contributions and unequal impacts on food security.

The study is structured as follows: Section 2 analyses the research on climate inequality and how food security is affected by climate change after the introduction. Furthermore, it The approach is discussed in Section 3. The issue of climatic disparity and how it affects food security in MENA nations is demonstrated in Section 4. We do the empirical analysis in Section 5. Conclusions and implications are covered in Sections 6 and 7.

2. Literature Review

2.1 Climate inequality

Climate inequality, also known as climate injustice or environmental inequality, highlights how climate change and environmental degradation affect different communities, regions, and socioeconomic categories. This inequality increases social, economic, and political disparities, rendering disadvantaged areas more susceptible to climate change (Schlosberg and Collins, 2014; Hendricks and Van Zandt, 2021).

Carbon emissions, primarily in the form of greenhouse gases like carbon dioxide (CO2), significantly contribute to climate change. Their uneven distribution has led to the emergence of climate inequality, wherein certain communities experience more severe consequences of climate change while contributing less to the issue (Alcañiz & Hubacek, 2021).

There is extensive documentation supporting the notion that countries with advanced industrialization and higher levels of economic activity have consistently been responsible for the highest levels of carbon emissions throughout history. However, the negative consequences of these emissions are experienced to a greater extent in underdeveloped countries and socially disadvantaged communities (Islam & Winkel, 2017).

Less developed nations struggle to adapt to climate change due to infrastructural and resource shortages. This includes harsh weather, rainfall variations, and increasing ocean levels. This vulnerability worsens climate change, producing population displacement, food shortages, and subsistence losses (Van Baalen and Mobjörk, 2018).

Geographical location plays a pivotal role in driving climate inequality. Climate change affects vulnerable nations like the Global South due to extreme weather, rising sea levels, and changing precipitation patterns (Rahman et al., 2019). Drought, coastal erosion, and hurricanes disproportionately impact the unprepared (Sultana, 2014). These communities frequently lack the means to relocate or implement viable adaptation measures. As a result, they face heightened vulnerabilities to the impacts of climate change (Wang and Liu, 2017; Nyika, 2022).

Income disparity renders poor individuals vulnerable. Low-income communities lack infrastructure and key services, making them more susceptible to climate change. They have limited climate adaptation and catastrophe recovery funds (Ajibade and McBean, 2014).

Environmental racism and climate injustice disproportionately harm historically oppressed communities. Discriminatory regulations allow polluting companies and waste facilities to operate in these areas, affecting health and climate resilience (Ahmed and Eklund, 2021).

Migration and displacement caused by climate change fuel inequality. Sea-level rise, desertification, and harsh weather force vulnerable communities to shift and perhaps marginalise them. Resource disputes and tensions may rise (Gonzalez, 2020).

Multiple measures are needed to reduce climate inequality. Recognise the historical and structural causes of inequality. This requires addressing how colonialism, institutional racism, and power inequality impact climate change susceptibility. Policymakers and stakeholders should emphasise disadvantaged people's climate adaptation and mitigation requirements (Sardo, 2023).

When addressing the issue of climate inequality, the goal is not to blame high-income, high-emitting groups while absolving low-income, low-emitting groups (Chancel et al., 2023). However, it is imperative that developed nations, which have traditionally been the primary contributors to greenhouse gas emissions, assume accountability for providing assistance in climate adaptation and mitigation endeavours within poorer countries (Afionis et al., 2017).

Mussini and Grossi (2015) investigated the effects of changes in country ranking and per capita CO2 emissions on carbon inequality in Europe during 1991–2011. It used a three-term decomposition methodology that helped detect the within-group and between-group contributions to each component of inequality change. Chancel (2022) analysed global climate inequality during 1990–2019 using environmental input-output tables and a framework differentiating emissions from consumption and investments. He concluded that global climate inequality was attributed mostly to within countries rather than between countries.

In addition, Semieniuk and Yakovenko (2020) investigated the historical evolution of both global CO2 emissions attributed territorially and global inequality in carbon footprints attributed to end consumers and contrasted that with the projected inequality to achieve ambitious climate mitigation goals. Finally, many studies measured carbon emissions in different countries and regions using different indicators, particularly those that studied the relationship between GDP and per capita emissions (Cai et al., 2018; Xie et al., 2019; Zheng et al., 2019; Steinberger et al., 2012).

2.2Climate Change & Food Security

Food security is a complex and important problem that has gained scholarly and policy attention. Food security means that all members of a population have reliable access to enough, safe, and nutritious food that meets their dietary needs, allowing them to live active and healthy lives (Leck et al., 2015).

This represents the basic human right to adequate nutrition for health. Food instability and malnutrition affect around 800 million people worldwide (Weiler et al., 2017). A large section of the world's population lacks reliable access to affordable, healthy, and safe food. Poverty, warfare, climate change, and economic upheavals all threaten food security (Adeyeye, 2017).

Numerous academic studies have explored the interplay between climate change and food security, examining complex dynamics and potential solutions. This research aims to contribute valuable insights to inform the decisions of policymakers, scholars, and practitioners alike.

Ajaj et al. (2019) investigated the implications of climate change on food security in the United Arab Emirates (UAE). The researchers investigated the influence of climate change on the agricultural sector in the United Arab Emirates (UAE), including temperature variations, changes in precipitation patterns, and the prevalence of extreme weather phenomena. The study also looked at the problems of water scarcity, soil degradation, and agricultural production unpredictability, which are exacerbated by population growth and urbanisation. The study's findings highlight the negative impact of climate change on agricultural productivity in the country, specifically through temperature increases, changes in precipitation patterns, and increased water scarcity.

Tull (2020) also sought to assess the possible effects of climate change on food security in MENA and identify important problems and prospects for adaptation. The study found that climate change threatens MENA food security. Climate change will reduce regional water resources. It may increase water competition between agriculture, industry, and residences. Rising temperatures and rainfall may limit agricultural productivity, especially in rain-fed areas, and more frequent and severe droughts and heat waves may affect crops and animals. Sea level rise may flood coastal regions and displace people, disrupting food production and distribution.

Moreover, Sivakumar et al. (2013) found that climate change may affect food security in West Asia and North Africa and sought adaptation alternatives to reduce these effects. The results found that climate change is already affecting WANA food security and will worsen. Yemen, Sudan, and Syria are the most vulnerable nations in the area due to food shortages. The poor and marginalised in WANA nations would be disproportionately affected by climate change in terms of food security.

Climate change will reduce WANA grain production by 10–20% by 2050. Regional water availability is predicted to decline 10–20% over the same period. Droughts and floods will become more frequent and intense. Finally, WANA requires a climate change adaptation strategy that covers agriculture, water management, and disaster risk reduction.

The Global Food Security Index used in this paper to assess the state of food security considers 4 dimensions: food affordability, availability, quality, and safety, alongside sustainability and adaptation:

1. Affordability

The "affordability" dimension of food security is crucial to ensuring subsistence and well-being for people and society. The economic accessibility of food means families and people may get a variety of healthy food without compromising their finances or health (Yeoh et al., 2014).

Affordability depends on population economics. Income, employment, and the economy affect food purchases. Even when food is abundant, the poor cannot afford it (Yeong et al., 2021).

Food price variations can affect affordability, especially for underprivileged groups. Global market fluctuations, supply chain interruptions, and inflationary pressures can cause food price surges. This makes getting vital nourishment difficult for low-income people (Zurek et al., 2022; Barret, 2020).

