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Climate Change at a Global Concept: Impacts and Adaptation Measures

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Climate change is a global concern and has affected all nations. Daily observations, scientific analyses, projections and recommendations on climate change and its global impacts, are needed at all levels of human and environmental development. This is important because of the conviction that approximately 3.3 to 3.6 billion people are highly vulnerable to climate change. Climate change has reduced food security, affected water quality and soil security, increased sea and land temperature, caused human mortality, caused soil damage through various kinds of erosion, increased flooding, and hindered efforts to achieve sustainable development goals. Climate change affects the global health, the global population and the global economy. This paper provides a general overview of the ideas and knowledge on concept of global climate change and maintains that climate change adaptation is required because of the increasing catastrophic events, which have reduced the quality of human life in all aspects (environment, health, economy, biodiversity). It has been suggested that global climate change research and development can help support advanced adaptation/mitigation measures.

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Keywords: Climate; climate change; global climate change; impact; adaptation.

1. INTRODUCTION

Climate change has become a global concern in the 21st century, as it affects all aspects of human life, anywhere, everywhere and in all nations [1,2,3,4]. Climate change is now largely accepted as a real, demanding and truly global problem [5,6]. Climate change is a unique issue of the 21st era and has affected many components of human life, the environment and overall ecosystems [7,8]. According to an IPCC recent report [4], approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change. The report further noted that in all regions, an increase in extreme heat events has resulted in human mortality and morbidity (very high confidence), and the global mean sea level increased by 0.20 [0.15 to 0.25 m] between 1901 and 2018, while food security has decreased, and water security has been affected; these factors hinder efforts to meet sustainable development goals with high confidence [4]. Various studies and observations have also been conducted to address the impact and consequences of climate change on humans, agriculture and the environment [9,10,11,12,13]. There is advanced documentation regarding principles, measures and strategies for climate change adaptation [14]. Similarly, awareness has been placed regarding the impact and adaptation strategies of climate change [15]. These multipurpose studies have explored ways to address global climate change issues and provide possible solutions, both present and future.

The human and environmental consequences caused by climate change are complex and not easy to quantify [16]. The combination of anthropogenic human activities, including night bush fires, bush burning, forest and vegetation fires for household cooking, agricultural land expansion, and greenhouse gas (GHG) emissions, was regarded as the most common climate change issue in the 21st century [17]. According to the IPCC report [4], global net anthropogenic GHG emissions were estimated to be 59 ± 6.6 GtCO2-eq9 in 2019, approximately 12% (6.5 $GtCO_2eq$) higher than in 2010 and 54% (21 GtCO2-eq) higher than in 1990, with the largest share and growth in gross GHG emissions occurring in CO_2 from fossil fuel combustion and industrial processes (CO_2-FFI) followed by methane, whereas the highest relative growth occurred in fluorinated gases (F-gases), starting from low levels in 1990. These anthropogenic human activities are responsible for many environmental changes that have triggered complex climate changes around the globe [18]. These disasters have consequently resulted in an increase in soil damage due to erosion and landslides, flooding due to sea level rise and irregular precipitation, drought due to a shortage of rainfall in the tropics, and hunger due to low agricultural production [19,20,21].

The global industrial sector, agricultural sector and deliberate deforestation due to city and town expansion or population increase are contributing significantly to global warming and unexpected temperature increases, irregular rainfall, and wind speeds [22,23,24]. These factors have affected agricultural development, the goal of which is to ensure food security in many ways [3]. These effects include a decline in cereal productivity, impacts on biodiversity, implications for human health, waves of forest development, and impacts on tourism and the economy [6]. This has called for better adaptation to climate change and better management of natural resources, food security, human health and environmental preservation (4,25). Therefore, this evaluation aimed to provide an overview of climate change from a global viewpoint while addressing the impact, causes and some adaptation/mitigation measures and principles worldwide. This paper aimed to demonstrate the concept of global climate change (GCC) by focusing on the impacts and adaptation measures useful for better adaptation of climate change in all nations.

