Environmental Science and Pollution Research (2022) 29:42539–42559
https://doi.org/10.1007/s11356-022-19718-6

REVIEW ARTICLE

A review of the global climate change impacts, adaptation, and sustainable mitigation measures

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Received: 26 August 2021 / Accepted: 10 March 2022 / Published online: 4 April 2022

Abstract
Climate change is a long-lasting change in the weather arrays across tropics to polls. It is a global threat that has embarked on to put stress on various sectors. This study is aimed to conceptually engineer how climate variability is deteriorating the sustainability of diverse sectors worldwide. Specifically, the agricultural sector's vulnerability is a globally concerning scenario, as sufficient production and food supplies are threatened due to irreversible weather fluctuations. In turn, it is challenging the global feeding patterns, particularly in countries with agriculture as an integral part of their economy and total productivity. Climate change has also put the integrity and survival of many species at stake due to shifts in optimum temperature ranges, thereby accelerating biodiversity loss by progressively changing the ecosystem structures. Climate variations increase the likelihood of particular food and waterborne and vector-borne diseases, and a recent example is a coronavirus pandemic. Climate change also accelerates the enigma of antimicrobial resistance, another threat to human health due to the increasing incidence of resistant pathogenic infections. Besides, the global tourism industry is devastated as climate change impacts unfavorable tourism spots. The methodology investigates hypothetical scenarios of climate variability and attempts to describe the quality of evidence to facilitate readers' careful, critical engagement. Secondary data is used to identify sustainability issues such as environmental, social, and economic viability. To better understand the problem, gathered the information in this report from various media outlets, research agencies, policy papers, newspapers, and other sources. This review is a sectorial assessment of climate change mitigation and adaptation approaches worldwide in the aforementioned sectors and the associated economic costs. According to the findings, government involvement is necessary for the country's long-term development through strict accountability of resources and regulations implemented in the past to generate cutting-edge climate policy. Therefore, mitigating the impacts of climate change must be of the utmost importance, and hence, this global threat requires global commitment to address its dreadful implications to ensure global sustenance.

Keywords Climate change · COVID-19 · Antimicrobial resistance · Biodiversity · Mitigation measures

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Introduction

Worldwide observed and anticipated climatic changes for the twenty-first century and global warming are significant global changes that have been encountered during the past 65 years. Climate change (CC) is an inter-governmental complex challenge globally with its influence over various components of the ecological, environmental, socio-political, and socio-economic disciplines (Adger et al. 2005; Leal Filho et al. 2021; Feliciano et al. 2022). Climate change involves heightened temperatures across numerous worlds (Battisti and Naylor 2009; Schuurmans 2021; Weisheimer and Palmer 2005; Yadav et al. 2015). With the onset of the industrial revolution, the problem of earth climate was amplified manifold (Leppänen et al. 2014). It is reported that the immediate attention and due steps might increase the probability of overcoming its devastating impacts. It is not plausible to interpret the exact consequences of climate change (CC) on a sectoral basis (Izaguirre et al. 2021; Jurgilevich et al. 2017), which is evident by the emerging level of recognition plus the inclusion of climatic uncertainties at both local and national level of policymaking (Ayers et al. 2014).

Climate change is characterized based on the comprehensive long-haul temperature and precipitation trends and other components such as pressure and humidity level in the surrounding environment. Besides, the irregular weather patterns, retreating of global ice sheets, and the corresponding elevated sea level rise are among the most renowned international and domestic effects of climate change (Lipczynska-Kochany 2018; Michel et al. 2021; Murshed and Dao 2020). Before the industrial revolution, natural sources, including volcanoes, forest fires, and seismic activities, were regarded as the distinct sources of greenhouse gases (GHGs) such as CO_2, CH_4, N_2O, and H_2O into the atmosphere (Murshed et al. 2020; Hussain et al. 2020; Sovacool et al. 2021; Usman and Balsalobre-Lorente 2022; Murshed 2022). United Nations Framework Convention on Climate Change (UNFCCC) struck a major agreement to tackle climate change and accelerate and intensify the actions and investments required for a sustainable low-carbon future at Conference of the Parties (COP-21) in Paris on December 12, 2015. The Paris Agreement expands on the Convention by bringing all nations together for the first time in a single cause to undertake ambitious measures to prevent climate change and adapt to its impacts, with increased funding to assist developing countries in doing so. As so, it marks a turning point in the global climate fight. The core goal of the Paris Agreement is to improve the global response to the threat of climate change by keeping the global temperature rise this century well below 2 °C over pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5° C (Sharma et al. 2020; Sharif et al. 2020; Chien et al. 2021.

