

Climate change at a global concept: Impacts and adaptation measures

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.

Keywords: *Climate, Climate Change, Global Climate Change, Impact, Adaptation*

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-eq in 2019, approximately 12% (6.5 GtCO₂eq) 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 CO₂ from fossil fuel combustion and industrial processes (CO₂-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.

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]:

- 60 a. *Climate change adaptation*: This refers to actions that help reduce vulnerability to the current or expected impacts
61 of climate change, such as weather extremes and natural disasters, sea-level rise, biodiversity loss, or food and
62 water insecurity.
- 63 b. *Climate resilience*: This is the capacity of a community or environment to anticipate and manage climate impacts,
64 minimize damage, and recover and transform as needed after an initial shock.
- 65 c. *Climate change justice*: This describes putting equity and human rights at the core of decision-making and action
66 on climate change.
- 67 d. *Climate change security*: This refers to evaluating, managing, and reducing the risks to peace and stability
68 brought about by the climate crisis; i.e. the concept also ensures that conflict prevention and peace building
69 interventions take climate impacts into account.
- 70 e. *Climate change finance*: This refers to financial resources and instruments that are used to support action on
71 climate change.
- 72 f. *Climate neutrality*: This refers to the concept of a state in which human activities result in no net effect on the
73 climate system; therefore, achieving such a state would require balancing residual emissions with emission
74 (carbon dioxide) removal as well as accounting for regional or local bio-geophysical effects of human activities.
- 75 g. *Climate projection*: This is the simulated response of the climate system to a scenario of future emissions or
76 concentrations of greenhouse gases and aerosols, generally derived using climate models.
- 77 h. *Climate sensitivity*: This refers to the change in the annual global mean surface temperature in response to a
78 change in the atmospheric CO₂ concentration or other radiative forcing.
- 79 i. *Climate model*: This is a numerical representation of the climate system based on the physical, chemical and
80 biological properties of its components, their interactions and feedback processes, and accounting for some of its
81 known properties.

82 **Climate and climate change**

84 “The brochure of knowledge defined climate as the average weather at a particular place, incorporating features such as
85 temperature, precipitation, humidity, and windiness; however, a more specific definition looks at climate as the mean state
86 and variability of these features over some extended time period” [29]. The NRDC [30] maintained that “climate refers to
87 the general weather conditions of a place as measured over many years”. The UNDP [27] considers “climate as the
88 average of weather patterns in a specific area over a longer period of time, usually 30 or more years, which represents the
89 overall state of the climate system”. “This weather and its specific patterns can refer to atmospheric conditions at a
90 particular time in a particular location, including temperature, humidity, precipitation, cloudiness, wind, and visibility”
91 [27]. “In a narrow sense, climate is usually defined as the average weather, or more rigorously, as the statistical
92 description of the mean and variability of relevant quantities over a period of time ranging from months to thousands or
93 millions of years” [28]. According to the World Meteorological Organization [31], “the classical period for averaging these
94 variables is 30 years”. “However, the relevant quantities are most often surface variables such as temperature,
95 precipitation and wind, which also include the statistical description of the climate system” [28]. NASA [32] noted that
96 “historically, the Earth's climate has changed, and most climate changes are attributed to very small variations in Earth's
97 orbit that change the amount of solar energy our planet receives”. “For example, just in the last 800,000 years, there have
98 been eight cycles of ice ages and warmer periods, with the end of the last ice age approximately 11,700 years ago
99 marking the beginning of the modern climate era and of human civilization” [32].