In tackling food security affordability, social safety nets and assistance programmes are crucial. Governments and organisations use food aid, monetary transfers, and nutrition education to bridge the gap between economic restrictions and nutritional needs (Narayanan and Gerber, 2017).

Income disparity haunts this environment. Income inequality can prolong food insecurity by making it harder for marginalised populations to get inexpensive, nutritious food (McArthur et al., 2018).

Promoting sustainable food systems also helps maintain costs. Encourage local food production, reduce food waste, and help small-scale farmers stabilise food prices and increase affordability in local areas (Reisch, 2021).

It is imperative to underscore that while affordability represents a pivotal facet of food security, it is inextricably linked to other dimensions, including availability, access, and utilization. The convergence of economic accessibility and nutritional value within food is vital for the realisation of comprehensive food security and the safeguarding of the health and well-being of global populations (Oruma et al., 2021).

2. Availability

Within the holistic framework of ensuring the nutritional well-being of populations, the dimension known as "availability" stands as a pivotal cornerstone in the realm of food security. This dimension revolves around the consistent presence of a diverse, safe, and nutritionally rich array of food sources, essential for meeting the dietary needs of individuals and communities (Lam et al., 2022).

At its core, food availability hinges on the productivity of agricultural systems. The capacity to generate an ample supply of crops and livestock serves as the bedrock for addressing the nutritional requirements of a global population in constant growth. Elements such as soil health, climatic conditions, water accessibility, and sustainable agricultural practices exert direct influence on the yield and variety of the food produced (Ponisio and Ehrlich, 2016).

Innovations in agricultural methods and technology can improve the food supply. Precision farming, hydroponics, agroforestry, and robust crop varieties have improved crop yields while reducing resource use and environmental effects (Majid et al., 2018).

The rich tapestry of commerce and distribution networks also affects food availability. Global markets allow food to transcend borders, alleviating local shortages and increasing food variety. Trade policies and agreements affect food commodity availability (Challinor et al., 2018).

Food availability is crucial to food security, but price, quality, and sustainability are also important. An excess of food does not guarantee food security; rather, a combination of an accessible, high-quality, and constant food supply provides the foundation for nutritional well-being (Cantarero, 2020).

This dimension evaluates a nation's agricultural output, its ability to meet its food needs, the quality of its farm infrastructure, and its investments in agricultural research and development. The impact of climate change and extreme weather events has adverse effects on food availability in several ways. For instance, extreme weather events lead to reduced crop yields, resulting in lower agricultural production. Additionally, climate change disrupts the smooth operation of agricultural supply chains by raising the risk of food spoilage during storage (IPCC 2022).

3. Quality and safety

Within the larger context of promoting the health and well-being of individuals and society, the aspect of food security known as "quality" plays a crucial role. The focal point of this dimension pertains to the intrinsic characteristics of the food that individuals consume, including its nutritional content, safety, and appropriateness for consumption. These factors have substantial consequences for human well-being and health (Wong et al., 2017).

Nutritional quality, as an integral component of food security, is paramount. The nutritive value of food assumes a central role in meeting the dietary requirements of individuals and in promoting their overall well-being. The adequate intake of essential nutrients, vitamins, and minerals stands as a linchpin for proper growth, cognitive development, and the prevention of a spectrum of health issues linked to diet (Fanzo, 2015).

Safety, another pivotal facet of food quality, warrants considerable attention. Contaminants, pathogens, and improper handling practices can compromise the safety of food, posing substantial health risks to consumers. Ensuring that food is devoid of harmful substances and adheres to rigorous safety standards emerges as a critical measure for safeguarding public health (Okpala and Korzeniowska, 2023; Forsythe, 2020).

Effectively promoting food quality necessitates the establishment of robust regulatory frameworks and rigorous oversight (Lara et al., 2019). Governments and international organisations frequently institute standards and regulations aimed at monitoring and controlling the nutritional content, safety, and labelling of food products. The cultivation of consumer awareness and education also plays a pivotal role in stimulating demand for high-quality food. In the context of food security, the dimension of food quality intimately intersects with other dimensions such as availability and affordability (Béné et al., 2016).

While the abundance of food is undeniably crucial, the nutritional adequacy and safety of that food are equally imperative. Low-quality food, even when accessible, can precipitate malnutrition and health ailments, thereby undercutting the overarching goal of achieving comprehensive food security (Tondel et al., 2022).

4. Sustainability and adaptation

Sustainability in food security is essential to ensuring the well-being of present and future generations. This dimension involves producing, distributing, and consuming food sustainably to protect natural resources, ecosystems, and the environment (Mensah, 2019; Cole et al., 2018).

Food security and sustainability involve several important factors. Agricultural practices are crucial to sustainability. Sustainable farming approaches maximise productivity while protecting soil quality, water purity, and ecological variety. Changing crop cycles, adding trees, and using organic farming methods preserve soil fertility and reduce chemical use (Guiné et al., 2021).

Water resource management is essential. Water is scarce, so sustainable food systems use it effectively. Irrigation solutions that reduce water waste and pollution enhance food production and ecosystems (Gliessman, 2021).

Sustainability and biodiversity conservation are linked. The pollination and pest control functions of diverse ecosystems boost agricultural output. Long-term food security is improved through biodiversity conservation, including habitat management and crop variety preservation (Rehman et al., 2022).

Food waste must be decreased for sustainable food security. Food is wasted a lot in the production, delivery, and eating processes. Enhancements in food preservation, logistics for transportation, and consumer education optimise food consumption and protect resources (Kasza et al., 2022). Mitigation and adaptation to climate change are necessary for sustainable food systems. Changes in precipitation patterns, temperature rises, and extreme weather can all have an impact on food production. Conservation tillage and drought-resistant crop cultivars aid in agriculture's adaptation to climate change and lower carbon footprints (Loboguerrero et al., 2019).

Sustainable food security requires inclusivity and ethics. Fair work, resource access, and social justice in food systems support sustainability and social responsibility (Berti and

Mulligan, 2016). "Food miles" emphasises the need to reduce food transportation's environmental impact. Local food production and distribution networks reduce carbon emissions from long transportation distances and build community resilience (Chen and Hsu, 2015).

Food security sustainability is linked to global goals like the UN's Sustainable Development Goals (SDGs). The second aim, "Zero Hunger," emphasises sustainable food systems that provide food security, environmental stewardship, and economic growth (Reyers and Selig, 2020).

3. Methodology

To fulfil the aim of this paper, first we conduct an analysis of the unequal contribution to and impact of climate change within the MENA region. Second, we conduct an empirical analysis to measure climate inequality within the region.

To address the problem of climate inequality between countries in MENA, this paper studies only 14 MENA countries due to data availability. The reason behind this selection is that the data from the Global Food Security Index used to measure food security is available only for 15 MENA countries. We classify these countries according to two criteria: their contribution to climate change and their level of income. According to this classification, the countries are divided into two groups: high-contribution (high-income countries) and low-contribution (middle- and low-income countries).

The 1st group includes the 6 Gulf countries: Qatar, Kuwait, the UAE, Saudi Arabia, Oman, and Bahrain. ***The 2nd group*** includes the other 8 MENA countries: Turkey, Jordan, Tunisia, Morocco, Algeria, Egypt, Syria, and Yemen. Note that the paper excludes Israel from the 15 countries because it fails to meet the 2 criteria used in the classification. Specifically, its contribution to climate change is relatively low compared to the Gulf countries, but, on the other hand, it's a high-income country.