Furthermore, the agreement aspires to strengthen nations' ability to deal with the effects of climate change and align financing flows with low GHG emissions and climate-resilient paths (Shahbaz et al. 2019; Anwar et al. 2021; Usman et al. 2022a). To achieve these lofty goals, adequate financial resources must be mobilized and provided, as well as a new technology framework and expanded capacity building, allowing developing countries and the most vulnerable countries to act under their respective national objectives. The agreement also establishes a more transparent action and support mechanism. All Parties are required by the Paris Agreement to do their best through "nationally determined contributions" (NDCs) and to strengthen these efforts in the coming years (Balsalobre-Lorente et al. 2020). It includes obligations that all Parties regularly report on their emissions and implementation activities. A global stock-take will be conducted every five years to review collective progress toward the agreement's goal and inform the Parties' future individual actions. The Paris Agreement became available for signature on April 22, 2016, Earth Day, at the United Nations Headquarters in New York. On November 4, 2016, it went into effect 30 days after the so-called double threshold was met (ratification by 55 nations accounting for at least 55% of world emissions). More countries have ratified and continue to ratify the agreement since then, bringing 125 Parties in early 2017. To fully operationalize the Paris Agreement, a work program was initiated in Paris to define mechanisms, processes, and recommendations on a wide range of concerns (Murshed et al. 2021). Since 2016, Parties have collaborated in subsidiary bodies (APA, SBSTA, and SBI) and numerous formed entities. The Conference of the Parties functioning as the meeting of the Parties to the Paris Agreement (CMA) convened for the first time in November 2016 in Marrakesh in conjunction with COP22 and made its first two resolutions. The work plan is scheduled to be finished by 2018. Some mitigation and adaptation strategies to reduce the emission in the prospective of Paris agreement are following firstly, a long-term goal of keeping the increase in global average temperature to well below 2 °C above pre-industrial levels, secondly, to aim to limit the rise to 1.5 °C, since this would significantly reduce risks and the impacts of climate change, thirdly, on the need for global emissions to peak as soon as possible, recognizing that this will take longer for developing countries, lastly, to undertake rapid reductions after that under the best available science, to achieve a balance between emissions and removals in the second half of the century. On the other side, some adaptation strategies are; strengthening societies' ability to deal with the effects of climate change and to continue & expand international assistance for developing nations' adaptation.

However, anthropogenic activities are currently regarded as most accountable for CC (Murshed et al. 2022). Apart from the industrial revolution, other anthropogenic activities include excessive agricultural operations, which further involve the high use of fuel-based mechanization, burning of agricultural residues, burning fossil fuels, deforestation, national and domestic transportation sectors, etc. (Huang et al. 2016). Consequently, these anthropogenic activities lead to climatic catastrophes, damaging local and global infrastructure, human health, and total productivity. Energy consumption has mounted GHGs levels concerning warming temperatures as most of the energy production in developing countries comes from fossil fuels (Balsalobre-Lorente et al. 2022; Usman et al. 2022b; Abbass et al. 2021a; Ishikawa-Ishiwata and Furuya 2022).

This review aims to highlight the effects of climate change in a socio-scientific aspect by analyzing the existing literature on various sectorial pieces of evidence globally that influence the environment. Although this review provides a thorough examination of climate change and its severe affected sectors that pose a grave danger for global agriculture, biodiversity, health, economy, forestry, and tourism, and to purpose some practical prophylactic measures and mitigation strategies to be adapted as sound substitutes to survive from climate change (CC) impacts. The societal implications of irregular weather patterns and other effects of climate changes are discussed in detail. Some numerous sustainable mitigation measures and adaptation practices and techniques at the global level are discussed in this review with an in-depth focus on its economic, social, and environmental aspects. Methods of data collection section are included in the supplementary information.

Review methodology

Related study and its objectives

Today, we live an ordinary life in the beautiful digital, globalized world where climate change has a decisive role. What happens in one country has a massive influence on geographically far apart countries, which points to the current crisis known as COVID-19 (Sarkar et al. 2021). The most dangerous disease like COVID-19 has affected the world's climate changes and economic conditions (Abbass et al. 2022; Pirasteh-Anosheh et al. 2021). The purpose of the present study is to review the status of research on the subject, which is based on "Global Climate Change Impacts, adaptation, and sustainable mitigation measures" by systematically reviewing past published and unpublished research work. Furthermore, the current study seeks to comment on research on the same topic and suggest future research on the same topic. Specifically, the present study aims: The first one is, organize publications to make them easy and quick to find. Secondly, to explore issues in this area, propose an outline of research for future work. The third aim of the study is to synthesize the previous literature on climate change, various sectors, and their mitigation measurement. Lastly, classify the articles according to the different methods and procedures that have been adopted.

