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Climate change and food security: Adaptation strategies and funding supports

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Abstract

Climate change significantly impacts food security and necessitates substantial funding and adaptation strategies to mitigate these effects. The relationship between increased atmospheric carbon dioxide, altered meteorological processes, and rising global temperatures intensifies vulnerabilities in food supply chains, especially in regions already facing food insecurity. This review examines recent innovations in adapting food security systems to climate-related challenges, highlighting both advancements and persistent obstacles. Innovations include technological advancements such as precision agriculture and climate-resilient crop varieties, which help optimize resource use and enhance crop resilience. Policy frameworks also play a critical role, with measures such as the Common Agricultural Policy of European Union and the Paris Agreement guiding climate-smart agricultural practices. Community-based adaptations, which integrate local knowledge and modern technologies, further contribute to resilience. Despite these efforts, challenges such as financial constraints, technological limitations, policy incoherence, and social inequities hinder effective adaptation. Addressing these challenges requires increased investment, improved infrastructure, coherent policies, and equitable support for vulnerable populations. Ultimately, adaptation is crucial not only for sustaining food security but also for aligning global efforts to mitigate the broader impacts of climate change.

Keywords: Climate change; Food security; Adaptation; Funding support; Greenhouse gases

1. Introduction

The discussion of climate change hinges on the effects of stored-up moisture, carbon dioxide, as well as other carbon-related gases in the hydrosphere, atmosphere and lithosphere systems. This is related to atmospheric moisture, sensible temperature, precipitation characteristics, and conditions on a sustained basis [1]. These constitute cumulative repercussions, impacting the meteorological processes and element interactions [2]. Therefore, culminating in climate diversity and adjustments on the surface of the earth. For instance, the increasing frequency and severity of extreme weather events, shifting climatic patterns, and rising global temperatures are intensifying the vulnerability of food supply chains worldwide [3]. These disruptions threaten the stability of food systems, particularly in regions already prone to food insecurity.

This review explores the recent innovations to adapt food security to these challenges and discusses the persistent obstacles that hinder effective adaptation. The variation and shifts modify positively or negatively on the physical and human environment [4, 5].

Climate is an average weather condition measured by determination of the patterns of variation in temperature, humidity, atmospheric pressure, wind precipitation, atmospheric particles and other meteorological variables in a given

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region over a long period of time, generally for 30 years [1]. The climate of a region is created by the climate system comprising the hydrosphere, lithosphere, atmosphere, cryosphere, and biosphere. This area is affected by its latitude, terrain and altitude, as well as nearby water bodies and their currents [6].

Weather is short-term changes in temperature, clouds, precipitation, humidity and wind in a region or a city [7]. It can differ from one day to another or within a day. For instance, the weather can change from cold or cloudy to sunny and warm in a day.

Change refers to the alteration in the nature, future course, or form of something, either naturally or artificially, causing it to differ from its current or past state, affecting functions, practices, or things.

Climate Change is an alteration in the mean weather of a city or region, which could be the average annual sunshine or humidity for a given period, like a month or year. It could be defined as a change in overall climate regarding average temperature or precipitation patterns on Earth [8].

Food security refers to the physical and economic access to safe, nutritious food that meets dietary needs and preferences for an active and healthy life [9]. It consists of four major dimensions: physical availability, utilization of food, economic access to the food, and stability of the above three dimensions within a given time. Physical availability is determined by food production, stock levels, and net trade, while economic and physical access depends on income, expenditure, markets, and prices [10].

Climate change affects food supply chains at multiple levels, from production to distribution and consumption [11, 12]. Extreme weather conditions like, floods, droughts, and heatwaves can damage crops, disrupt transportation networks, and reduce the durability of perishable goods. Changes in temperature and precipitation patterns can also alter growing seasons and the geographical distribution of crops, leading to mismatches between supply and demand [3]. For example, a study by Lesk et al. [13] highlighted the vulnerability of global grain production to extreme weather events, which could lead to significant shortfalls in supply and increased volatility in food prices. Similarly, Porter et al. [14] emphasized that climate-induced changes in agricultural productivity could increase global food insecurity, particularly in low-income regions.