The time series covered is 2012–2020 due to the availability of data on both the GFSI and CO2 emissions. The GFSI time series data starts in 2012, while the latest published data on CO2 emissions is from 2020.

4. Analysis of Climate Inequality Within the MENA Region

4.1. Climate inequality: Inequality of contribution to climate change Within MENA

Climate inequality in contributions to carbon emissions persists between regions across the world. For instance, North America is considered the highest emitting region, with an average per capita emission of about 18.8 tonnes of carbon dioxide equivalent (tCO2e) in 2020, which is much higher than the world average of 5.6 tonnes as shown in Fig. (1). On the other hand, Sub-Saharan Africa is considered the lowest emitting region, with an average per capita emission of about 18.8 tons. Although the MENA region's average per capita emission is slightly above the world average (5.6 tons), recording about 7 tonnes, the inequality is much more apparent between countries in the region.

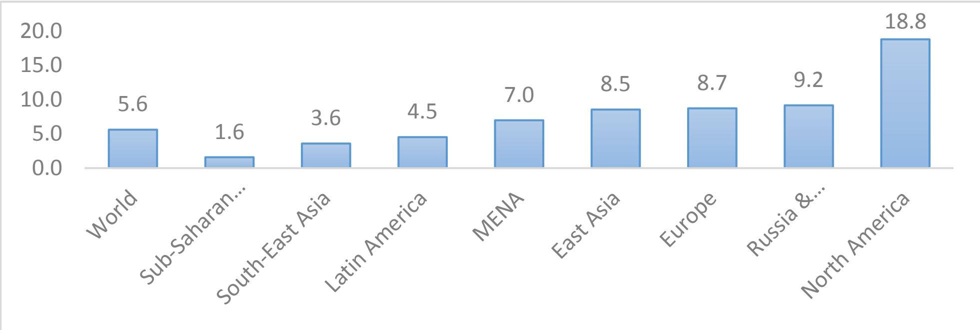


Figure (١): tCO2e/capita by region 2020
Source: World inequality database 2023

Gulf countries emit more than other MENA countries. As illustrated in fig. 2, the 6 Gulf nations averaged 23.9 tonnes per capita emissions, whereas the remaining MENA countries averaged 3.4 tonnes. The Gulf nations' substantial contribution is due to fossil fuel burning in the energy sector. Gulf nations are among the world's biggest polluters (Babonneau et al., 2023). Another reason is the high level of carbon-intensive consumption associated with rich people living in these high-income countries. These people own large apartments, drive luxury cars, and consume more goods and services (Chancel et al., 2023).

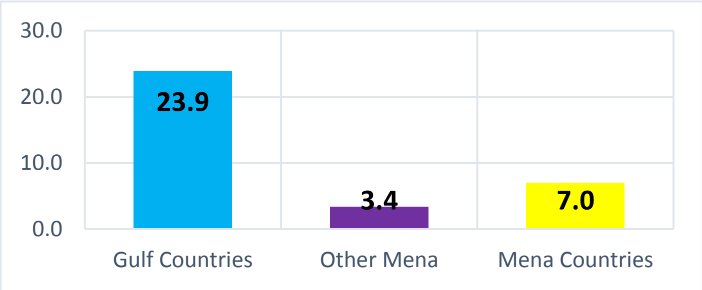
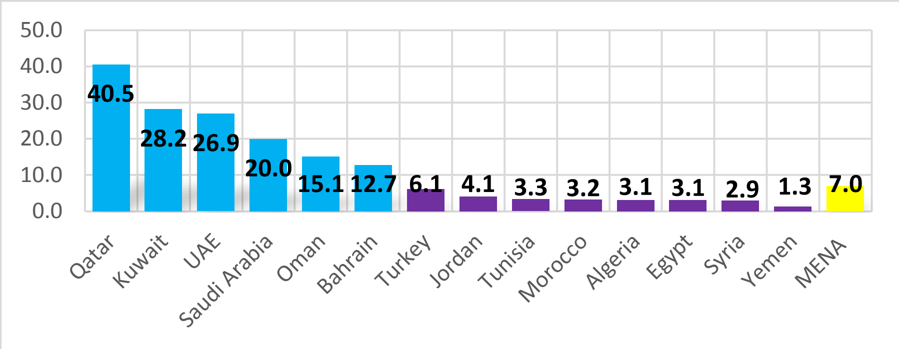


Figure (٢): tCO2e/capita between groups of MENA region 2020
Source: World inequality database 2023

Note: [1] The average of MENA region is 7.0. this value is for all MENA countries not only the 14 countries included in our study. [2] The values of the 2 groups Gulf and Other MENA is an average value of per capita emissions calculated by the authors.

At figure (3), it is observable that when the MENA region was magnified, it was found that Qatar has the highest carbon emissions in the region, recording 40.5 tonnes of carbon dioxide equivalent (tCO2e) compared to only 1.3 tonnes in Yemen. In addition, the emissions of all Gulf countries are much higher than the region's average. On the other hand, the emissions of the other group are much lower than the average, except for Turkey. Thus, these large differences in carbon emissions show the extent of climate inequality's contribution to climate change between countries in the MENA region.

Figure (3) tCO2e/capita of MENA countries 2020



Source: World inequality database 2023

4.2.Climate inequality: Inequality of Impact of climate change on Food Security Within MENA

This paper uses the Global Food Security Index (GFSI) to assess the state of food security in MENA countries. The GFSI was developed by the Economist Intelligence Unit (EIU), which considers 4 dimensions: food affordability, availability, quality, and safety, alongside sustainability and adaptation across 113 countries.

By looking at the MENA region, it can be found that it recorded an average score compared to the world average in 2020. Its best performance was in the 2 dimensions of affordability, quality, and safety, while its worst performance was in the sustainability and adaptation dimensions. During the past decade, the region has encountered distinct food price volatility, specifically in countries with political instability.

In this regard, among the key strengths of the MENA countries, on average, is their economic development progress towards providing their people with affordable food and relatively low dependency on food aid, except for the distressed countries of Yemen, Syria, and Jordan. On the other hand, climate risk exposure is one of the most significant challenges facing the region, especially given the high risk of droughts and storms. Another risk concerning climate change is water shortages. In terms of policy commitments to climate change, it has the worst performance among world regions.

However, if we dig deeper inside the MENA region, inequality becomes more apparent. Being the wealthiest countries in the region, food security in Gulf countries is reinforced by adequate agricultural infrastructure, in addition to well-funded food safety net programmes compared to other MENA countries.