Review methodology for reviewers

This review-based article followed systematic literature review techniques that have proved the literature review as a rigorous framework (Benita 2021; Tranfield et al. 2003). Moreover, we illustrate in Fig. 1 the search method that we have started for this research. First, finalized the research theme to search literature (Cooper et al. 2018). Second, used numerous research databases to search related articles and download from the database (Web of Science, Google Scholar, Scopus Index Journals, Emerald, Elsevier Science Direct, Springer, and Sciverse). We focused on various articles, with research articles, feedback pieces, short notes, debates, and review articles published in scholarly journals. Reports used to search for multiple keywords such as "Climate Change," "Mitigation and Adaptation," "Department of Agriculture and Human Health," "Department of Biodiversity and Forestry," etc.; in summary, keyword list and full text have been made. Initially, the search for keywords yielded a large amount of literature.

Since 2020, it has been impossible to review all the articles found; some restrictions have been set for the literature exhibition. The study searched 95 articles on a different database mentioned above based on the nature of the study. It excluded 40 irrelevant papers due to copied from a previous search after readings tiles, abstract and full pieces. The criteria for inclusion were: (i) articles focused on "Global Climate Change Impacts, adaptation, and sustainable mitigation measures," and (ii) the search key terms related to study requirements. The complete procedure yielded 55 articles for our study. We repeat our search on the "Web of Science and Google Scholars" database to enhance the search results and check the referenced articles.

In this study, 55 articles are reviewed systematically and analyzed for research topics and other aspects, such as the methods, contexts, and theories used in these studies. Furthermore, this study analyzes closely related areas to provide unique research opportunities in the future. The study also discussed future direction opportunities and research questions by understanding the research findings climate changes and other affected sectors. The reviewed paper framework analysis process is outlined in Fig. 2.

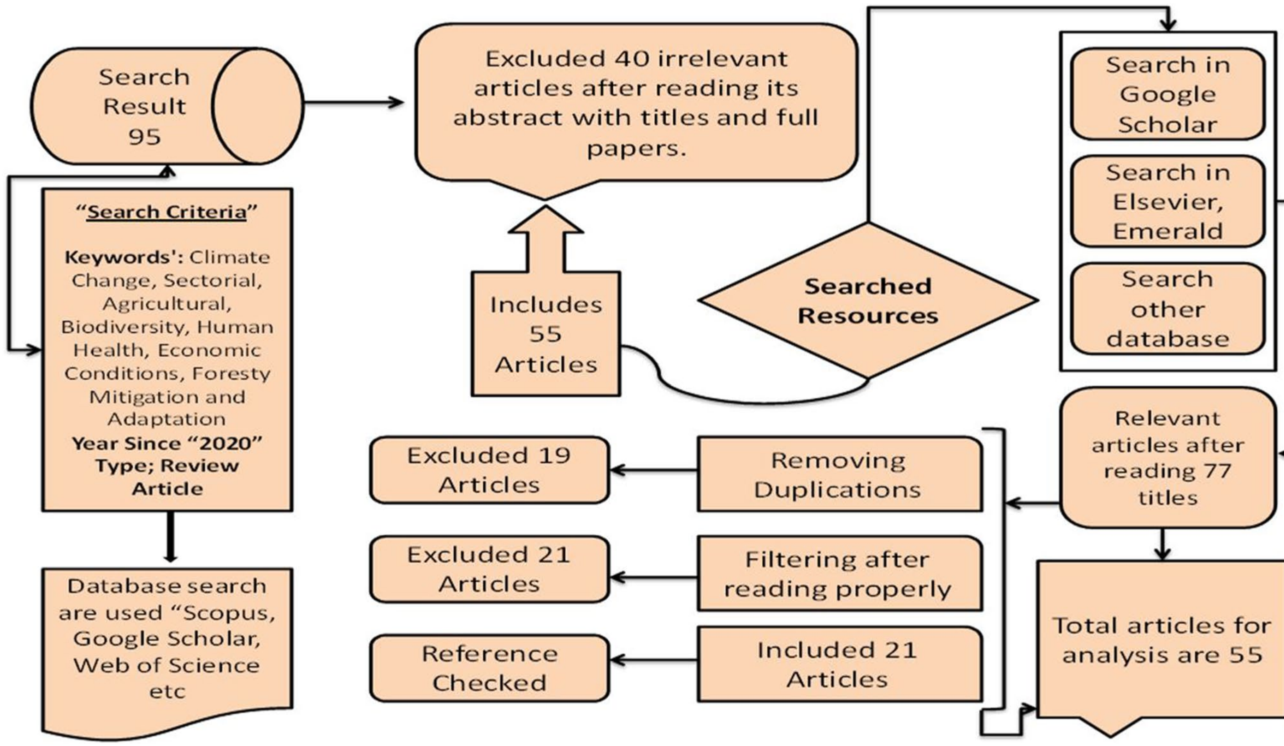

Fig. 1 Methodology search for finalized articles for investigations. **Source:** constructed by authors