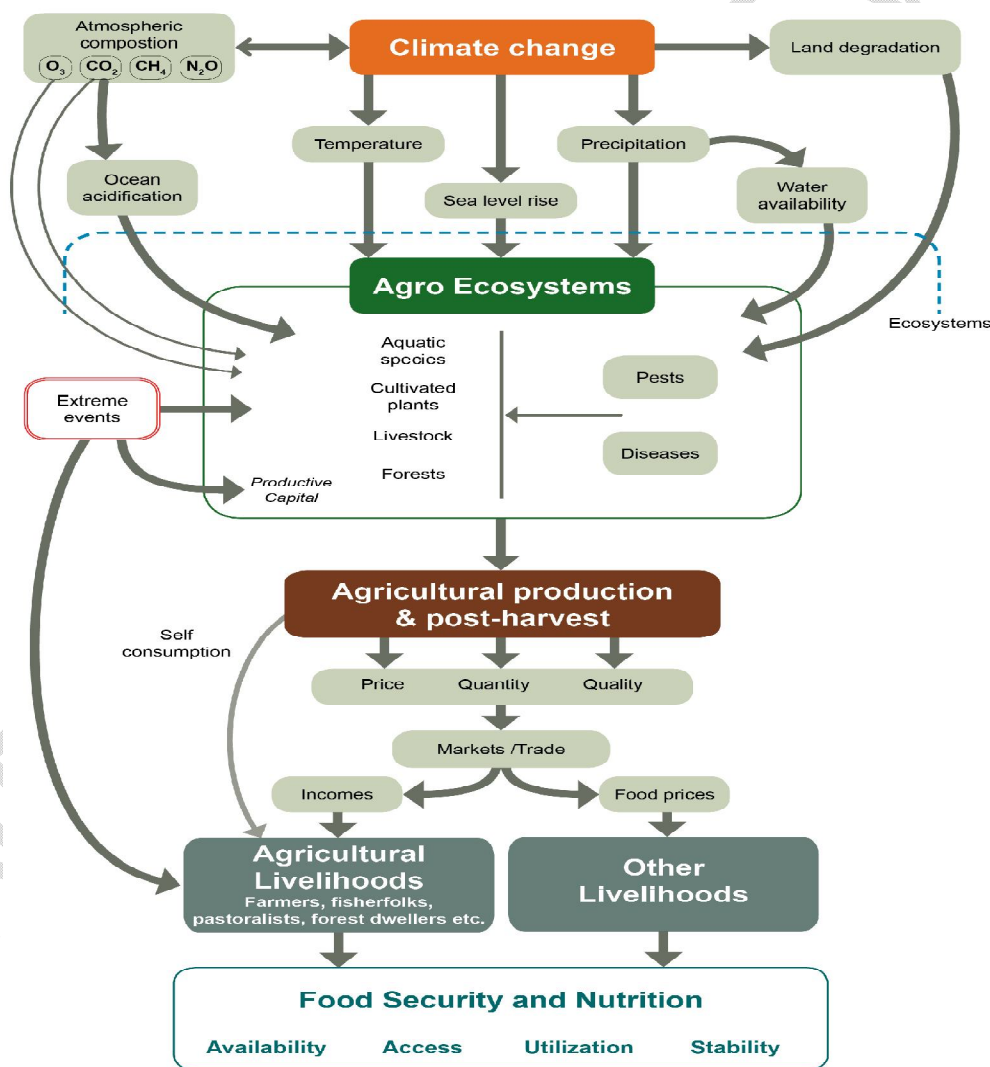
100
101 “Overall, climate change is a concept that is derived from the terms climate and changes that transpire within it – both
102 positively and negatively” [33]. “Significant contributions have been provided regarding the perception of climate change.
103 Similarly, various descriptions have been positioned in an attempt to define the term ‘climate change’.According to the
104 United Nations, climate change refers to long-term shifts in temperature and weather patterns, and such shifts can be
105 natural due to changes in solar activity or large volcanic eruptions” [34].According to the IPCC [28], “climate change refers
106 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
107 the variability of its properties and that persists for an extended period, typically decades or longer”. “In other words, this
108 may be due to natural internal processes or external forcings such as modulations of solar cycles, volcanic eruptions and
109 persistent anthropogenic changes in the composition of the atmosphere or in land use” [28]. According to the UNFCCC
110 [35], climate change is regarded as ‘a change of climate which is attributed directly or indirectly to human activity that
111 alters the composition of the global atmosphere and which is in addition to natural climate variability observed over
112 comparable time periods’. “This concept distinguishes between climate change attributable to human activities altering the
113 atmospheric composition and climate variability attributable to natural causes” [28].
114