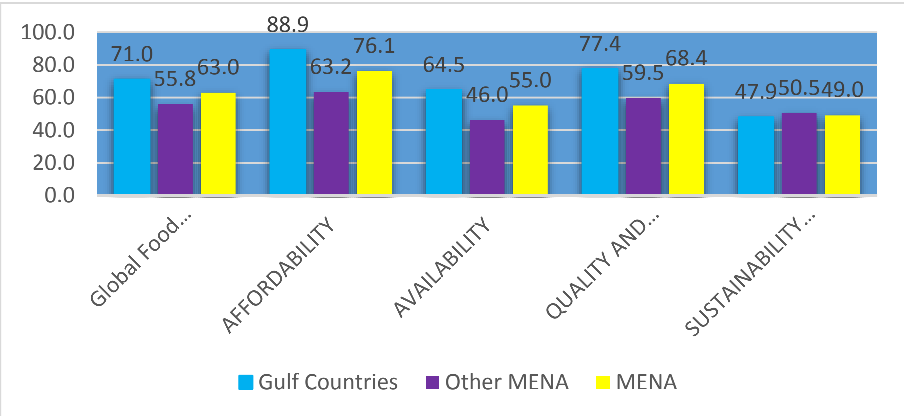


Figure (4): Global Food Security Index between groups of MENA Region 2020

Source: Global Food Security Index, Economist Intelligence Unit 2023

* The average values for Gulf and other MENA countries are calculated by the authors

With respect to the ***food affordability*** dimension of the GFSI, the Gulf countries suffer less in terms of poverty and perform much better than other MENA countries, especially Yemen, Syria, and Egypt, which suffer high poverty rates. Climate-related price shocks for agricultural goods negatively affect food security. The provision of strong food safety net programmes in Gulf countries makes their populations more resilient to price shocks and enhances their ability to cope with climate change hazards compared to other MENA countries. Consequently, they recorded an average score in food affordability of 88.9, which is higher than that of other MENA (63.2), as shown in figure 4. In addition, the top 5 best performers in the region are the Gulf countries, which recorded a score in food affordability above the average of the MENA region, while the worst performers are from the other group, with Syria and Yemen recording a very weak performance, as shown in table (1).

Table 1: Top Vs Weakest Performers of Food Affordability Dimension

Top 5 Best Performers in 2020		**Top 5 Weakest Performers in 2020**	
Country	**Score**	**Country**	**Score**
Qatar	**92.2**	**Syria**	**38.6**
Kuwait	**90.1**	**Yemen**	**45.6**
UAE	**86.7**	**Turkey**	**54.7**
Oman	**88.4**	**Egypt**	**64.2**
Bahrain	**88.1**	**Tunisia**	**73.6**

Source: Global Food Security Index – Economist Intelligence Unit 2023

The performance of MENA region recorded an average score of 55 in terms of ***food availability.*** However, there's a noticeable contrast between gulf and other MENA countries whereby the former group achieved an average score of 64.5 compared to 46 for the latter._Notably, Qatar, UAE, Saudi Arabia, Oman, and Turkey led the area, while Yemen, Syria, Tunisia, Morocco, and Algeria lagged (Table 2).

The troubled nations of the MENA region, including Syria and Yemen, persist in confronting the problem of achieving food sufficiency. In the MENA region, the prevalence of food assistance reliance is generally low, except for Syria and Yemen, which are characterised by political instability, and Jordan, which bears a significant burden of hosting a substantial refugee population.

FAO predicted that food supplies in the MENA region will remain robust in the face of the COVID-19 crisis. Nonetheless, the MENA region faces potential trade disruptions because it heavily relies on cereal imports. The countries most at risk are those affected by conflicts and instability.

There are still shortcomings in the infrastructure and transportation systems of MENA nations. In this region, there is a significant gap between the Gulf countries, which have well-developed road networks, and other MENA nations, where most roads are in moderate to poor condition. Particularly, Yemen is in an exceptionally unfavourable position and ranks poorly on a global scale.

Table 2: Top Vs Weakest Performers of Food Availability Dimension

Top 5 Best Performers in 2020		Top 5 Weakest Performers in 2020	
Country	**Score**	**Country**	**Score**
Qatar	72.5	Yemen	27.4
UAE	69.6	Syria	27.5
Saudi Arabia	68	Tunisia	47
Oman	65.3	Morocco	49.5
Turkey	59.5	Algeria	50

Source: Global Food Security Index – Economist Intelligence Unit 2023

Furthermore, among the nations in the MENA area, Egypt, Algeria, and Turkey are identified as the countries with the lowest performance in terms of food loss, both within the region and on a worldwide scale.

Within the GFSI, the third dimension, -**Quality & Safety** - assesses both the diversity and nutritional quality of the average diet, in addition to examining food safety measures. It is worth noting that when we specifically examine the MENA region in this context, their performance in this dimension exceeds the global average.

However, when considering the average quality and safety score of Gulf countries, which stands at (77.4), it becomes evident that this score holds greater significance compared to that of the other MENA region, which is rated at (59.5). Thus, it can be found that the top five performers in the region belong to the Gulf countries, surpassing the MENA region's average. Conversely, the countries falling into the latter category, including Syria and Yemen, demonstrate lower performance, as indicated in the table (3).

Table 3: Top Vs Weakest Performers of Food Quality & Safety Dimension

Top 5 Best Performers in 2020		Top 5 Weakest Performers in 2020	
Country	**Score**	**Country**	**Score**
UAE	82.60	Yemen	48.70
Bahrain	79.50	Syria	50.40
Kuwait	78.70	Egypt	52.80
Oman	76.00	Algeria	54.50
Qatar	75.90	Jordan	59.40

Source: Global Food Security Index – Economist Intelligence Unit 2023

Moreover, it was found that all MENA countries provide electricity access to nearly their entire populations, except Yemen (62%), and Syria (86%). In addition, these two countries have experienced deteriorations in food safety conditions and issues related to nutrition.

It is observed in figure (2.4) that the average score of the MENA region in ***Sustainability and Adaptation*** is 49.0, which is considered the worst among all the dimensions. All countries in the MENA region are at a significant risk of experiencing drought, while Gulf nations face specific challenges related to storms and heightened temperatures. Additionally, GCC countries are the most exposed to rising temperatures.

MENA countries heavily rely on food imports, and their economies are deeply dependent on revenues generated from natural resources. These nations have one of the highest levels of food import dependency, with approximately 75% of their cereal consumption relying on imported sources on average.

Water scarcity poses a significant and widespread threat to all MENA nations. While water quality concerns are less pronounced, they are notably elevated in Yemen. Across the MENA region, over half of the countries lack any form of climate adaptation strategy. A mere four nations have displayed modest dedication to establishing pre-emptive warning systems or environmentally conscious agricultural techniques, with their commitment to handling exposure falling well below the international norm.

5. Empirical Analysis of Climate Inequality Within MENA

This paper analyses data using statistical techniques and tests during the period 2012-2020. Table (4) describes all the variables used in the study.

Table 1: Variables used in the study:

Variables Nature	Variables	Symbol	Data Source
Independent Variables	National carbon footprint - Per capita emissions	**CO2pce**	**World inequality Database**
Control Variables	Agriculture value added per worker	**ALP**	**FAOSTAT**
	Population, total	**POP**	**World Development Indicators**
	GDP Per Capita	**GDPPC**	
Dependent Variable	Global Food Security Index	**GFSI**	**Economist Intelligence Unit**
	Affordability	**$GFSI_{AF}$**	
	Availability	**$GFSI_{AV}$**	
	Quality and Safety	**$GFSI_{QS}$**	
	Sustainability and Adaptation	**$GFSI_{SA}$**	

To reach the aim of the paper the following statistical techniques and tests were employed:

1. ***Descriptive statistics***
2. ***Correlation Matrix***: to determine the degree of correlation between the variables used in the study.
3. ***t-test***: to determine if there is a significant difference in the mean values of the variables between the 2 groups of countries (high- and low- emission countries).
4. ***Panel Data Regression Models***: to study the impact of carbon emissions on food security between the 2 groups of countries.