Natural disasters and climate change's socio-economic consequences

Natural and environmental disasters can be highly variable from year to year; some years pass with very few deaths before a significant disaster event claims many lives (Symanski et al. 2021). Approximately 60,000 people globally died from natural disasters each year on average over the past decade (Ritchie and Roser 2014; Wiranata and Simbolon 2021). So, according to the report, around 0.1% of global deaths. Annual variability in the number and share of deaths from natural disasters in recent decades are shown in Fig. 3. The number of fatalities can be meager—sometimes less than 10,000, and as few as 0.01% of all deaths. But shock events have a devastating impact: the 1983–1985 famine and drought in Ethiopia; the 2004 Indian Ocean earthquake and tsunami; Cyclone Nargis, which struck Myanmar in 2008; and the 2010 Port-au-Prince earthquake in Haiti and now recent example is COVID-19 pandemic (Erman et al. 2021). These events pushed global disaster deaths to over 200,000—more than 0.4% of deaths in these years. Low-frequency, high-impact events such as earthquakes and tsunamis are not preventable, but such high losses of human life are. Historical evidence shows that earlier disaster detection, more robust infrastructure, emergency preparedness, and response programmers have substantially reduced disaster deaths worldwide. Low-income is also the most vulnerable to disasters; improving living conditions, facilities, and response services in these areas would be critical in reducing natural disaster deaths in the coming decades.

The interior regions of the continent are likely to be impacted by rising temperatures (Dimri et al. 2018; Goes et al. 2020; Mannig et al. 2018; Schuurmans 2021). Weather patterns change due to the shortage of natural resources (water), increase in glacier melting, and rising mercury are likely to cause extinction to many planted species (Gampe et al. 2016; Mihiretu et al. 2021; Shaffril et al. 2018).On the other hand, the coastal ecosystem is on the verge of devastation (Perera et al. 2018; Phillips 2018). The temperature rises, insect disease outbreaks, health-related problems, and seasonal and lifestyle changes are persistent, with a strong probability of these patterns continuing in the future (Abbass et al. 2021c; Hussain et al. 2018). At the global level, a shortage of good infrastructure and insufficient adaptive capacity are hammering the most (IPCC 2013). In addition to the above concerns, a lack of environmental education and knowledge, outdated consumer behavior, a scarcity of incentives, a lack of legislation, and the government's lack of commitment to climate change contribute to the general public's concerns. By 2050, a 2 to 3% rise in mercury and a drastic shift in rainfall patterns may have serious consequences (Huang et al. 2022; Gorst et al. 2018). Natural and environmental calamities caused huge losses