115 The Encyclopedia Britannica [29] defined “climate change as a periodic modification of Earth’s climate caused by changes
116 in the atmosphere as well as interactions between the atmosphere and various other geologic, chemical, biological, and
117 geographic factors within the Earth system”. This definition agreed with the one presented by the NRDC [30]. “They
118 considered climate change to be a significant variation in average weather conditions (e.g., conditions becoming warmer,
119 wetter, or drier) over several decades or more; thus, the longer-term trend differentiates climate change from natural
120 weather variability”[30].According to the US-EPA [36], “climate change refers to any significant change in climate
121 measures lasting for an extended period of time”. “In other words, climate change includes major changes in temperature,
122 precipitation, or wind patterns, among other effects, that occur over several decades or longer” [36].“Additionally, climate
123 change is characterized by long-term changes in the Earth’s climate that are warming the atmosphere, ocean and land”
124 [27].According to the FAO [33], “climate change refers to a trend of significant fluctuations in major weather patterns and
125 conditions caused by increased greenhouse gases; this trend has seen significant variations in temperature, rain, wind,
126 and other factors over a period of years”. Similarly, the ISDR [37] defined “climate change as the alteration of the world’s
127 climate that we are causing through fossil fuel burning, clearing forests and other practices that increase the concentration
128 of greenhouse gases in the atmosphere”.
129

130 ***Impact of climate change***

131 “Climate change impacts human lives and health in a variety of ways, including threatening the essential ingredients of
132 good health, such as clean air, safe drinking water, a nutritious food supply and safe shelter, and has the potential to
133 undermine decades of progress in global health” [38].“The global impacts of climate change on agriculture will depend on
134 shocks at the local and regional levels, and it is therefore important to understand the likely impacts at these scales” [5].
135 “Climate change affects the balance of ecosystems that support life and biodiversity and impact health and causes more
136 extreme weather events, such as more intense and/or frequent hurricanes, floods, heat waves, and droughts [27].Climate
137 change has severe negative effects on agricultural development” [39]. “The negative effects on agricultural production and
138 the livelihoods of farmers, foresters and fisherfolks are already felt in many places” [40].
139

140 “Climate change is a serious threat to food security and agricultural productivity for industrial development” [3]. Food
 141 security is defined as ‘a situation that exists when all people, at all times, have physical, social, and economic access to
 142 sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life’
 143 [41]. “Climate change is a barrier to food security and has even caused an increase in hunger, poverty and malnutrition”
 144 [42, 43]. Indeed, a highlight of the potential risks induced by climate change for most vulnerable countries and populations
 145 indicated that four out of the eight key risks have direct penalties for food security [44]: (a) loss of rural livelihoods and
 146 income, (b) loss of marine and coastal ecosystems and livelihoods, (c) loss of terrestrial and inland water ecosystems and
 147 livelihoods, and (d) food insecurity and breakdown of food systems. Typically, these direct penalties for food security and
 148 nutrition can be understood from a range of physical, biological and biophysical impacts on ecosystems and agro-
 149 ecosystems, translating into general impacts on agricultural production (Fig. 1, [45]). “These various impacts of climate
 150 change on food and water security have recently been noted to hinder efforts to meet sustainable development goals with
 151 very high confidence” [4].



153
 154 **Fig. 1.** Schematic representation of the cascading effects
 155 of climate change impacts on food security and nutrition [45]
 156

157 “Climate change will have the greatest impact on agricultural water management by further sharpening the trade-offs
158 between the conservation and protection of natural ecosystems, which ultimately support agriculture, and the allocation of
159 land and water to sustain productive agriculture” [5]. “This could generate a situation whereby climate change will impact
160 the livelihoods and income of small-scale food producers and, through food price increases and volatility, the livelihoods
161 of poor net food buyers, constraining these populations to reduce their food consumption in terms of quantity and quality”
162 [45]. This means that well-being, health conditions and malnutrition, among many other human health issues, may be
163 affected [38]. This also means that there will be significant agricultural setbacks, food price increases, and increased
164 demand for corn, soybean and wheat for human consumption and industrial production [46].