2. GLOBAL CLIMATE CHANGE: *A BASIC CONCEPT*

Global climate change (GCC) is a long-lasting change in weather arrays across the tropics caused by pollution and is a worldwide threat that has led to stress in various sectors [6]. The name GCC is used in this theoretical perception to describe a universal concern regarding climate change issues, which have become daily news in all nations [26]. In this overview, we used the UNDP Glossary of the key terms [27] and IPCC Annex I Glossary [28] to define GCC as a general awareness of climate change, climate change adaptation, climate change resilience, climate change justice, climate change security, climate change finance, climate change models, climate change neutrality, climate change

sensitivity, and climate change sustainability in a given geographical area. We also viewed other related entities, such as climate change geography, climate change agriculture, climate change industry, climate change religion, and climate change politics or governance, as well as local climate change, national climate change, and international climate change, to be integral components of the GCC. Indeed, the concept of climate change and key components highlighted in the GCC can be regarded collectively as issues that need to be considered at national and international level for successful adaptation of climate change in a given area [15]. Therefore, we believed that the adaptation of the GCC must include the contribution from all nations, and inclusions of all cultures, norms and values of the global societies. However, to help understand the concept of GCC in a more detail description, we have provided reference notes below as defined by UNDP Glossary of the key terms [27] and IPCC Annex I Glossary [28]:

a. *Climate change adaptation:* This refers to actions that help reduce vulnerability to the current or expected impacts of climate change, such as weather extremes and natural disasters, sea-level rise, biodiversity loss, or food and water insecurity.
b. *Climate resilience:* This is the capacity of a community or environment to anticipate and manage climate impacts, minimize damage, and recover and transform as needed after an initial shock.
c. *Climate change justice:* This describes putting equity and human rights at the core of decision-making and action on climate change.
d. *Climate change security:* This refers to evaluating, managing, and reducing the risks to peace and stability brought about by the climate crisis; i.e. the concept also ensures that conflict prevention and peace building interventions take climate impacts into account.
e. *Climate change finance:* This refers to financial resources and instruments that are used to support action on climate change.
f. *Climate neutrality:* This refers to the concept of a state in which human activities result in no net effect on the climate system; therefore, achieving such a state would require balancing residual emissions with emission (carbon dioxide) removal as well as accounting for regional or local bio-geophysical effects of human activities.
g. *Climate projection:* This is the simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases and aerosols, generally derived using climate models.
h. *Climate sensitivity:* This refers to the change in the annual global mean surface temperature in response to a change in the atmospheric CO_2 concentration or other radiative forcing.
i. *Climate model:* This is a numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties.

2.1 Climate and Climate Change

"The brochure of knowledge defined climate as the average weather at a particular place, incorporating features such as temperature, precipitation, humidity, and windiness; however, a more specific definition looks at climate as the mean state and variability of these features over some extended time period" [29]. The NRDC [30] maintained that "climate refers to the general weather conditions of a place as measured over many years". The UNDP [27] considers "climate as the average of weather patterns in a specific area over a longer period of time, usually 30 or more years, which represents the overall state of the climate system". "This weather and its specific patterns can refer to atmospheric conditions at a particular time in a particular location, including temperature, humidity, precipitation, cloudiness, wind, and visibility" [27]. "In a narrow sense, climate is usually defined as the average weather, or more rigorously, as the statistical description of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years" [28]. According to the World Meteorological Organization [31], "the classical period for averaging these variables is 30 years". "However, the relevant quantities are most often surface variables such as temperature, precipitation and wind, which also include the statistical description of the climate system" [28]. NASA [32] noted that "historically, the Earth's climate has changed, and most climate changes are attributed to very small variations in Earth's orbit that change the amount of solar energy our

planet receives". "For example, just in the last 800,000 years, there have been eight cycles of ice ages and warmer periods, with the end of the last ice age approximately 11,700 years ago marking the beginning of the modern climate era and of human civilization" [32].

"Overall, climate change is a concept that is derived from the terms climate and changes that transpire within it – both positively and negatively" [33]. "Significant contributions have been provided regarding the perception of climate change. Similarly, various descriptions have been positioned in an attempt to define the term 'climate change'. According to the United Nations, climate change refers to long-term shifts in temperature and weather patterns, and such shifts can be natural due to changes in solar activity or large volcanic eruptions" [34]. According to the IPCC [28], "climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer". "In other words, this may be due to natural internal processes or external forcings such as modulations of solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use" [28]. According to the UNFCCC [35], climate change is regarded as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. "This concept distinguishes between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes" [28].