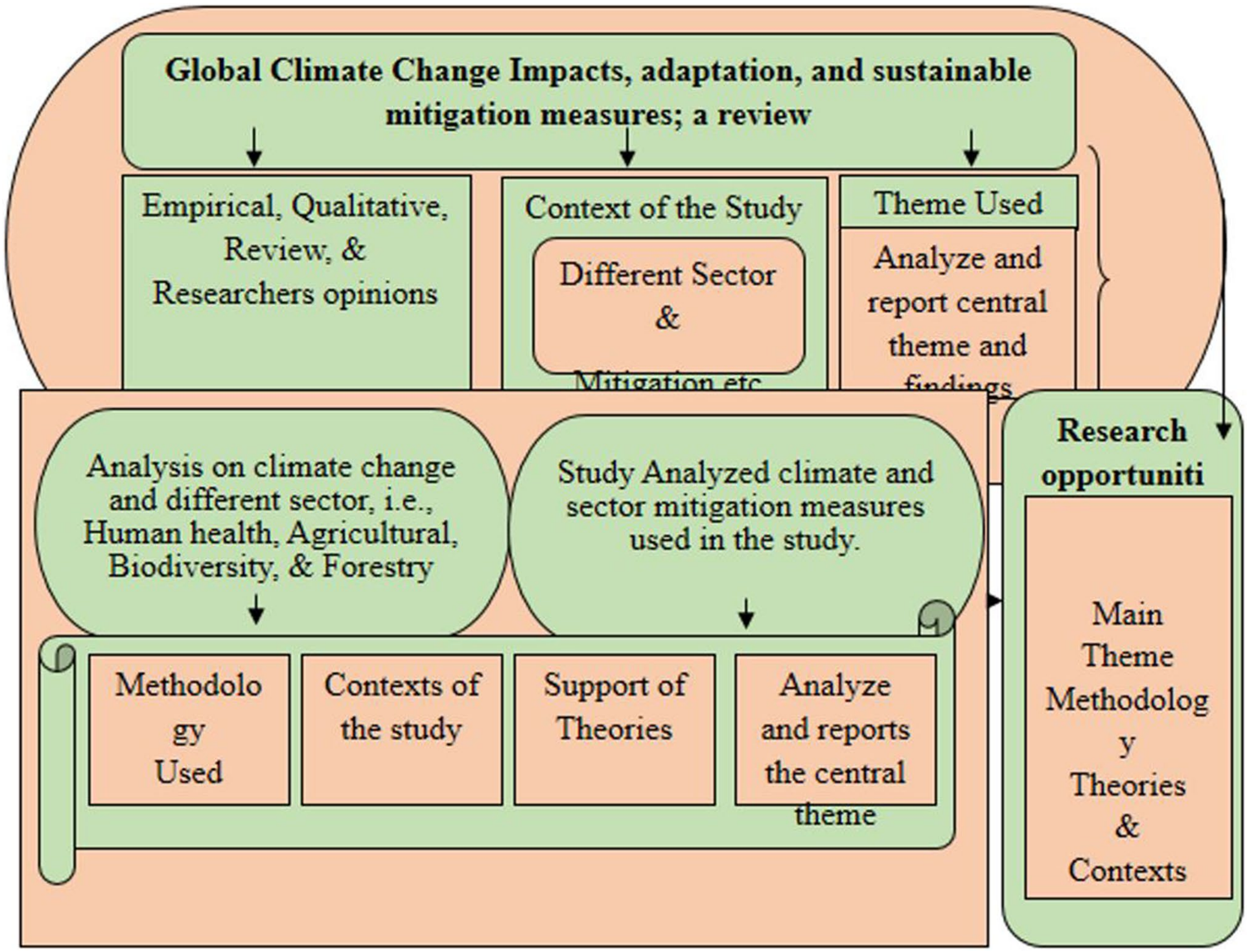

Fig. 2 Framework of the analysis Process. **Source:** constructed by authors

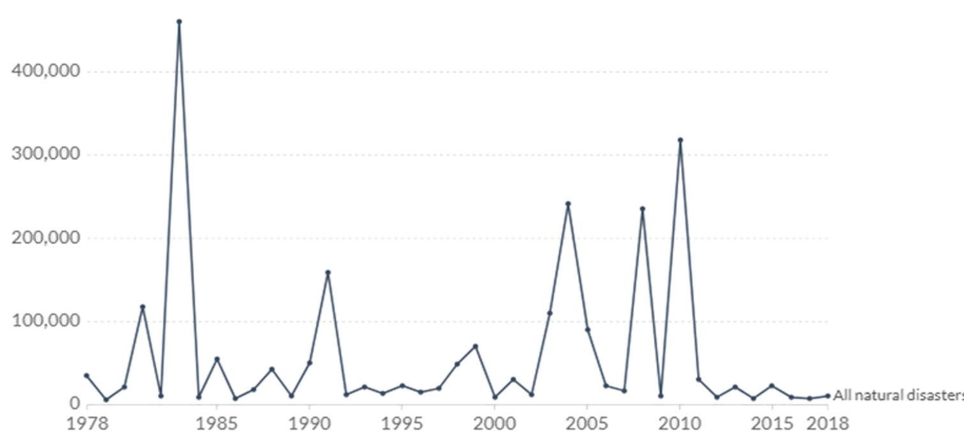

Fig. 3 Global deaths from natural disasters, 1978 to 2020. **Source** EMDAT (2020)

globally, such as decreased agriculture outputs, rehabilitation of the system, and rebuilding necessary technologies (Ali and Erenstein 2017; Ramankutty et al. 2018; Yu et al. 2021) (Table 1). Furthermore, in the last 3 or 4 years, the world has been plagued by smog-related eye and skin diseases, as well as a rise in road accidents due to poor visibility.

Table 1 Main natural danger statistics for 1985–2020 at the global level

Key natural hazards statistics from 1978 to 2020				
Country	1978 change	2018	Absolute change	Relative
Drought	63	0	−63	−100%
Earthquake	25,162	4,321	−20,841	−83%
Extreme temperature	150	536	+386	+257%
Extreme weather	3676	1,666	−2,010	−55%
Flood	5,897	2,869	−3,028	−51%
Landslide	86	275	+189	+220%
Mass movement	50	17	−33	−66%
Volcanic activity	268	878	+610	+228%
Wildfire	2	247	+245	+12,250%
All – natural disasters	35,036	10,809	−24,227	−69%

Source: EM-DAT (2020)

Climate change and agriculture

Global agriculture is the ultimate sector responsible for 30–40% of all greenhouse emissions, which makes it a leading industry predominantly contributing to climate warming and significantly impacted by it (Grieg; Mishra et al. 2021; Ortiz et al. 2021; Thornton and Lipper 2014). Numerous agro-environmental and climatic factors that have a dominant influence on agriculture productivity (Pautasso et al. 2012) are significantly impacted in response to precipitation extremes including floods, forest fires, and droughts (Huang 2004). Besides, the immense dependency on exhaustible resources also fuels the fire and leads global agriculture to become prone to devastation. Godfray et al. (2010) mentioned that decline in agriculture challenges the farmer's quality of life and thus a significant factor to poverty as the food and water supplies are critically impacted by CC (Ortiz et al. 2021; Rosenzweig et al. 2014). As an essential part of the economic systems, especially in developing countries, agricultural systems affect the overall economy and potentially the well-being of households (Schlenker and Roberts 2009). According to the report published by the Intergovernmental Panel on Climate Change (IPCC), atmospheric concentrations of greenhouse gases, i.e., CH_4, CO_2, and N_2O, are increased in the air to extraordinary levels over the last few centuries (Usman and Makhdum 2021; Stocker et al. 2013). Climate change is the composite outcome of two different factors. The first is the natural causes, and the second is the anthropogenic actions (Karami 2012). It is also forecasted that the world may experience a typical rise in temperature stretching from 1 to 3.7 °C at the end of this century (Pachauri et al. 2014). The world's crop production is also highly vulnerable to these global temperature-changing trends as raised temperatures will pose severe negative impacts on crop growth (Reidsma et al. 2009). Some of the recent modeling about the fate of global agriculture is briefly described below.