2. Climate change causes on earth

Some causes of climate change are natural, which include changes in Earth's orbits, the amount of energy coming from the sun, ocean changes and volcanic eruptions [15]. However, current issues cannot be explained only by nature. Many scientists attribute this to the combustion of oil, coal and gas, which generate most of the required energy that is used daily and add heat-trapping gases in the atmosphere, such as carbon dioxide [16, 17]. Natural variations in climate system components and their interactions result in climate variability on Earth. These components are the atmosphere, hydrosphere, cryosphere, and lithosphere (restricted to the surface soil) [18].

Climate change is of two types: human-induced and nature-induced climate change. Anthropogenetic or human-induced climate change falls into four categories, which are; Change in the concentration of the natural component gases of the lower atmosphere, changes in the water vapour content of the troposphere and stratosphere, alteration of the surface characteristics of the lands and oceans in such a way as to change the interaction between the atmosphere and those surfaces, and lastly, the introduction of finely divided solid substances into the lower atmosphere, along with gases not normally found in substantial amounts in the unpolluted atmosphere [19].

Natural causes of climate change are the introduction of gases, particulates and moisture into the atmosphere through volcanic eruptions as well as desert winds in the form of desert bowls, and ocean turbulence, waves, coastal currents and marine-borne thunderstorms. These increase the gas dust and vapour contents of the atmosphere as factors that create greenhouse conditions. Another natural factor in climate change is the alternation in the intensity of solar radiation in several sunspots [15]. This represents the most well-known expression of the changing solar activity [20]. Other natural causes are internal climatic effects such as the EL Nino. These are low in relation to human factors.

2.1. Orbital Forcing Theory

This is also known as Milankovitch's theory, which states that the amount of energy reaching different parts of the Earth from the sun varies according to the shape of the earth's orbit around the sun. Three parameters vary regularly and predictably to determine the amount and distribution of solar radiation at the earth's surface. [21].

The first variable orbital parameter is the eccentricity of orbit, where gravitational forces result in the shape of the earth orbit around the sun to redirect from almost circular to elliptical. As this widens, the difference in the distance of the earth from the sun at orbits farthest and closest points also affects the severity of the seasons. The season will be severe when the distance between the earth and the sun is maximum [22]. The next Orbital factor is the tilt of the earth. The earth tilting of its axis varies approximately from 21 to 24°. The greater the tilt, the more intense the seasons [23]. Another variable is Ariel Wobble. This leads to a phenomenon called the precession of the equinoxes. The gravitational pull effected by the moon and sun causes the earth to wobble on its axis like a spinning top. The axis describes a circle in space and determines when the seasons occur and, most importantly, the season when the earth is closest to the sun [9].

Since precession regulates whether summer occurs in a specific hemisphere at a close or faraway point in the orbit around the sun, this third element controls how the first two components interact. Volcanic eruptions are divided into two parts: Intrusive eruptions and explosive eruptions. Most of the time, lava flows are not very interesting to meteorologists. Vast dust, pebbles, and gases are propelled to enormous altitudes. The volume of material thrown into the atmosphere during an explosive eruption may be up to $1km^3$ or more [24]. These gases emitted are primarily water vapour, carbon dioxide, sulphur dioxide and small quantities of other gases that impact global temperatures [25]. Some of these emissions include:

- **Sulfur dioxide:** When emitted at high altitudes (12–14 km or higher), acid droplets in the stratosphere reflect and partially scatter sunlight far from the earth, resulting in surface cooling. The droplets have a moderate effect and can cool the climate for some months or perhaps a year or two if they are present in high enough concentrations. When the droplets fall out of the stratosphere, temperatures return to normal [23].
- **Carbon dioxide**: Affects global climate warming when released in significant amounts. Any effects of CO emissions are long-lasting because of their several hundred-year atmospheric lifetime. This is much smaller than that produced by burning fossil fuels and changing land use [26].
- **Plate Tectonics**: Tectonic plate movement reorganizes the land and ocean of the world, influencing both local and global temperature patterns as well as the circulation patterns of the atmosphere and ocean. The geography of the oceans is determined by the positions of the continents, which in turn affects the patterns of ocean circulation. The location of the seas is important in controlling the transfer of heat and moisture across the globe, which determines global climate [27].
- **Human Influences:** Anthropogenic influences are those aspects of human activity that have a significant and mostly irreversible impact on climate fluctuation. Emissions from burning fossil fuels are the primary cause of the rise in CO_2 levels; aerosols, or particulate matter in the atmosphere, and cement production follow. Other factors include land use, ozone depletion and deforestation [27].
- **Greenhouse Gases:** By ingesting long-wave radiation, these gases store heat in the atmosphere and avert increased terrestrial radiation and the resulting heat loss, contributing to global warming. The most significant greenhouse gases include chlorofluorocarbons (CFCs), methane, nitrous oxide, carbon dioxide, and water vapour. Methyl chloroform and carbon tetrachloride are two more. The four leading greenhouse gases that have negative impacts are methane (CH), carbon dioxide (CO), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Ozone also contributes to global warming [15, 28].
- **Sulphur Hexafluoride (SF)**: This powerful gas can be found in air-soled trainers, circuit breakers, insulators, and other electrical equipment. Loudspeakers and magnesium are also melted with it. The problem with releasing this gas is its thermal energy-trapping potential of 25,000 times that of carbon dioxide [17].

2.2. Sources of Green House Gases are

- Several factories worldwide burn large quantities of coal, oil and natural gases, thereby releasing CO_2.
- Power stations based on fossil fuels are major sources of manmade CO_2.
- Huge fleets of cars, trains, airplanes, and other vehicles burn a lot of gas and diesel, which results in enormous annual carbon dioxide emissions.
- The two leading causes of CO_2 emissions are the burning of firewood and deforestation. Deforestation is thought to have contributed between 90 and 180 billion tonnes of carbon to the atmosphere.
- With over 2 trillion tonnes of unoxidized carbon stored in them, the earth, soil, and plants are massive unoxidized carbon storage sites. The carbon is oxidised by the trees and then released as CO_2.
- A significant portion of CO_2 emissions are caused by large-scale forest fires, which humans can start intentionally or accidentally.
- The amount of CO_2 in the atmosphere has increased as a result of the loss of forest cover brought on by urbanization, industrialization, and other factors.

- When appliances and equipment are operated and maintained, these molecules—which are used as coolants and propellants—are released into the environment along with halogenated gas (CFCs). These gases drastically affect the climate [1].

2.3. Impact of Green House Effect on Global Climate

The infrared absorptive tendency of CO_2 has made it possible to treat CO_2 as a key determinant of global temperatures. Estimation of the fluctuations in global temperature with the doubling of CO_2 content in the atmosphere causes climate changes with global temperature changes. The greenhouse effect will result to the following significant changes.

- Rise in earth temperature leads to rising ocean and sea levels, causing flooding over low-lying regions. A little rise in sea level might significantly impact habitation patterns, forcing many people to relocate and putting many of the most significant cities at risk of flooding. Thus, the increasing sea levels may cause many emerging or impoverished countries to lose significant tracts of valuable coastal land.
- The summer will be longer and hotter in temperate zones, while the winter will be brief and warmer. Certain cities are expected to become severely hot due to a warmer climate.
- The amount of rainfall will significantly rise. Furthermore, soil erosion, drought, and desertification will only worsen.
- The currently arid subtropics are predicted to get even dryer, while the tropics might get wetter.
- As a result of the sharp decline in forest cover and the quickening pace of industrialization and urbanization, an impenetrable gas layer will form on the surface of the atmosphere, turning Earth into a scorching blast furnace.
- The ecosystem will be disrupted due to the effects on the plants and animals.
- The most obvious effect of climate change will be on agriculture [10]. Since carbon dioxide (CO_2) is a requirement for plant growth, plants will grow more quickly as atmospheric CO_2 levels rise. Although the yields of main crops may rise as a result of irregular plant growth, the soil may become more deficient in nutrients as a result of the increased yields. Larger plants with higher yields have the potential to produce a variety of complex issues, including:
  - Ecosystem disruption;
  - Lower prices for farmers due to increased output.
  - Owing to reduced nitrogen in the soil, plants will probably be more vulnerable to pests.
  - Rapid deterioration of the soil will result in lower crop yields.