165
166 “Climate change can lead to sea level rise and coastal erosion as a result of ocean warming, the melting of glaciers, and
167 the loss of ice sheets” [19]. “The *El Niño*-Southern Oscillation (ENSO) is a recurring cycle that refers to year-to-year
168 variations in sea surface temperatures, convective rainfall, surface air pressure, and atmospheric circulation that occur
169 across the equatorial Pacific Ocean” [45]. “The term *El Niño* was initially used to describe a warm-water current that
170 periodically flows along the coasts of Ecuador and Peru, disrupting the local fishery” [47]. “This *El Niño* can cause
171 changes in sea level because of annual temperature variations” [48]. “The IPCC reported that the average rate of sea level
172 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,
173 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.
174 [49] revealed that “satellite altimetry recorded that the global mean sea level rose at a rate of $\sim 3 \pm 0.4$ mm/y from 1993 to
175 2017”. Neremet al. [19] projected “an increase in this rate of 0.084 ± 0.025 mm/y² using altimeter records coupled with
176 careful consideration of interannual and decadal variability as well as potential instrument errors” [19]. According to these
177 observations, “if the sea level continues to change at this rate and acceleration, the sea-level rise by 2100 (~ 65 cm) would
178 be more than double the amount if the rate remained constant at 3 mm/y. Undoubtedly, this increase in sea level
179 continuously affects fish, causing flooding and leading to city damage, food insecurity and irregular economic stability” [50,
180 51].

181
182 “There are significant signs of fish migrating poleward due to climate change, which has led to sea temperature rise,
183 resulting in the rapid ‘tropicalization’ of mid- and high-latitude systems” [45]. “This has affected the economy and small-
184 scale fisheries lifestyle, thereby increasing poverty in the tropics” [2]. “This may shorten the fish market in many affected
185 local areas primarily because of the increasing pressure on aquatic resources through climatic drivers and human
186 stressors such as pollution and overfishing without appropriate measures taken” [52]. The IPCC [51] reported that “these
187 impacts occurred as a result of both gradual atmospheric warming and related physical and chemical changes in the
188 marine environment”. “The physical changes include changes in sea surface temperature, ocean circulation, waves and
189 storm systems, whereas the chemical changes include changes in salinity content, oxygen concentration and
190 acidification” [53]. “Indeed, climate change has caused substantial damage and increasingly irreversible losses in
191 terrestrial, freshwater, cryospheric, and coastal and open ocean ecosystems (high confidence); hundreds of local losses
192 of species have been driven by increases in the magnitude of heat extremes (high confidence) with mass mortality events
193 recorded on land and in the ocean (very high confidence)” [4].

194
195 Forest and natural vegetation areas are not excluded from the impacts of climate change. The FAO [45] reported that
196 “climate change and climate variability are threatening the delivery of a range of crucial goods (wood and non-wood) and

197 environmental services from forests on which an estimated 1.6 billion people fully or partly depend". "A report by the
198 World Bank noted that climate change is threatening more than 1 billion people who depend directly or indirectly on
199 valuable forest resources (e.g., timber, firewood, medicinal herbs, fruits, various kinds of agriculture, and industrial
200 materials)" [54]. Climate change, together with land degradation and deforestation, has affected many distinct forest
201 resources that are of economic value to human development for many years [55].
202

203 "Climate change is also a threat to human life. According to a report by the WHO [38], between 2030 and 2050, climate
204 change is expected to cause approximately 250 000 additional deaths per year from malnutrition, malaria, diarrhea and
205 heat stress alone, and the direct damage costs to health are estimated to be between US\$ 2–4 billion per year by 2030.
206 According to reports by the IPCC [51], as a result of climate change contributions to disasters, over the period 1991-2005,
207 3,470 million people were affected by disasters, 960,000 people died, and economic losses were US\$ 1,193 billion" [37].
208 EMDAT [56] reported that the number of global deaths from natural disasters from 1978 to 2020 reached 300 000 to 400
209 000 people.
210

211 "Rapid and dramatic shifts in climate cause more severe impacts, which include (a) droughts, floods, and unpredictable
212 rain patterns; (b) increased temperatures and more frequent heat waves; and (c) higher sea levels and increased water
213 temperatures" [33]. These circumstances affect soil and biodiversity, hinder plant growth, change the productivity of
214 forests and vegetation, affect animal and wildlife health conditions, and reduce the productivity of agricultural produce
215 [22]. Additionally, climate change can lead to potentially decreased rainfall, increased carbon dioxide (CO₂), and
216 increased temperatures, reducing the productivity of farms, ranches, and forests, which affects the food supply, raises
217 prices, and affects national and international incomes [57].
218