The Encyclopedia Britannica [29] defined "climate change as a periodic modification of Earth's climate caused by changes in the atmosphere as well as interactions between the atmosphere and various other geologic, chemical, biological, and geographic factors within the Earth system". This definition agreed with the one presented by the NRDC [30]. "They considered climate change to be a significant variation in average weather conditions (e.g., conditions becoming warmer, wetter, or drier) over several decades or more; thus, the longer-term trend differentiates climate change from natural weather variability" [30]. According to the US-EFA [36], "climate change refers to any significant change in climate measures lasting for an extended period of time". "In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer" [36]. "Additionally, climate change is characterized by long-term changes in the Earth's climate that are warming the atmosphere, ocean and land" [27]. According to the FAO [33], "climate change refers to a trend of significant fluctuations in major weather patterns and conditions caused by increased greenhouse gases; this trend has seen significant variations in temperature, rain, wind, and other factors over a period of years". Similarly, the ISDR [37] defined "climate change as the alteration of the world's climate that we are causing through fossil fuel burning, clearing forests and other practices that increase the concentration of greenhouse gases in the atmosphere".

2.2 Impact of Climate Change

"Climate change impacts human lives and health in a variety of ways, including threatening the essential ingredients of good health, such as clean air, safe drinking water, a nutritious food supply and safe shelter, and has the potential to undermine decades of progress in global health" [38]. "The global impacts of climate change on agriculture will depend on shocks at the local and regional levels, and it is therefore important to understand the likely impacts at these scales" [5]. "Climate change affects the balance of ecosystems that support life and biodiversity and impact health and causes more extreme weather events, such as more intense and/or frequent hurricanes, floods, heat waves, and droughts [27]. Climate change has severe negative effects on agricultural development" [39]. "The negative effects on agricultural production and the livelihoods of farmers, foresters and fisherfulks are already felt in many places" [40].

"Climate change is a serious threat to food security and agricultural productivity for industrial development" [3]. Food security is defined as 'a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' [41]. "Climate change is a barrier to food security and has even caused an increase in hunger, poverty and malnutrition" [42,43]. Indeed, a highlight of the potential risks induced by climate change for most vulnerable countries and populations indicated that four out

of the eight key risks have direct penalties for food security [44]: (a) loss of rural livelihoods and income, (b) loss of marine and coastal ecosystems and livelihoods, (c) loss of terrestrial and inland water ecosystems and livelihoods, and (d) food insecurity and breakdown of food systems. Typically, these direct penalties for food security and nutrition can be understood from a range of physical, biological and biophysical impacts on ecosystems and agro-ecosystems, translating into general impacts on agricultural production (Fig. 1,) [45]. “These various impacts of climate change on food and water security have recently been noted to hinder efforts to meet sustainable development goals with very high confidence” [4].

“Climate change will have the greatest impact on agricultural water management by further sharpening the trade-offs between the conservation and protection of natural ecosystems, which ultimately support agriculture, and the allocation of land and water to sustain productive agriculture” [5]. “This could generate a situation whereby climate change will impact the livelihoods and income of small-scale food producers and, through food price increases and volatility, the livelihoods of poor net food buyers, constraining these populations to reduce their food consumption in terms of quantity and quality” [45]. This means that well-being, health conditions and malnutrition, among many other human health issues, may be affected [38]. This also means that there will be significant agricultural setbacks, food price increases, and increased demand for corn, soybean and wheat for human consumption and industrial production [46].