The global climate will be significantly impacted by the combined temperature effect of CO_2 and water vapour. The earth's surface temperature will rise as CO_2 levels rise, which will cause surface water to evaporate. For every doubling of CO_2 concentration, the overall effect is anticipated to result in a 2–3^{o} rise in surface temperature.

3. Impact of climate Change

The impact is rising sea levels, ice cover and snow melting, rainfall patterns and seasons will be changing, floods, droughts and heat waves, and hurricanes will increase all over the continents. Nigeria is experiencing flooding in Lagos, Benue, Anambra, Nsukka, Bayelsa, Rivers, Victoria Island and many other parts of Nigeria. About 30 out of the 36 states are already experiencing this with other effects due to climate warming.

It is expected that if global temperatures rise by 2.0 to 4.5°C, glaciers will retreat, ice caps in Greenland and Antarctica will melt, and ice deposits will disappear from the planet's surface.

Rising CO_2 concentrations and hotter tropical waters may cause an increase in cyclones, hurricanes, and mountain snowmelt, perhaps leading to more monsoon floods.

Rising sea levels are anticipated to wipe out entire countries and flood cities from Mumbai to Boston in only three decades. However, if allowed unchecked, it might alter the planet's rainfall and temperature [15].

A little increase in global temperature can negatively impact food production. Biological productivity will decline as the surface layer warms. It is, therefore, important to cover at least one-third of the total land area with forest [29].

Today, the loss of trees substantially impacts the amount of CO_2 in the atmosphere due to the population explosion. If deforestation continues, atmospheric CO_2 concentrations may rise to roughly 0.0355% by volume.

At higher atmospheric altitudes, photochemical reactions in CO_2 generate the exceedingly dangerous gas CO.

$$CO_2 + hf \longrightarrow CO + O \quad \text{……………..} \; (uv)$$

CO_2 content increases in tropical climates affect plant photosynthesis, necessitating improved crop varieties and updated agricultural techniques. The release of carbon dioxide (CFCs) is causing a 20% temperature increase, threatening future generations. Nigeria faces unpredictable weather patterns, erratic rains, destructive floods, soil erosion, coastal storms, and ocean surges due to climate change.

Adebayo [30] reported severe storm surges in April and August along the coastal areas of Lagos, Delta, River, Akwa Ibom and Cross River States in 1988, 1990, 1992, 1994 and 1995. The storm surges of August 1995 was particularly intense and persisted for two days (17th and 18th August) and caused losses estimated at $12,500,00.00

Nwajiuba [31] noted that the timing and intensity of harmattan (the cold, dusty wind) from the Sahara desert that used to hit Nigeria between mid-November and December in the past now come in March. The associated dust and coldness of the harmattan wind have also weakened. The bio-model rainfall peak that distinguishes the equatorial climate, which deepens in August (August break), is scarcely discernible.

3.1.1. Mitigation measures for increasing greenhouse effect

- CO_2 levels can be significantly decreased if the utilization of fossil fuels in remarkably developed and industrialized countries like the UK, Japan, USA, Russia, France, Canada and Germany are reduced.
    - Advanced countries should take responsibility for decreasing global warming. Not all countries are encouraged to implement the advanced resolutions because developing countries will encounter severe energy crisis challenges.
    - The developed countries are also causing global warming due to increased population density.
- Advanced research is needed to evaluate the potential of methane-derived methanol for efficient usage in transportation. Methanol may be used as a substitute for petroleum goods.
- Restriction of CO_2 and CFC emissions from companies and autos. Solar energy could be a viable alternative to fossil fuels in tropical and subtropical nations with abundant sunlight yearly.
- Developed countries should provide economic support to undeveloped countries for commercial solar energy production.
- The developed countries should give sufficient economic aid to the underdeveloped countries to generate solar energy on a commercial scale.
- Biogas is another viable alternative to standard household energy sources. In addition to creating fuel, converting cow manure into biogas naturally fertilizes crops. Bog plants can thus be established and operated in rising markets such as Bangladesh, China, India, Nigeria, and Pakistan.
- Improving wooded areas will reduce CO_2 levels and mitigate the warming effect. Given that trees are a significant natural "sink" of CO_2. They can use CO_2 for photosynthesis.