5.1. Descriptive statistics

Table 2 Variables Descriptive Statistics

Variables	Sample Size	Descriptive Statistics			
		Minimum	**Maximum**	**Mean**	**Std. Dev.**
CO2pce	126	1.332	46.729	13.031	12.632
ALP	126	2023.360	41741.530	13254.809	8398.560
POP	126	1224939	107465134	27182975.8	28993836.6
GDPPC	126	726.739	72870.374	16266.364	17964.064
GFSI	126	38.100	74.000	59.992	9.517
$GFSI_{AF}$	126	33.400	92.400	74.210	15.796
$GFSI_{AV}$	126	24.900	72.500	51.464	11.944
$GFSI_{QS}$	126	41.900	84.300	66.001	10.444
$GFSI_{SA}$	126	33.300	61.100	44.608	6.524

5.2.Correlation Matrix

Table 3: Correlation Matrix

Variables	Corr.	CO2pce	ALP	POP	GDPPC	GFSI
CO2pce	**Corr.**	1				
	***p*-value**					
ALP	**Corr.**	0.353	1			
	***p*-value**	0.000				
POP	**Corr.**	-0.466	-0.244	1		
	***p*-value**	0.000	0.006			
GDPPC	**Corr.**	0.952	0.283	-0.430	1	
	***p*-value**	0.000	0.001	0.000		
GFSI	**Corr.**	0.650	0.537	-0.274	0.651	1
	***p*-value**	0.000	0.000	0.002	0.000	

Table (5) shows that there is a statistically significant correlation between GFSI and **CO2pce ،ALP, POP and GDPPC** where *p–value* < $\alpha = 0.05$.

5.3. t-Test

The t-test is used to determine whether there is a significant difference in the mean values of the variables between the 2 groups of countries (high- and low- emission countries).

Table 4: Testing for the differences between High- and Low- emissions group of countries

Variables	Emissions	Sample Size	Descriptive Statistics				*t*–test	
			Min	Max	Mean	Std. Dev.	t	*p*-value
CO2pce	**High**	54	12.719	46.729	25.725	9.300	**-19.999**	**0.000**
	Low	72	1.332	6.935	3.511	1.389		
ALP	**High**	54	9388.14	41741.53	17430.52	7880.26	**-5.339**	**0.000**
	Low	72	2023.360	28453.5	10123.0	7390.5		
POP	**High**	54	1224939.0	35997107.0	9100804.0	11305012.4	**7.187**	**0.000**
	Low	72	7211863.0	107465134.0	40744604.6	30812599.9		
GDPPC	**High**	54	17662.24	72870.37	32566.08	16608.16	**-14.297**	**0.000**
	Low	72	726.739	12072.4	4041.6	2937.3		
GFSI	**High**	54	57.400	74.000	67.067	4.397	**-9.433**	**0.000**
	Low	72	38.100	67.300	54.686	8.854		
$GFSI_{AF}$	**High**	54	63.700	92.400	86.356	5.243	**-10.011**	**0.000**
	Low	72	33.400	86.500	65.100	14.914		
$GFSI_{AV}$	**High**	54	44.800	72.500	59.802	7.464	**-8.950**	**0.000**
	Low	72	24.900	61.500	45.211	10.819		
$GFSI_{QS}$	**High**	54	59.300	84.300	73.957	6.377	**-9.845**	**0.000**
	Low	72	41.900	78.500	60.033	8.800		
$GFSI_{SA}$	**High**	54	33.300	53.600	42.778	5.503	**2.801**	**0.006**
	Low	72	33.800	61.100	45.981	6.919		

Table 7 reveals that there's a significant difference between high- and low- emissions MENA countries in terms of all variables. This result supports our hypothesis of a significant difference between high- and low- emissions MENA countries in terms of the unequal contribution to climate change and its unequal impact on food security.

5.4. Regression Analysis

Since the aim of this paper is to study climate inequality in 14 countries of the MENA region during 2012-2020, it uses Panel (longitudinal) Data model that combines cross-sectional data for the 14 countries and time series data for the period 2012-2020. This method is applied through the following models:

1. Pooled Regression Model.
2. Fixed Effect Model.
3. Random Effect Model.

To determine the appropriate Panel Data Model, the study used the following tests:

1. Wald Test (Restricted F-test)
2. Breusch-Pagan LM (Lagrange Multiplier)
3. Hausman test

Table 5: Pooled, fixed and Random Models summary

Emissions	LM test		Wald test		Hausman test		Best model
	Breusch-Pagan	*p-value*	F	*p-value*	χ^2	*p-value*	
High	13.418	0.000	7.053	0.000	12.244	0.016	**Fixed effect model**
Low	168.156	0.000	34.458	0.000	2.574	0.632	**Random effect model**

From table (5) it can be found that:

1. ***Lagrange Multiplier***: *P-value = 0.000 < α = 0.05 indicting that the Random effect model is better than Pooled regression model*

2. ***Wald test:*** *p-value = 0.000*< *α* = 0.05 indicating that fixed effect model is better than pooled regression model.
3. ***Hausman test:***

a. ***For high emission group****: p-value = 0.016* < *α* = 0.05 indicating that fixed effect is better than random effect model.

b. ***For low emissions group:*** *p-value = 0.632* > *α* = 0.05 indicating that random effect is better than fixed effect model.

Based on these results, ***fixed effect model*** *is used for high emissions gulf countries group while using* **random effect model** *for the other group.*

Variables	*High emissions countries*				*Low emissions countries*			
	Regression Coefficients		*t*-test		Regression Coefficients		*t*-test	
	Value	S.E.	*t*	*p*-value	Value	S.E.	*t*	*p*-value
Constant	74.228	12.560	5.910	0.000	38.745	6.2045	6.245	0.000
CO2pce	-0.5336	0.2762	-1.932	0.060	1.8325	1.3972	1.312	0.194
ALP	0.0004	0.0001	3.259	0.002	0.0005	0.0003	1.947	0.056
POP	4.5E-07	6.7E-07	0.667	0.508	1.1E-07	8.4E-08	1.330	0.188
GDPPC	-0.0001	0.0002	-0.877	0.385	-4.6E-05	0.0009	-0.054	0.957
R^2	0.681				0.146			
Adjusted R^2	0.615				0.094			
S.E. estimate	2.727				2.676			
F **test**	10.425				2.852			
***p*-value**	0.000				0.030			

From table (6), the results of the regression analysis reveal the following:

First: with respect to high emissions Gulf countries:

1. There's a statistically significant negative impact of **CO2pce** on **GFSI whereby the p-value = 0.06** < *α = 0.10.*
2. There's a statistically significant positive impact of Agricultural labour productivity ALP on GFSI whereby the p-value = 0.002 < *α = 0.05.*
3. The overall regression model is statistically significant at 5% significance level.
4. An R^2 = 0.681 reflects that the explanatory variables can explain about 68.1% of the variation in GFSI whereas the remaining variation may be due to random error or other explanatory variables not used in the study.
5. In addition, the problem of multicollinearity does not exist whereby the value of The Variance Inflation Factor (VIF) for all variables is below 10 ranging between a minimum of 1.292 and a maximum of 2.224.