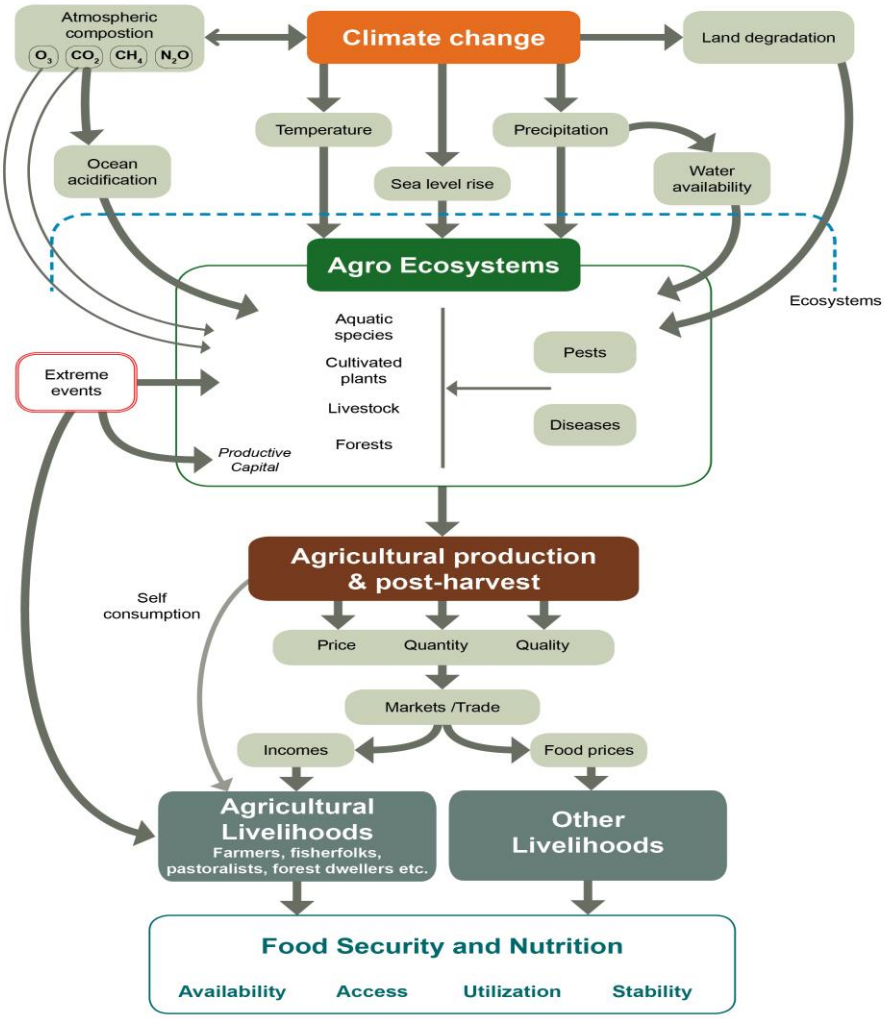

Fig. 1. Schematic representation of the cascading effects of climate change impacts on food security and nutrition [45]

"Climate change can lead to sea level rise and coastal erosion as a result of ocean warming, the melting of glaciers, and the loss of ice sheets" [19]. "The *El Niño*-Southern Oscillation (ENSO) is a recurring cycle that refers to year-to-year variations in sea surface temperatures, convective rainfall, surface air pressure, and atmospheric circulation that occur across the equatorial Pacific Ocean" [45]. "The term *El Niño* was initially used to describe a warm-water current that periodically flows along the coasts of Ecuador and Peru, disrupting the local fishery" [47]. "This *El Niño* can cause changes in sea level because of annual temperature variations" [48]. "The IPCC reported that the average rate of sea level rise was 1.3 (0.6 to 2.1) mm yr-1 between 1901 and 1971, increased to 1.9 (0.8 to 2.9) mm yr-1 between 1971 and 2006, and further increased to 3.7 (3.2 to 4.2) mm yr-1 between 2006 and 2018 (high confidence)" [4]. A study by Ablain et al. [49] revealed that "satellite altimetry recorded that the global mean sea level rose at a rate of ~3 ± 0.4 mm/y from 1993 to 2017". Nerem et al. [19] projected "an increase in this rate of 0.084 ± 0.025 mm/y2 using altimeter records coupled with careful consideration of interannual and decadal variability as well as potential instrument errors" [19]. According to these observations, "if the sea level continues to change at this rate and acceleration, the sea-level rise by 2100 (~65 cm) would be more than double the amount if the rate remained constant at 3 mm/y. Undoubtedly, this increase in sea level continuously affects fish, causing flooding and leading to city damage, food insecurity and irregular economic stability" [50,51].

"There are significant signs of fish migrating poleward due to climate change, which has led to sea temperature rise, resulting in the rapid 'tropicalization' of mid- and high-latitude systems" [45]. "This has affected the economy and small-scale fisheries lifestyle, thereby increasing poverty in the tropics" [2]. "This may shorten the fish market in many affected local areas primarily because of the increasing pressure on aquatic resources through climatic drivers and human stressors such as pollution and overfishing without appropriate measures taken" [52]. The IPCC [51] reported that "these impacts occurred as a result of both gradual atmospheric warming and related physical and chemical changes in the marine environment". "The physical changes include changes in sea surface temperature, ocean circulation, waves and storm systems, whereas the chemical changes include changes in salinity content, oxygen concentration and acidification" [53]. "Indeed, climate change has caused substantial damage and increasingly irreversible losses in terrestrial, freshwater, cryospheric, and coastal and open ocean ecosystems (high confidence); hundreds of local losses of species have been driven by increases in the magnitude of heat extremes (high confidence) with mass mortality events recorded on land and in the ocean (very high confidence)" [4].