219 ***Causes of climate change***

220 Although climate change has a significant correlation with natural weather conditions and natural atmospheric and
221 environmental events [22], many factors and anthropogenic human activities are noted to worsen this situation. According
222 to the United Nations, fossil fuels—coal, oil and gas—are by far the largest contributors to global climate change,
223 accounting for more than 75% of global greenhouse gas emissions and nearly 90% of all carbon dioxide emissions
224 [58]. These factors cause climate crises, leading to complex environmental disasters [51]. The UNDP described this
225 climate crisis as a serious problem that is likely caused by changes in the planet's climate, including weather extremes
226 and natural disasters, ocean acidification and sea-level rise, loss of biodiversity, food and water insecurity, health risks,
227 economic disruption, displacement, and even violent conflict [27]. This climate crisis has also created many pole holes
228 that position global warming all most everywhere on the globe. Global warming is real and alarming [28]. This global
229 warming is generally regarded as the recent and ongoing increase in the global average temperature near the Earth's
230 surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere [59]. Global warming is
231 increasing the Earth's average surface temperature and occurs when the concentration of greenhouse gases in the
232 atmosphere increases [27]. Widespread changes in extreme temperatures have been observed in many regions of the
233 world over the last 50 years, most notably, high-temperature days, nights and heat [37].
234

235 GHG emissions result from the extraction and burning of fossil fuels and are major contributors to both climate change
236 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].

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 (CO₂), 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]. 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].

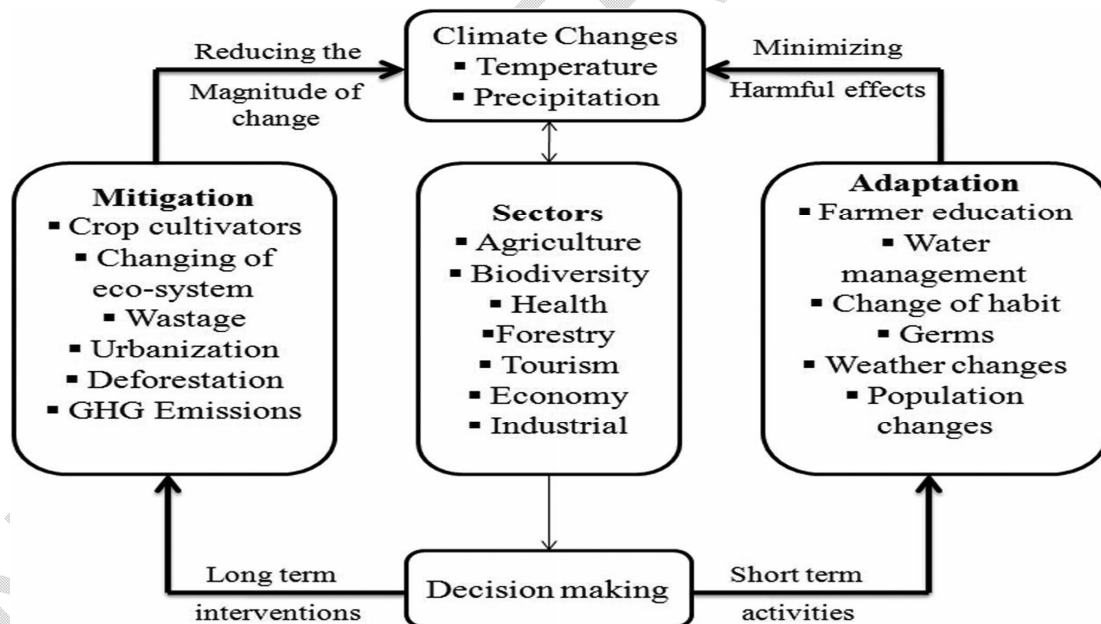


Fig. 2. Sectoral impacts of climate change with adaptation and mitigation measures [40]

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

303 plant biodiversity as it involved the use of animal manures, minimum tillage practices, composting, tree plantation
304 and integrated pest management activities.