Decline in cereal productivity

Crop productivity will also be affected dramatically in the next few decades due to variations in integral abiotic factors such as temperature, solar radiation, precipitation, and CO_2. These all factors are included in various regulatory instruments like progress and growth, weather-tempted changes, pest invasions (Cammell and Knight 1992), accompanying disease snags (Fand et al. 2012), water supplies (Panda et al. 2003), high prices of agro-products in world's agriculture industry, and preeminent quantity of fertilizer consumption. Lobell and field (2007) claimed that from 1962 to 2002, wheat crop output had condensed significantly due to rising temperatures. Therefore, during 1980–2011, the common wheat productivity trends endorsed extreme temperature events confirmed by Gourdji et al. (2013) around South Asia, South America, and Central Asia. Various other studies (Asseng, Cao, Zhang, and Ludwig 2009; Asseng et al. 2013; García et al. 2015; Ortiz et al. 2021) also proved that wheat output is negatively affected by the rising temperatures and also caused adverse effects on biomass productivity (Calderini et al. 1999; Sadras and Slafer 2012). Hereafter, the rice crop is also influenced by the high temperatures at night. These difficulties will worsen because the temperature will be rising further in the future owing to CC (Tebaldi et al. 2006). Another research conducted in China revealed that a 4.6% of rice production per 1 °C has happened connected with the advancement in night temperatures (Tao et al. 2006). Moreover, the average night temperature growth also affected rice *indicia* cultivar's output pragmatically during 25 years in the Philippines (Peng et al. 2004). It is anticipated that the increase in world average temperature will also cause a substantial reduction in yield (Hatfield et al. 2011; Lobell and Gourdji 2012). In the southern hemisphere, Parry et al. (2007) noted a rise of 1–4 °C in average daily temperatures at the end of spring season unti the middle of summers, and this raised temperature reduced crop output by cutting down the time length for phenophases eventually reduce the yield (Hatfield and Prueger 2015; R. Ortiz 2008). Also, world climate models have recommended that humid and subtropical regions expect to be plentiful prey to the upcoming heat strokes (Battisti and Naylor 2009). Grain production is the amalgamation of two constituents: the average weight and the grain output/m_2, however, in crop production. Crop output is mainly accredited to the grain quantity (Araus et al. 2008; Gambín and Borrás 2010). In the times of grain set, yield resources are mainly strewn between hitherto defined components, i.e., grain usual weight and grain output, which presents a trade-off between them (Gambín and Borrás 2010) beside disparities in per grain integration (B. L. Gambín et al. 2006). In addition to this, the maize crop is also susceptible to raised temperatures, principally in the flowering stage (Edreira and Otegui 2013). In reality, the lower grain number is associated with insufficient acclimatization due to intense photosynthesis and higher respiration and the high-temperature effect on the reproduction phenomena (Edreira and Otegui 2013). During the flowering phase, maize visible to heat (30–36 °C) seemed less anthesis-silking intermissions (Edreira et al. 2011). Another research by Dupuis and Dumas (1990) proved that a drop in spikelet when directly visible to high temperatures above 35 °C in vitro pollination. Abnormalities in kernel number claimed by Vega et al. (2001) is related to conceded plant development during a flowering phase that is linked with the active ear growth phase and categorized as a critical phase for approximation of kernel number during silking (Otegui and Bonhomme 1998).

The retort of rice output to high temperature presents disparities in flowering patterns, and seed set lessens and lessens grain weight (Qasim et al. 2020; Qasim, Hammad, Maqsood, Tariq, & Chawla). During the daytime, heat directly impacts flowers which lessens the thesis period and quickens the earlier peak flowering (Tao et al. 2006). Antagonistic effect of higher daytime temperature d on pollen sprouting proposed seed set decay, whereas, seed set was lengthily reduced than could be explicated by pollen growing at high temperatures 40◦C (Matsui et al. 2001).

The decline in wheat output is linked with higher temperatures, confirmed in numerous studies (Semenov 2009; Stone and Nicolas 1994). High temperatures fast-track the arrangements of plant expansion (Blum et al. 2001), diminution photosynthetic process (Salvucci and Crafts-Brandner 2004), and also considerably affect the reproductive operations (Farooq et al. 2011).