Forest and natural vegetation areas are not excluded from the impacts of climate change. The FAO [45] reported that "climate change and climate variability are threatening the delivery of a range of crucial goods (wood and non-wood) and environmental services from forests on which an estimated 1.6 billion people fully or partly depend". "A report by the World Bank noted that climate change is threatening more than 1 billion people who depend directly or indirectly on valuable forest resources (e.g., timber, firewood, medicinal herbs, fruits, various kinds of agriculture, and industrial materials)" [54]. Climate change, together with land degradation and deforestation, has affected many distinct forest resources that are of economic value to human development for many years [55].

"Climate change is also a threat to human life. According to a report by the WHO [38], between 2030 and 2050, climate change is expected to cause approximately 250 000 additional deaths per year from malnutrition, malaria, diarrhea and heat stress alone, and the direct damage costs to health are estimated to be between US$ 2–4 billion per year by 2030. According to reports by the IPCC [51], as a result of climate change contributions to disasters, over the period 1991-2005, 3,470 million people were affected by disasters, 960,000 people died, and economic losses were US$ 1,193 billion" [37]. EMDAT [56] reported that the number of global deaths from natural disasters from 1978 to 2020 reached 300 000 to 400 000 people.

"Rapid and dramatic shifts in climate cause more severe impacts, which include (a) droughts, floods, and unpredictable rain patterns; (b) increased temperatures and more frequent heat waves; and (c) higher sea levels and increased water temperatures" [33]. These circumstances affect soil and biodiversity, hinder plant growth, change the productivity of forests and vegetation, affect animal and wildlife health conditions, and reduce the productivity of agricultural produce

[22]. Additionally, climate change can lead to potentially decreased rainfall, increased carbon dioxide (CO2), and increased temperatures, reducing the productivity of farms, ranches, and forests, which affects the food supply, raises prices, and affects national and international incomes [57].

2.3 Causes of Climate Change

Although climate change has a significant correlation with natural weather conditions and natural atmospheric and environmental events [22], many factors and anthropogenic human activities are noted to worsen this situation. According to the United Nations, fossil fuels—coal, oil and gas—are by far the largest contributors to global climate change, accounting for more than 75% of global greenhouse gas emissions and nearly 90% of all carbon dioxide emissions [58]. These factors cause climate crises, leading to complex environmental disasters [51]. The UNDP described this climate crisis as a serious problem that is likely caused by changes in the planet's climate, including weather extremes and natural disasters, ocean acidification and sea-level rise, loss of biodiversity, food and water insecurity, health risks, economic disruption, displacement, and even violent conflict [27]. This climate crisis has also created many pole holes that position global warming all most everywhere on the globe. Global warming is real and alarming [28]. This global warming is generally regarded as the recent and ongoing increase in the global average temperature near the Earth's surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere [59]. Global warming is increasing the Earth's average surface temperature and occurs when the concentration of greenhouse gases in the atmosphere increases [27]. Widespread changes in extreme temperatures have been observed in many regions of the world over the last 50 years, most notably, high-temperature days, nights and heat [37].

GHG emissions result from the extraction and burning of fossil fuels and are major contributors to both climate change and air pollution [38]. The gases produced by this emission absorb more solar radiation and trap more heat, thus causing the planet to become hotter. However, burning fossil fuels, deforestation, and livestock farming are human activities that release greenhouse gases and contribute to global warming [2]. These anthropogenic human activities in the industrial age, and predominantly during the last century, are expressively altering the global planet's climate through the release of harmful greenhouse gases, which trap heat from the sun in the atmosphere and keep it warm [27]. Poverty, deforestation, and land use practices, including land expansion for agriculture, are also factors that are causing an increase in climate change [14].