4. Climate change adaptation

Adaptation refers to anticipating the negative effects of climate change, taking appropriate action to prevent or mitigate the harm they can cause, and grasping opportunities as they occur. It has been proved that taking early, well-planned action to adapt can save lives and money in the long run. Among the adaptation techniques is to make better use of the restricted water supplies. The degree of adaptation is related to the situational attention on environmental challenges. Thus, adaptation necessitates a situational assessment of sensitivity and vulnerability to environmental influences. Adaptive capability is intimately related to social and economic growth. The economic costs of adapting to climate change are expected to be billions of dollars annually for the next several decades. However, the exact figure is unknown. Donor countries pledged $100 billion annually through the Green Climate Fund by 2020 to help developing countries adapt to climate change. However, the fund was established during COP16 in Cancun, and no contributions from affluent countries have been received. The adaptation issue increases with the extent and rate of climate change [32].

Climate change mitigation, which seeks to reduce greenhouse gas (GHG) emissions and improve their removal from the atmosphere (via carbon sinks), is another response to climate change. Although most emission reductions do not mitigate the future effects of climate change, adaptation is still necessary. Without mitigation measures, the effects of climate change will be so severe that some natural ecosystems will be unable to adapt. Climate adaptation programs are seen to interfere with existing development projects and have unintended consequences for vulnerable groups. Unchecked climate change would have a massive financial and social impact on human systems.

Taking food security as a case study, research has shown that the success of food security in a region depends on several factors. Climate stability is a major factor and vice versa [8]. Figure 1 presents the relationship between climate change and food security. Environmental factors such as climate quality of air, soil and water, as well as ecosystem and pollution level of the region, will affect agricultural production. Consequently, when the environmental factors are wrong, the farming system, labour and natural resources would not be productive. However, if the environmental conditions, agriculture and production are at their best, human health and well-being of the people will be improved. Also, processing, distribution and marketing will expand to meet the increasing needs of the consumers. Furthermore, food production and availability will ensure food security and safety stability.

4.1. Innovations in Climate Change Adaptation for Food Security

In response to the challenges posed by climate change, various innovations have emerged to enhance the resilience of food supply chains. These innovations span across technology, policy, and community-based approaches.

4.2. Technological Innovations

Technological advancements are crucial in adapting food supply chains to climate change. Precision agriculture, for instance, uses data-driven techniques to optimize crop management practices, reducing resource use and minimizing the impact of climate variability [12]. Remote sensing and geographic information systems (GIS) are increasingly used to monitor crop conditions, forecast yields, and assess risks associated with climate change [33].

Another significant innovation is the development of climate-resilient crop varieties through biotechnology. Genetically modified crops that are more tolerant to drought, heat, and pests can maintain yields under adverse conditions. For example, drought-resistant maize varieties have been introduced in sub-Saharan Africa, where climate change severely threatens food security [34].