Second: with respect to low emissions other MENA countries:

1. There's no statistically significant negative impact of **CO2pce** on **GFSI whereby the p-value = 0.194** > *α = 0.10.*
2. There's a statistically significant positive impact of Agricultural labour productivity **ALP** on **GFSI whereby the p-value = 0.056** < *α = 0.10.*
3. The overall regression model is statistically significant at 5% significance level.

4. An R^2 = 0.146 reflects that the explanatory variables can explain about 14.6% of the variation in GFSI whereas the remaining variation may be due to random error or other explanatory variables not used in the study.
5. In addition, the problem of multicollinearity does not exist whereby the value of The Variance Inflation Factor (VIF) for all variables is below 10 ranging between a minimum of 1.160 and a maximum of 1.832.

Thus, the results of the 2 regression models support the hypothesis of this paper in the sense that, for other MENA group, their own low carbon emissions do not significantly affect their food security despite their worse performance on food security. On the other hand, high carbon emissions of gulf countries are significantly affecting their food security. This result supports our claim of climate inequality between MENA countries.

6. Conclusion

Considering the comprehensive analysis conducted in this research, it is evident that the interplay between climate inequality and food security presents a complex and pressing issue, particularly between countries in the MENA region. This conclusion aims to summarise the key findings and implications derived from the study.

According to Climate Change and Food Security, the study revealed a direct correlation between climate change and food security. Climatic fluctuations, including extreme weather events, reduced agricultural production, and water resource limitations, have significantly impacted food security within the MENA region. This impact is particularly pronounced due to the region's heavy reliance on agriculture, coupled with its vulnerability to changing climate patterns. It is worth noting that the region’s worst food security performance pertains to sustainability and adaptation.

For climate inequality, the research highlights the concept of climate inequality, emphasising that low- and middle-income countries, which contribute less to climate change, often bear a disproportionately higher burden of its consequences. This inequality is evident within the MENA region, where countries with varying levels of carbon emissions experience differential impacts on their food security.

We conclude that the MENA region isn’t among the highest emitters across the world; inequality is much more apparent when we dig deeper within the region. The study reveals that there’s a significant difference in the contribution to climate change between high-emission Gulf countries and low-emission other MENA countries. In addition, the region recorded an average performance with respect to the GFSI compared to the world average. However, there’s a significant difference between high-emission Gulf countries and low-emission other MENA countries with respect to the food security environment.

The regression analysis reveals that for other MENA groups, their own low carbon emissions do not significantly affect their food security, despite their worse performance on food security. On the other hand, the high carbon emissions of Gulf countries are significantly affecting their food security.

It is essential to acknowledge the existing research gap in the study of climate inequality, particularly within the context of MENA countries. This research contributes to filling this gap by examining the differences in climate change contributions and their effects on food security among 14 selected MENA countries. The study employed a rigorous methodological approach, including regression analysis, to assess the relationships between carbon emissions, agricultural productivity, and the Global Food Security Index (GFSI). The results of the analysis were instrumental in drawing meaningful conclusions. However, future research may need to use other econometric methodologies to quantify the differential impact of climate change on food security within the MENA, comprising additional variables (such as the individual dimensions of the GFSI and other variables related to climate change).

These findings highlight the differential effects of carbon emissions on food security within the MENA region. In conclusion, this research contributes valuable insights into the intersection of climate change, food security, and inequality in the MENA region. By shedding light on the differential impacts of carbon emissions on food security, it calls for targeted interventions and policy measures to address climate-related challenges and promote equitable food security outcomes. Addressing climate inequality within the MENA region is not only a scientific imperative but also a moral and humanitarian one, as it holds the key to ensuring a sustainable and just future for all its inhabitants. Further research and international cooperation are crucial to advancing these objectives.

7. Implications

The research findings have significant policy and practical implications. They suggest that efforts to mitigate climate change and improve food security should consider the unique circumstances of individual countries within the region. High carbon emissions Gulf countries should prioritize emissions reduction strategies to safeguard their food security, while low emissions countries should focus on enhancing agricultural productivity. This study provides empirical evidence supporting the notion of climate inequality within the MENA region. It underscores the need for international cooperation and climate justice to address the disparities in climate impacts and their consequences on food security.

References

Adeyeye, S. A. O. (2017). The role of food processing and appropriate storage technologies in ensuring food security and food availability in Africa. *Nutrition and Food Science*, *47*(1), 122-139.

Afionis, S., Sakai, M., Scott, K., Barrett, J., and Gouldson, A. (2017). Consumption-based carbon accounting: does it have a future?. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(1), e438.

Ahmed, S., and Eklund, E. (2021). Climate change impacts in coastal Bangladesh: Migration, gender and environmental injustice. *Asian Affairs*, *52*(1), 155-174.

Ajaj, R. M., Shahin, S. M., and Salem, M. A. (2019). The challenges of climate change and food security in the United Arab Emirates (UAE): From deep understanding to quick actions. *Current Nutrition and Food Science*, *15*(5), 422-429.

Ajibade, I., and McBean, G. (2014). Climate extremes and housing rights: A political ecology of impacts, early warning and adaptation constraints in Lagos slum communities. *Geoforum*, *55*, 76-86.

Alcañiz, I., and Hubacek, K. (2021). Closing the climate inequality gap. *Journal of Cleaner Production*, *292*, 126076.

Arsel, M. (2023). Climate change and class conflict in the Anthropocene: sink or swim together?. *The Journal of Peasant Studies*, *50*(1), 67-95.

Babonneau, F., Badran, A., Haurie, A. et al. GCC Countries Strategic Options in a Global Transition to Zero-Net Emissions.

Barrett, C. B., Benton, T. G., Fanzo, J., Herrero, M. T., Nelson, R., Bageant, E., ... and Wood, S. A. (2020). Socio-technical innovation bundles for agri-food systems transformation.

Batat, W. (2021). A phenomenological exploration into sustainability in the foodservice industry in the MEA region. *Journal of Services Marketing*, *35*(7), 918-932.

Bell, C., and Masys, A. J. (2020). Climate change, extreme weather events and global health security a lens into vulnerabilities. *Global health security: Recognizing vulnerabilities, creating opportunities*, 59-78.

Béné, C., Arthur, R., Norbury, H., Allison, E. H., Beveridge, M., Bush, S., ... and Williams, M. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. *World development*, *79*, 177-196.

Berti, G., and Mulligan, C. (2016). Competitiveness of small farms and innovative food supply chains: The role of food hubs in creating sustainable regional and local food systems. *Sustainability*, *8*(7), 616.

Bezner Kerr, R., T. Hasegawa, R. Lasco, I. Bhatt, D. Deryng, A. Farrell, H. Gurney-Smith, H. Ju, S. Lluch-Cota, F. Meza, G. Nelson, H. Neufeldt, and P. Thornton, 2022: Food, Fibre, and Other Ecosystem Products Supplementary Material. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)].

Blok, A. (2020). Urban green gentrification in an unequal world of climate change. *Urban Studies*, *57*(14), 2803-2816.