3. POLICIES AND MITIGATION/ ADAPTATION MEASURES

Appropriate policies at the national and international levels are needed to enable and support climate change mitigation measures and adaptation. There is also a need to adapt food producers, especially to support small-scale food producers, in their efforts to adapt to climate change [25,45]. This mitigation is defined by the IPCC [47] as "*an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks*". Many policies regarding mitigation and individual measures have been implemented to achieve these mitigation measures globally [47]. Policies such as transport, food and energy use choices have the potential to reduce greenhouse gas emissions and produce major health cobenefits, particularly by abating air pollution and climate change [38]. This is part of climate-resilient pathways, which are iterative processes for managing change within complex systems to reduce disruptions and enhance opportunities associated with climate change [40]. Indeed, unless climate change is addressed, agricultural productivity will decline, with serious implications for food security, and millions of low-income people will be at risk of hunger and poverty [40].

Building resilient agricultural systems is one of the important ways to achieve better adaptation to climate change. By implementing measures that are very system- and local specific, agricultural systems can be made more resilient so that individual farmers, forest dwellers, fisher-folks and those along the supply chain will need to adopt a suite of measures, the details of which will be contingent on individual circumstances [45]. This is important because of the need to ensure food security and help reduce poverty, hunger and malnutrition at the local, national and international levels. Institutional and individual efforts must be combined to support the rural population at the local level, where catastrophic

events as a result of climate change will be more damaging. Broad adaptation strategies relevant to the successful achievement of food security, hunger reduction, malnutrition abolition and poverty limitation have been outlined by the FAO and other international organizations, such as the UNDP and IPCC. To this end, some adaptation measures have been considered to help the reader become more acquainted with the concept of climate change adaptation programs at a global position

According to the FAO [45], in this classical report, the following measures are taken into consideration: (a) increasing the efficiency of scarce resource use in productive systems (e.g., water, which is an important aspect of building resilient livelihoods); (b) adaptive changes in crop management (e.g., use of adapted varieties, planting dates, cultivar choice, and more advanced irrigation with shield or shelter belts); (c) adaptation options for livestock production at different scales (e.g., animals, feeding/housing systems, production systems and institutions); (d) more resilient healthy, diversified forest ecosystems, which are better able to cope with stress, recover from damage and adapt autonomously to change; and (d) fishing and fish-farming practices and management will need to adapt to changing species composition and location and increased risks at sea. These recommended measures by the FAO [45] individual report has focused on five key subjects in agriculture: soil and water conservation, crop management, animal production, forest management, and fish management practices [45]. Specifically, research and development in academia and research institutions should focus on outlining more technologically advanced research in these five subject areas. This will help increase the integration of diverse ideas, skills and scientific knowledge for successful climate change adaptation programs globally.

Carbon dioxide (CO_2), methane and nitrous oxide are released by greenhouse emissions and other industrial sectors. This emission is a serious problem for soil, human health and the environment and specifically contributes to climate change and global warming [60,61]. Mitigation and climate change adaptation are required [25]. The FAO [61] noted that carbon dioxide can be reduced through (a) reducing the rate of deforestation and forest degradation, (b) better control of wildfires, (c) preventing the practice of burning crop residues after harvest, (d) preventing pasture degradation, (e) reducing emissions in arable farming by adopting no-till systems, (f) reducing emissions from commercial fishing operations, and (g) increasing the efficiency of energy use by commercial agriculture and agro-industries. However, methane and nitrous oxide can be reduced through (a) improving nutrition for ruminant livestock, (b) more efficient management of livestock waste, (c) more efficient management of irrigation water on rice paddies, (d) more efficient management of applications of nitrogen fertilizer and manure on cultivated fields, and (d) reclamation of treated municipal wastewater for aquifer recharge and irrigation [62]. Abbass et al. [6] constructed a constructive framework indicating some of the key components of mitigation adaptation measures to help mitigate the impacts of climate change. These key components are important factors useful for addressing the impact of climate change [63]. Agriculture, biodiversity, health, forestry, tourism, economy, and industry are key sectors for adapting and mitigating climate change policies Fig. 2, [40].