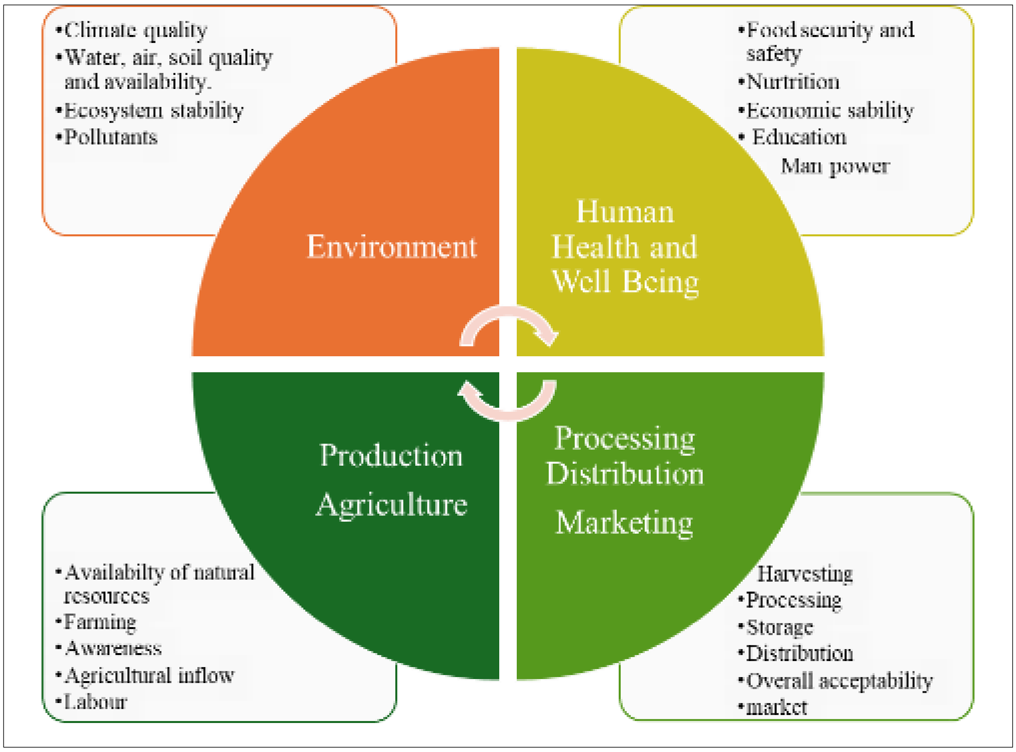

Figure 1 Climate change impact on food security**.**

4.3. Policy Interventions

Effective policy frameworks are essential for supporting climate change adaptation in food supply chains. Governments and international organizations increasingly recognize the need for policies that promote sustainable agricultural practices, reduce greenhouse gas emissions, and enhance the resilience of food systems [27].

For instance, the European Union's Common Agricultural Policy (CAP) includes measures to encourage climate-smart agriculture and improve food production's sustainability [35]. Similarly, the Paris Agreement has prompted countries to include food security and agriculture in their Nationally Determined Contributions (NDCs), highlighting the importance of integrating climate adaptation into food policy [36].

4.4. Community-Based Adaptation

Community-based approaches to adaptation involve local stakeholders in developing and implementing strategies that address specific climate-related challenges in food supply chains [32]. These approaches often leverage traditional knowledge and practices, making them more culturally appropriate and sustainable.

For example, in Bangladesh, community-based adaptation projects have successfully integrated traditional agricultural practices with modern technologies to improve the resilience of local food systems to climate change [7]. Such initiatives emphasize the importance of local context in designing effective adaptation strategies. Curbing dangerous climate change requires high emissions cuts and the use of alternate energy resources and energy-efficient technology.

4.5. Challenges in Adapting Food Supply Chains to Climate Change

Despite the progress made, significant challenges remain in adapting food supply chains to climate change. These challenges include financial constraints, technological limitations, policy incoherence, and social inequities.

4.5.1. Financial Constraints

One of the primary barriers to climate change adaptation in food supply chains is the lack of financial resources. Smallholder farmers and small and medium-sized enterprises (SMEs) often lack access to the capital needed to invest in climate-resilient technologies and practices. This financial gap is particularly pronounced in developing countries, where the impacts of climate change are most severe [9]. Innovative financing mechanisms, such as climate-smart agriculture bonds and insurance schemes, are emerging to address this issue. However, their uptake remains limited due to a lack of awareness and the perceived risks associated with investing in adaptation measures [11].

4.5.2. Technological Limitations

While technological innovations have great potential to enhance the resilience of food supply chains, their adoption is often hindered by various factors. These include the high costs of technology, the lack of technical expertise, and the limited availability of infrastructure in rural areas [32]. For instance, the adoption of precision agriculture technologies in low-income regions is constrained by the lack of access to reliable internet and electricity and the high costs of sensors and other equipment [29]. Furthermore, the benefits of biotechnology, such as genetically modified crops, are often not realized in regions where regulatory frameworks and public acceptance are lacking [10].

4.5.3. Policy Incoherence

Policy incoherence, both within and between countries, poses a significant challenge to climate change adaptation in food supply chains. In many cases, agricultural policies are not aligned with climate goals, leading to conflicts and inefficiencies. For example, subsidies for fossil fuel-based inputs, such as fertilizers and pesticides, often undermine efforts to promote sustainable agricultural practices [33]. Additionally, the lack of coordination between agricultural and environmental policies can result in fragmented and ineffective adaptation strategies [3].