Brenton, P., Chemutai, V., and Pangestu, M. (2022). Trade and food security in a climate change-impacted world. *Agricultural Economics*, *53*(4), 580-591.

by WID.world, W. (2023, January 30). *Climate inequality report 2023, fair taxes for a sustainable future in the Global South - wid - World Inequality database*. WID. https://wid.world/news-article/climate-inequality-report-2023-fair-taxes-for-a-sustainable-future-in-the-global-south/

Byers, K. S. (2022). *The Mangrove Walks: An Econometric Analysis of Climate Migration Drivers from Coastal Bangladesh and their Geopolitical Impacts* (Doctoral dissertation, University of Arkansas).

Cai, X., Che, X.H., Zhu, B.Z., Zhao, J., Xie, R., 2018. Will developing countries become pollution havens for developed countries? An empirical investigation in the Belt and road. J. Clean. Prod. 198, 624–632.

Campbell, B. M., Hansen, J., Rioux, J., Stirling, C. M., and Twomlow, S. (2018). Urgent action to combat climate change and its impacts (SDG 13): transforming agriculture and food systems. *Current opinion in environmental sustainability*, *34*, 13-20.

Cantarero, M. M. V. (2020). Of renewable energy, energy democracy, and sustainable development: A roadmap to accelerate the energy transition in developing countries. *Energy Research and Social Science*, *70*, 101716.

Challinor, A. J., Adger, W. N., Benton, T. G., Conway, D., Joshi, M., and Frame, D. (2018). Transmission of climate risks across sectors and borders. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *376*(2121), 20170301.

Chancel, L. (2022). Global carbon inequality over 1990–2019. *Nature Sustainability*, 5(11), 931-938.

Chen, W. T., and Hsu, C. I. (2015). Greenhouse gas emission estimation for temperature-controlled food distribution systems. *Journal of Cleaner Production*, *104*, 139-147.

Cole, M. B., Augustin, M. A., Robertson, M. J., and Manners, J. M. (2018). The science of food security. *npj Science of Food*, *2*(1), 14.

Colenbrander, S., Dodman, D., and Mitlin, D. (2018). Using climate finance to advance climate justice: the politics and practice of channelling resources to the local level. *Climate policy*, *18*(7), 902-915.

Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J. P., Iglesias, A., ... & Xoplaki, E. (2018). Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change*, *8*(11), 972-980.

Duenwald, M. C., Abdih, M. Y., Gerling, M. K., Stepanyan, V., Al-Hassan, A., Anderson, G., ... & Sanchez, J. (2022). *Feeling the Heat: Adapting to Climate Change in the Middle East and Central Asia*. International Monetary Fund.

Fanzo, J. (2015). Ethical issues for human nutrition in the context of global food security and sustainable development. *Global Food Security*, *7*, 15-23.

Forsythe, S. J. (2020). *The microbiology of safe food*. John Wiley and Sons.

Gliessman, S. R. (2021). *Package price agroecology: The ecology of sustainable food systems*. CRC press.

Gonzalez, C. (2020). Climate change, race, and migration. *Journal of Law and Political Economy*, *1*(1).

Govindan, R., and Al-Ansari, T. (2019). Computational decision framework for enhancing resilience of the energy, water and food nexus in risky environments. *Renewable and Sustainable Energy Reviews*, *112*, 653-668.

Guerrero Lara, L., Pereira, L. M., Ravera, F., and Jiménez-Aceituno, A. (2019). Flipping the Tortilla: Social-ecological innovations and traditional ecological knowledge for more sustainable agri-food systems in Spain. *Sustainability*, *11*(5), 1222.

Guiné, R. D. P. F., Pato, M. L. D. J., Costa, C. A. D., Costa, D. D. V. T. A. D., Silva, P. B. C. D., and Martinho, V. J. P. D. (2021). Food security and sustainability: discussing the four pillars to encompass other dimensions. *Foods*, *10*(11), 2732.

Hallegatte, S. (2016). *Shock waves: managing the impacts of climate change* *on poverty*. World Bank Publications.

Hendricks, M. D., and Van Zandt, S. (2021). Unequal protection revisited: Planning for environmental justice, hazard vulnerability, and critical infrastructure in communities of color. *Environmental justice*, *14*(2), 87-97.

Howarth, C., and Viner, D. (2022). Integrating adaptation practice in assessments of climate change science: The case of IPCC Working Group II reports. *Environmental Science and Policy*, *135*, 1-5.

Iheonu, C., Asongu, S., Emeka, E. T., and Orjiakor, E. (2022). Climate change and agricultural productivity in West Africa. *European Xtramile Centre of African Studies WP/22/065*.

Islam, N., and Winkel, J. (2017). Climate change and social inequality.

Kaczan, D. J., and Orgill-Meyer, J. (2020). The impact of climate change on migration: a synthesis of recent empirical insights. *Climatic Change*, *158*(3-4), 281-300.

Kasza, G., Veflen, N., Scholderer, J., Münter, L., Fekete, L., Csenki, E. Z., ... and Izsó, T. (2022). Conflicting issues of sustainable consumption and food safety: risky consumer behaviors in reducing food waste and plastic packaging. *Foods*, *11*(21), 3520.

Kumar, R., Kumar, A., and Saikia, P. (2022). Deforestation and forests degradation impacts on the environment. In *Environmental Degradation: Challenges and Strategies for Mitigation* (pp. 19-46). Cham: Springer International Publishing.

Lam, Y., Winch, P. J., Nizame, F. A., Broaddus-Shea, E. T., Harun, M. G. D., and Surkan, P. J. (2022). Salinity and food security in southwest coastal Bangladesh: impacts on household food production and strategies for adaptation. *Food Security*, 1-20.

Leck, H., Conway, D., Bradshaw, M., and Rees, J. (2015). Tracing the water–energy–food nexus: Description, theory and practice. *Geography Compass*, *9*(8), 445-460.

Leichenko, R., and Silva, J. A. (2014). Climate change and poverty: vulnerability, impacts, and alleviation strategies. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(4), 539-556.

Loboguerrero, A. M., Campbell, B. M., Cooper, P. J., Hansen, J. W., Rosenstock, T., and Wollenberg, E. (2019). Food and earth systems: priorities for climate change adaptation and mitigation for agriculture and food systems. *Sustainability*, *11*(5), 1372.

Majid, I., Nayik, G. A., Dar, S. M., and Nanda, V. (2018). Novel food packaging technologies: Innovations and future prospective. *Journal of the Saudi Society of Agricultural Sciences*, *17*(4), 454-462.

McArthur, L. H., Ball, L., Danek, A. C., and Holbert, D. (2018). A high prevalence of food insecurity among university students in Appalachia reflects a need for educational interventions and policy advocacy. *Journal of nutrition education and behavior*, *50*(6), 564-572.

Menezes-Silva, P. E., Loram-Lourenço, L., Alves, R. D. F. B., Sousa, L. F., Almeida, S. E. D. S., and Farnese, F. S. (2019). Different ways to die in a changing world: Consequences of climate change for tree species performance and survival through an ecophysiological perspective. *Ecology and evolution*, *9*(20), 11979-11999.

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent social sciences*, *5*(1), 1653531.

Mugambiwa, S. S., and Tirivangasi, H. M. (2017). Climate change: A threat towards achieving 'Sustainable Development Goal number two'(end hunger, achieve food security and improved nutrition and promote sustainable agriculture) in South Africa. *Jàmbá: Journal of Disaster Risk Studies*, *9*(1), 1-6.