In another progressive contribution made by the UNDP [27], a series of pathways useful for climate change adaptation are provided. We understand that there is need to present an overview of these pathways as observed by UNDP (27):

a. *Regenerative agriculture:* This is a way of farming that nurtures and restores soil health. We considered this pathway as essentially useful for ensuring water use efficiency, control soil erosion, and promotes animal and plant biodiversity as it involved the use of animal manures, minimum tillage practices, composting, tree plantation and integrated pest management activities.
b. *Reforestation:* This is the process of replanting trees in areas with recent tree cover but where forests were lost due to wildfires, drought, disease, or human activity such as agricultural clearing.
c. *Afforestation:* This is the process of planting trees in areas that have not been forested in recent history. UNDP considered this pathway useful for restoring abandoned and degraded agricultural lands, preventing desertification, creating carbon sinks, and generating new economic opportunities for local communities [27].

d. *Rewilding:* This is the mass restoration of ecosystems that have been damaged by human activity, and focuses on saving specific species through dedicated human intervention. UNDP considered rewilding to help combat climate change by removing more carbon dioxide from the atmosphere through healthy natural processes such as natural woodland regeneration [27].
e. *Circular economy:* This refers to models of production and consumption that minimize waste and reduce pollution, promote sustainable uses of natural resources, and help regenerate nature. This pathway can help many nations to create new jobs by turning large area of land into green.
f. *Blue economy:* This concept seeks to promote economic development, social inclusion, and the preservation or improvement of livelihoods while simultaneously ensuring the environmental sustainability of the ocean and coastal areas. UNDP [27] looked at the blue economy as pathway with diverse components, which includes the establishment of traditional ocean industries such as fisheries, tourism, and maritime transport, as well as emerging activities such as offshore renewable energy, aquaculture, seabed extractive activities, and marine biotechnology [27].
g. *Green jobs:* These are decent jobs that contribute to protecting and restoring the environment and addressing climate change. According to UNDP green jobs help improve energy and raw material efficiency, limit greenhouse gas emissions, minimize waste and pollution, protect and restore ecosystems, and support adaptation to the impacts of climate change [27].

Generally, agriculture must adapt to climate change and contribute to climate change mitigation. This means that changes in agricultural practices are required to provide livelihood options for poor farming households, broader food systems, reduced food waste and losses, and changes in dietary patterns to reduce their carbon footprint [40]. This entails that actions that strengthen climate change resilience must involve the adoption of practices that enable vulnerable people to protect existing livelihood systems, diversify their sources of income, change their livelihood strategies, or migrate if this is the best option [62]. For these reasons, however, the FAO developed actions that could strengthen resilience for agriculturally based livelihood systems [62]. These actions are specific and have provided the best recommendations for climate change adaptation, as outlined by FAO [64]: (a) research and dissemination of crop varieties and breeds adapted to changing climatic conditions, (b) the effective use of genetic resources, (c) promotion of agro-forestry, integrated farming systems and adapted forest management practices, (d) improved infrastructure for small-scale water capture, storage and use, (e) improved soil management practices, and (f) adaptation of farming systems and livelihood strategies to rapidly changing agro-ecological conditions. Therefore, technology transfer and innovation should be fostered to ease farming system transitions in all nations and give opportunities to rural and low-income farmers in villages and cities [65-67].

4. STRATEGIES AND PRINCIPLES FOR CLIMATE CHANGE ADAPTATION

In more recent developments, strategies and principles have been established to help manage climate change and ensure food security, economic sustainability, and environmental friendliness. The Sustainable Development Goals (SDGs) coded in the FAO Strategies on Climate Change as SDGs 13, 14 and 15 are targets set by the FAO to combat climate change and its impact on Earth's resources, including humans and the environment. These targets are described as follows [61]:

a. *SDG 13: Climate Action:* FAO will take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy.
b. *SDG 14: Life below Water:* The FAO provides measures to conserve and sustainably use the ocean, seas and marine resources for sustainable development.
c. *SDG 15: Life on Land:* FAO aims to provide measures to protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

However, to meet the above targets, the FAO Strategy on climate change is founded on the following principles, which are directly linked to