4.5.4. Social Inequities

Climate change exacerbates existing social inequities, particularly in food supply chains. Vulnerable groups, including women, smallholder farmers, and indigenous population, are often disproportionately affected by climate impacts and have limited capacity to adapt. For instance, women in rural areas often have less access to resources, information, and decision-making power, making it more difficult for them to adopt climate-resilient practices [7]. Addressing these social inequities is crucial for ensuring that adaptation efforts are inclusive and effective.

5. Funding Support For Climate Change Mitigation

Table 1 presents dome funding agencies supporting adaptation to climate change and their roles. This information aims to create awareness of climate change, its impact on food security, and possible solutions with available support. This is hoped to guide people in facing their challenges for a sustainable future.

Table 1 Some funding organizations that support climate change adaptation and functions

S/n	Organization/ website	Functions
1	Green Climate Fund (GCF) https://www.greenclimate.fund	The GCF is a global fund established under the UNFCCC to support developing countries in climate change adaptation and mitigation practices. It finances large-scale projects to reduce greenhouse gas emissions and increase resilience to climate impacts.
2	Global Environment Facility (GEF) https://www.thegef.org	GEF provides grants and financing to address environmental challenges, including climate change. It focuses on integrating climate action into sustainable development efforts, with investments targeting low-carbon technologies and climate resilience.
3	International Climate Finance (ICF) https://www.gov.uk/government/collections/international-climate-finance	The ICF is the United Kingdom's fund to support climate change adaptation and low-carbon development in developing countries. It helps to reduce emissions and builds resilience to the impacts of climate change, particularly in poor and vulnerable communities.
4	Nordic Development Fund (NDF) https://www.ndf.fi	The NDF provides grants and loans for climate-related projects in low-income countries, with a focus on climate resilience, adaptation, and green energy solutions. It works primarily in Africa, Asia, and Latin America.
5	Adaptation Fund https://www.adaptation-fund.org	The Adaptation Fund was established to finance adaptation projects in vulnerable countries. It focuses on supporting activities that reduce the adverse effects of climate change through ecosystem resilience, improved infrastructure, and enhanced adaptive capacity.
6	Climate Investment Funds (CIF) https://www.climateinvestmentfunds.org	CIF funds developing countries to support climate change mitigation and adaptation initiatives. It focuses on clean technology, sustainable forest management, renewable energy and climate resilience.
7	European Union (EU) Climate Action Funding https://ec.europa.eu/clima/policies/budget/mainstreaming_en	The EU provides various funding mechanisms for climate action, including the LIFE program and Horizon Europe. These funds support innovation, low-carbon technologies, and resilience-building activities across member and partner countries.
8	World Bank Group https://www.worldbank.org	The World Bank provides financial and technical support for climate-smart agriculture and food security projects, focusing on low- and middle-income countries, promoting resilient food systems and livelihoods.
9	International Fund for Agricultural Development (IFAD) https://www.ifad.org	IFAD, a UN agency, focuses on reducing rural poverty and improving food security by funding climate-smart agriculture programs and enhancing smallholder farmers' resilience to climate change.
10	Climate Works Foundation https://www.climateworks.org	Climate Works, a philanthropic organization, funds global climate change projects, collaborating with over 750 partners across 50 countries, focusing on innovative, scalable solutions.

6. Conclusion

In conclusion, climate change presents a formidable challenge to global food security, with its impacts reaching deeply into food production, distribution, and consumption. The relationship between shifting climatic patterns and food systems underscores the urgent need for comprehensive adaptation strategies. Technological innovations, such as precision agriculture and climate-resilient crop varieties, offer promising solutions to enhance the resilience of food supply chains. Policy interventions and community-based approaches also play critical roles in addressing the multifaceted issues posed by climate change. However, significant challenges remain, including financial constraints, technological limitations, policy incoherence, and social inequities. A collaborative approach involving governments, international organizations, the private sector, and local communities is essential to navigate these challenges effectively. Developing innovative financing mechanisms, improving access to technology, aligning policies with climate goals, and addressing social inequities are crucial steps towards building a resilient food system. As we move forward, it is imperative to integrate these strategies to mitigate the impacts of climate change and ensure food security for future generations. Continued research, investment, and action are necessary to adapt to the evolving climate landscape and safeguard the stability of global food systems.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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