The destructive impacts of CC induced weather extremes to deteriorate the integrity of crops (Chaudhary et al. 2011), e.g., Spartan cold and extreme fog cause falling and discoloration of betel leaves (Rosenzweig et al. 2001), giving them a somehow reddish appearance, squeezing of lemon leaves (Pautasso et al. 2012), as well as root rot of pineapple, have reported (Vedwan and Rhoades 2001). Henceforth, in tackling the disruptive effects of CC, several short-term and long-term management approaches are the crucial need of time (Fig. 4). Moreover, various studies (Chaudhary et al. 2011; Patz et al. 2005; Pautasso et al. 2012) have demonstrated adapting trends such as ameliorating crop diversity can yield better adaptability towards CC.

Climate change impacts on biodiversity

Global biodiversity is among the severe victims of CC because it is the fastest emerging cause of species loss. Studies demonstrated that the massive scale species dynamics are considerably associated with diverse climatic events (Abraham and Chain 1988; Manes et al. 2021; A. M. D. Ortiz et al. 2021). Both the pace and magnitude of CC are altering the compatible habitat ranges for living entities of marine, freshwater, and terrestrial regions. Alterations in general climate regimes influence the integrity of ecosystems in numerous ways, such as variation in the relative abundance of species, range shifts, changes in activity timing, and microhabitat use (Bates et al. 2014). The geographic distribution of any species often depends upon its ability to tolerate environmental stresses, biological interactions, and dispersal constraints. Hence, instead of the CC, the local species must only accept, adapt, move, or face extinction (Berg et al. 2010). So, the best performer species have a better survival capacity for adjusting to new ecosystems or a decreased perseverance to survive where they are already situated (Bates et al. 2014). An important aspect here is the inadequate habitat connectivity and access to microclimates, also crucial in raising the exposure to climate warming and extreme heatwave episodes. For example, the carbon sequestration rates are undergoing fluctuations due to climate-driven expansion in the range of global mangroves (Cavanaugh et al. 2014).

Similarly, the loss of kelp-forest ecosystems in various regions and its occupancy by the seaweed turfs has set the track for elevated herbivory by the high influx of tropical fish populations. Not only this, the increased water temperatures have exacerbated the conditions far away from the physiological tolerance level of the kelp communities (Vergés et al. 2016; Wernberg et al. 2016). Another pertinent danger is the devastation of keystone species, which even has more pervasive effects on the entire communities in that habitat (Zarnetske et al. 2012). It is particularly important as CC does not specify specific populations or communities. Eventually, this CC-induced redistribution of species may deteriorate carbon storage and the net ecosystem productivity (Weed et al. 2013). Among the typical disruptions, the prominent ones include impacts on marine and terrestrial productivity,