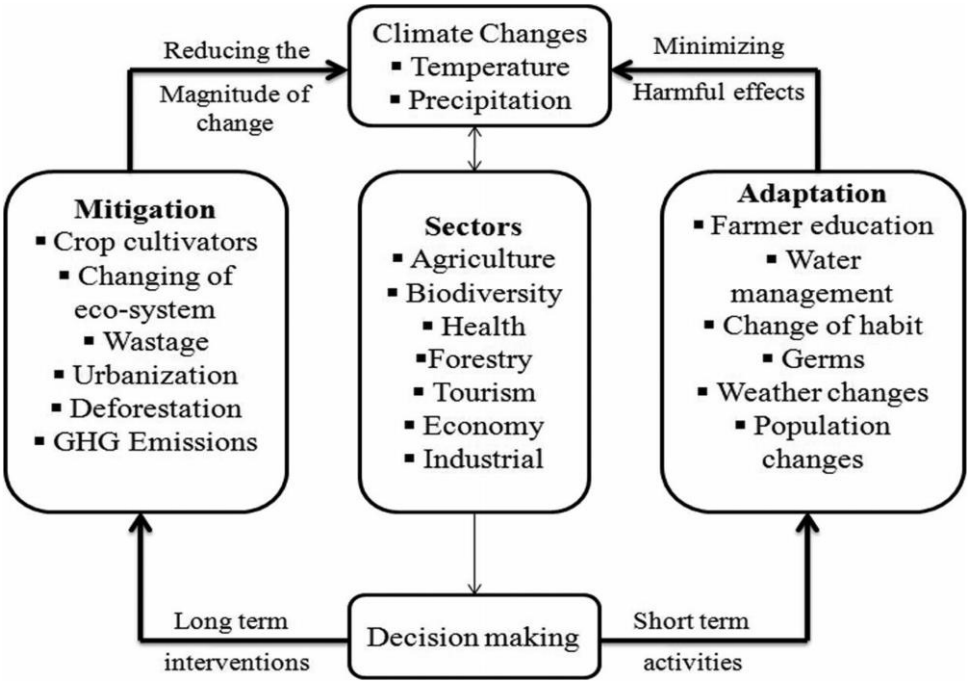

Fig. 2. Sectoral impacts of climate change with adaptation and mitigation measures [40]

the FAO Strategic Framework 2022–31. Some of these principles are as follows [14]: (a) sustainable agri-food systems, which should be inclusive, resilient and adaptive to climate change and its impacts by contributing to low-emission economies while providing sufficient, safe and nutritious foods for healthy diets, as well as other agricultural products and services, for present and future generations, leaving no one behind; (b) putting farmers, livestock keepers, fishers, aqua-culturists and forest-dependent people at the centre in particular, small-scale producers, indigenous peoples, women, youth, local and marginalized communities, and people in vulnerable situations; (c) embracing good practices and innovations, which include supporting the stocktaking of existing good practices and local, traditional and indigenous knowledge; (d) *building* on science-based evidence, including open science and data that requires the generation, sharing and efficient utilization, in a multidisciplinary manner, of the most reliable gender- and age-disaggregated data on global, regional and local scales; (e) promoting country-driven climate action for sustainable results; and (f) delivering through strategic partnerships.

5. WAY FORWARD

Climate change impact can be reduced based on nature and condition of a given environment. We believed that in rural areas of sub-Saharan Africa and some part of Asia and Arab nations, forest regeneration, planting of shelterbelt, tree plantation within and around the village areas, planting of economic trees such as mango close to the household surroundings, are helpful. Women more especially in Africa and Asia should be encourage to plant trees of economic values such as cashew, guava and mango because of their contribution to local communities, global trade and environmental security. Rural villages in Africa and Asia, which are vulnerable to flooding, landslides, and gullies, should be relocated to more safe areas. In Europe and United State of America, localities and township that have experienced regular flooding, forest fire outbreaks, and landslides for two years, should be provided with a nearby safe accommodation for easy relocation. Water bodies and forest areas need to be monitored on daily basis. Policy makers should be guided with the current advices and recommendations provided by IPCC and FAO on climate change adaptation policies, which are suitable and accommodated to their localities.

6. CONCLUSION

Climate change is real and potentially affects many components of human life, as noted in recent IPCC reports and other relevant studies. Climate change is already impacting and will

progressively impact agricultural productivity, human health and nutrition and could increase poverty, food insecurity, water scarcity, soil damage and economic imbalances. Through effects on agriculture, climate change influences people and nations depending on nature and vulnerabilities to soil, water, and the economy. The impacts of climate change on food security and human development can be described as dramatic changes that occur due to changes in temperature leading to global warming, shortages of rainfall leading to drought, and irregular precipitation leading to flooding, soil erosion, landslides, and crop damage. Mitigation and adaptation are required at all levels—local to support the rural population and national and international to potentially support research and development. Advance strategies and principles are outlined by the FAO and UNDP, among others. However, more scientifically advanced principles and mitigation measures are needed because of the continuous impact of climate change, which appears to be dynamic and irregular annually and globally. This paper has provided an advanced highlight of what climate change is and has revived the awareness that climate change is real and affects almost everyone on the planet.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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