Mbow, C., Rosenzweig, C. E., Barioni, L. G., Benton, T. G., Herrero, M., Krishnapillai, M., ... & Diouf, A. A. (2020). *Food security* (No. GSFC-E-DAA-TN78913). IPCC.

Mussini, M., and Grossi, L. (2015). Decomposing changes in CO2 emission inequality over time: The roles of re-ranking and changes in per capita CO2 emission disparities. *Energy Economics*, *49*, 274-281.

Narayanan, S., and Gerber, N. (2017). Social safety nets for food and nutrition security in India. *Global food security*, *15*, 65-76.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review*, *109*(6), 1991-2014.

Nyika, J. M. (2022). Climate change situation in Kenya and measures towards adaptive management in the water sector. In *Research anthology on environmental and societal impacts of climate change* (pp. 1857-1872). IGI Global.

Nyiwul, L. (2021). Climate change adaptation and inequality in Africa: Case of water, energy and food insecurity. *Journal of Cleaner Production*, *278*, 123393.

Okpala, C. O. R., and Korzeniowska, M. (2023). Understanding the relevance of quality management in agro-food product industry: From ethical considerations to assuring food hygiene quality safety standards and its associated processes. *Food Reviews International*, *39*(4), 1879-1952.

Oruma, S. O., Misra, S., and Fernandez-Sanz, L. (2021). Agriculture 4.0: an implementation framework for food security attainment in Nigeria's post-Covid-19 era. *Ieee Access*, *9*, 83592-83627.

Palmer, T., and Stevens, B. (2019). The scientific challenge of understanding and estimating climate change. *Proceedings of the National Academy of Sciences*, *116*(49), 24390-24395.

Perrott, B. (2014). The sustainable organisation: Blueprint for an integrated model. *Journal of Business Strategy*, *35*(3), 26-37.

Ponisio, L. C., and Ehrlich, P. R. (2016). Diversification, yield and a new agricultural revolution: Problems and prospects. *Sustainability*, *8*(11), 1118.

Rahaman, A., Kumari, A., Zeng, X. A., Khalifa, I., Farooq, M. A., Singh, N., ... and Aadil, R. M. (2021). The increasing hunger concern and current need in the development of sustainable food security in the developing countries. *Trends in Food Science and Technology*, *113*, 423-429.

Rahman, M. M., Ahmad, S., Mahmud, A. S., Hassan-uz-Zaman, M., Nahian, M. A., Ahmed, A., ... and Streatfield, P. K. (2019). Health consequences of climate change in Bangladesh: an overview of the evidence, knowledge gaps and challenges. *Wiley Interdisciplinary Reviews: Climate Change*, *10*(5), e601.

Rehman, A., Farooq, M., Lee, D. J., and Siddique, K. H. (2022). Sustainable agricultural practices for food security and ecosystem services. *Environmental Science and Pollution Research*, *29*(56), 84076-84095.

Reisch, L. A. (2021). Shaping healthy and sustainable food systems with behavioural food policy. *European Review of Agricultural Economics*, *48*(4), 665-693.

Reyers, B., and Selig, E. R. (2020). Global targets that reveal the social–ecological interdependencies of sustainable development. *Nature Ecology and Evolution*, *4*(8), 1011-1019.

Sardo, M. C. (2023). Responsibility for climate justice: Political not moral. *European Journal of Political Theory*, *22*(1), 26-50.

Schlosberg, D., and Collins, L. B. (2014). From environmental to climate justice: climate change and the discourse of environmental justice. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(3), 359-374.

Semieniuk, G., and Yakovenko, V. M. (2020). Historical evolution of global inequality in carbon emissions and footprints versus redistributive scenarios. *Journal of Cleaner Production*, *264*, 121420.

Shan, Y., Huang, Q., Guan, D., and Hubacek, K. (2020). China CO2 emission accounts 2016–2017. *Scientific data*, *7*(1), 54.

Sivakumar, M. V., Lal, R., Selvaraju, R., and Hamdan, I. (Eds.). (2013). *Climate change and food security in West Asia and North Africa*. Springer Netherlands.

Steele, W., Mata, L., and Fünfgeld, H. (2015). Urban climate justice: creating sustainable pathways for humans and other species. *Current opinion in environmental sustainability*, *14*, 121-126.

Steinberger, J.K., Roberts, J.T., Peters, G.P., Baiocchi, G., 2012. Pathways of human development and carbon emissions embodied in trade. Nat. Clim. Change 2, 81–85.

Sultana, F. (2014). Gendering climate change: Geographical insights. *The Professional Geographer*, *66*(3), 372-381.

The Economist Newspaper. (n.d.). The economist. https://impact.economist.com/sustainability/project/food-security-index/

The Economist Newspaper. (n.d.-a). The economist. https://impact.economist.com/sustainability/project/food-security-index/resource-library

Tondel, F., D'Alessandro, C., and Dekeyser, K. (2022). The effects of major economies' policies on climate action, food security and water in developing countries. *The Netherlands: ECDPM: Maastricht*.

Tull, K. (2020). The projected impacts of climate change on food security in the Middle East and North Africa (MENA).

UNDP Annual Report 2022: United Nations Development Programme. UNDP. (n.d.). https://www.undp.org/publications/undp-annual-report-2022

Van Baalen, S., and Mobjörk, M. (2018). Climate change and violent conflict in East Africa: Integrating qualitative and quantitative research to probe the mechanisms. *International Studies Review*, *20*(4), 547-575.

von Braun, J., and Birner, R. (2017). Designing global governance for agricultural development and food and nutrition security. *Review of Development Economics*, *21*(2), 265-284.

Wang, S., and Liu, X. (2017). China's city-level energy-related CO2 emissions: Spatiotemporal patterns and driving forces. *Applied energy*, *200*, 204-214.

Weiler, A. M., McLaughlin, J., and Cole, D. C. (2017). Food security at whose expense? A critique of the Canadian temporary farm labour migration regime and proposals for change. *International Migration*, *55*(4), 48-63.

Wong, J. T., de Bruyn, J., Bagnol, B., Grieve, H., Li, M., Pym, R., and Alders, R. G. (2017). Small-scale poultry and food security in resource-poor settings: A review. *Global Food Security*, *15*, 43-52.

World Bank. (2020). *Poverty and shared prosperity 2020: Reversals of fortune*. The World Bank.

Xie, Q.W., Hu, P., Jiang, A., Li, Y.J., 2019. Carbon emissions allocation based on satisfaction perspective and data envelopment analysis. Energy Pol. 132, 254–264.

Yeoh, J. S. W., Lê, Q., Terry, D. R., and McManamey, R. (2014). Challenges of food security for migrants living in a regional area of Australia: food availability, accessibility and affordability. *Journal of Food Security*, *2*(3), 72-78.

Yeong, S. W., Sandhu, M. K., and Ting, H. (2021). The future of food: responsible production, acquisition, consumption and disposition. *British Food Journal*, *123*(9), 2953-2958.

Zheng, J.L., Mi, Z.F., D'Maris, C., Stanimira, M., Shan, Y.L., Guan, D.B., Wang, S.Y., 2019. Regional development and carbon emissions in China. Energy Econ. 81, 25–36.Zurek, M., Ingram, J., Sanderson Bellamy, A., Goold, C., Lyon, C., Alexander, P., ... and Withers, P. J. (2022). Food system resilience: concepts, issues, and challenges. *Annual Review of Environment and Resources*, *47*, 511-534.