- 305 b. *Reforestation*: This is the process of replanting trees in areas with recent tree cover but where forests were lost
306 due to wildfires, drought, disease, or human activity such as agricultural clearing.
- 307 c. *Afforestation*: This is the process of planting trees in areas that have not been forested in recent history. UNDP
308 considered this pathway useful for restoring abandoned and degraded agricultural lands, preventing
309 desertification, creating carbon sinks, and generating new economic opportunities for local communities [27].
- 310 d. *Rewilding*: This is the mass restoration of ecosystems that have been damaged by human activity, and focuses
311 on saving specific species through dedicated human intervention. UNDP considered rewilding to help combat
312 climate change by removing more carbon dioxide from the atmosphere through healthy natural processes such as
313 natural woodland regeneration [27].
- 314 e. *Circular economy*: This refers to models of production and consumption that minimize waste and reduce pollution,
315 promote sustainable uses of natural resources, and help regenerate nature. This pathway can help many nations
316 to create new jobs by turning large area of land into green.
- 317 f. *Blue economy*: This concept seeks to promote economic development, social inclusion, and the preservation or
318 improvement of livelihoods while simultaneously ensuring the environmental sustainability of the ocean and
319 coastal areas. UNDP [27] looked at the blue economy as pathway with diverse components, which includes the
320 establishment of traditional ocean industries such as fisheries, tourism, and maritime transport, as well as
321 emerging activities such as offshore renewable energy, aquaculture, seabed extractive activities, and marine
322 biotechnology [27].
- 323 g. *Green jobs*: These are decent jobs that contribute to protecting and restoring the environment and addressing
324 climate change. According to UNDP green jobs help improve energy and raw material efficiency, limit greenhouse
325 gas emissions, minimize waste and pollution, protect and restore ecosystems, and support adaptation to the
326 impacts of climate change [27].

327
328 Generally, agriculture must adapt to climate change and contribute to climate change mitigation. This means that changes
329 in agricultural practices are required to provide livelihood options for poor farming households, broader food systems,
330 reduced food waste and losses, and changes in dietary patterns to reduce their carbon footprint [40]. This entails that
331 actions that strengthen climate change resilience must involve the adoption of practices that enable vulnerable people to
332 protect existing livelihood systems, diversify their sources of income, change their livelihood strategies, or migrate if this is
333 the best option [62]. For these reasons, however, the FAO developed actions that could strengthen resilience for
334 agriculturally based livelihood systems [62]. These actions are specific and have provided the best recommendations for
335 climate change adaptation, as outlined by FAO [64]: (a) research and dissemination of crop varieties and breeds adapted
336 to changing climatic conditions, (b) the effective use of genetic resources, (c) promotion of agro-forestry, integrated
337 farming systems and adapted forest management practices, (d) improved infrastructure for small-scale water capture,
338 storage and use, (e) improved soil management practices, and (f) adaptation of farming systems and livelihood strategies
339 to rapidly changing agro-ecological conditions. Therefore, technology transfer and innovation should be fostered to ease
340 farming system transitions in all nations and give opportunities to rural and low-income farmers in villages and cities.

342 STRATEGIES AND PRINCIPLES FOR CLIMATE CHANGE ADAPTATION

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

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

355
356 However, to meet the above targets, the FAO Strategy on climate change is founded on the following principles, which are
357 directly linked to the FAO Strategic Framework 2022–31. Some of these principles are as follows [14]: (a) sustainable
358 agri-food systems, which should be inclusive, resilient and adaptive to climate change and its impacts by contributing to
359 low-emission economies while providing sufficient, safe and nutritious foods for healthy diets, as well as other agricultural
360 products and services, for present and future generations, leaving no one behind; (b) putting farmers, livestock keepers,
361 fishers, aqua-culturists and forest-dependent people at the centre in particular, small-scale producers, indigenous
362 peoples, women, youth, local and marginalized communities, and people in vulnerable situations; (c) embracing good
363 practices and innovations, which include supporting the stocktaking of existing good practices and local, traditional and
364 indigenous knowledge; (d) *building* on science-based evidence, including open science and data that requires the
365 generation, sharing and efficient utilization, in a multidisciplinary manner, of the most reliable gender- and age-
366 disaggregated data on global, regional and local scales; (e) promoting country-driven climate action for sustainable
367 results; and (f) delivering through strategic partnerships.

369 WAY FORWARD

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

381 CONCLUSION

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