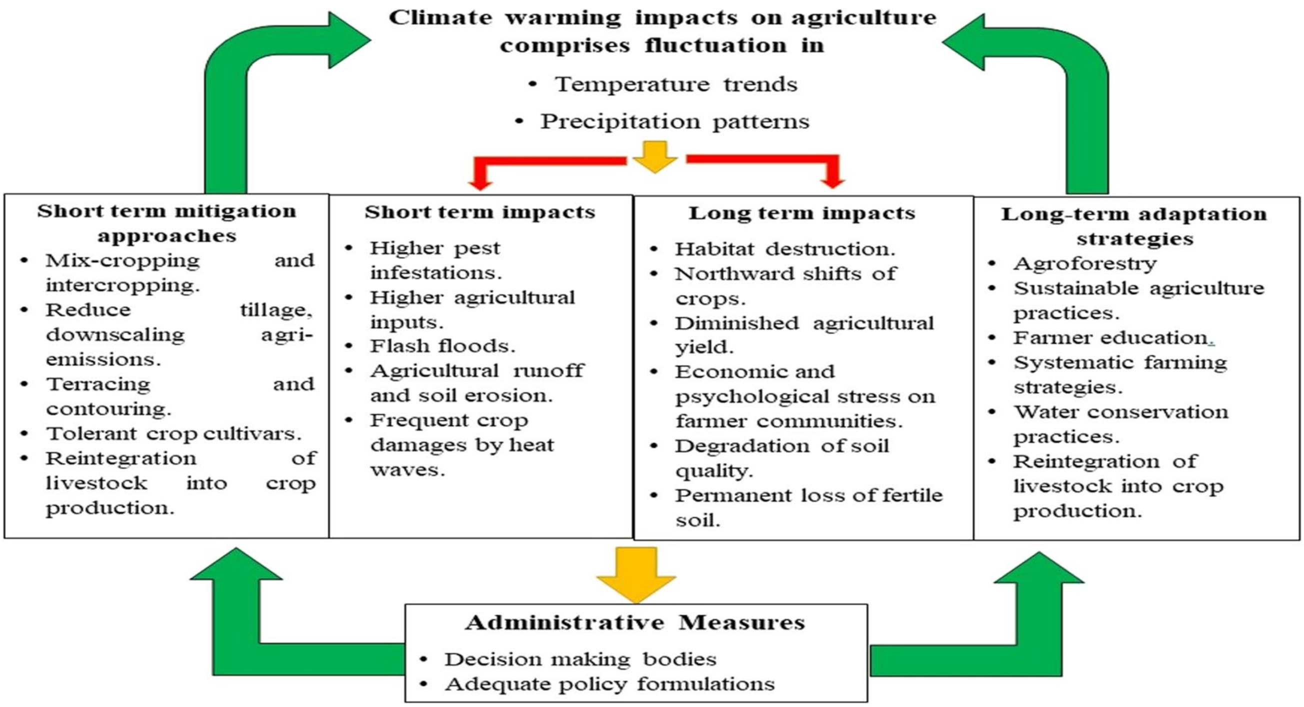

Fig. 4 Schematic description of potential impacts of climate change on the agriculture sector and the appropriate mitigation and adaptation measures to overcome its impact. **Source:** constructed by authors

marine community assembly, and the extended invasion of toxic cyanobacteria bloom (Fossheim et al. 2015).

The CC-impacted species extinction is widely reported in the literature (Beesley et al. 2019; Urban 2015), and the predictions of demise until the twenty-first century are dreadful (Abbass et al. 2019; Pereira et al. 2013). In a few cases, northward shifting of species may not be formidable as it allows mountain-dwelling species to find optimum climates. However, the migrant species may be trapped in isolated and incompatible habitats due to losing topography and range (Dullinger et al. 2012). For example, a study indicated that the American pika has been extirpated or intensely diminished in some regions, primarily attributed to the CC-impacted extinction or at least local extirpation (Stewart et al. 2015). Besides, the anticipation of persistent responses to the impacts of CC often requires data records of several decades to rigorously analyze the critical pre and post CC patterns at species and ecosystem levels (Manes et al. 2021; Testa et al. 2018).

Nonetheless, the availability of such long-term data records is rare; hence, attempts are needed to focus on these profound aspects. Biodiversity is also vulnerable to the other associated impacts of CC, such as rising temperatures, droughts, and certain invasive pest species. For instance, a study revealed the changes in the composition of plankton communities attributed to rising temperatures. Henceforth, alterations in such aquatic producer communities, i.e., diatoms and calcareous plants, can ultimately lead to variation in the recycling of biological carbon. Moreover, such changes are characterized as a potential contributor to CO_2 differences between the Pleistocene glacial and interglacial periods (Kohfeld et al. 2005).

Climate change implications on human health

It is an understood corporality that human health is a significant victim of CC (Costello et al. 2009). According to the WHO, CC might be responsible for 250,000 additional deaths per year during 2030–2050 (Watts et al. 2015). These deaths are attributed to extreme weather-induced mortality and morbidity and the global expansion of vector-borne diseases (Lemery et al. 2021; Yang and Usman 2021; Meierrieks 2021; UNEP 2017). Here, some of the emerging health issues pertinent to this global problem are briefly described.

Climate change and antimicrobial resistance with corresponding economic costs

Antimicrobial resistance (AMR) is an up-surging complex global health challenge (Garner et al. 2019; Lemery et al. 2021). Health professionals across the globe are extremely worried due to this phenomenon that has critical potential to reverse almost all the progress that has been achieved so far in the health discipline (Gosling and Arnell 2016). A massive amount of antibiotics is produced by many pharmaceutical industries worldwide, and the pathogenic microorganisms are gradually developing resistance to them, which can be comprehended how strongly this aspect can shake the foundations of national and global economies (UNEP 2017). This statement is supported by the fact that AMR is not developing in a particular region or country. Instead, it is flourishing in every continent of the world (WHO 2018). This plague is heavily pushing humanity to the post-antibiotic era, in which currently antibiotic-susceptible pathogens will once again lead to certain endemics and pandemics after being resistant(WHO 2018). Undesirably, if this statement would become a factuality, there might emerge certain risks in undertaking sophisticated interventions such as chemotherapy, joint replacement cases, and organ transplantation (Su et al. 2018). Presently, the amplification of drug resistance cases has made common illnesses like pneumonia, post-surgical infections, HIV/AIDS, tuberculosis, malaria, etc., too difficult and costly to be treated or cure well (WHO 2018). From a simple example, it can be assumed how easily antibiotic-resistant strains can be transmitted from one person to another and ultimately travel across the boundaries (Berendonk et al. 2015). Talking about the second- and third-generation classes of antibiotics, e.g., most renowned generations of cephalosporin antibiotics that are more expensive, broad-spectrum, more toxic, and usually require more extended periods whenever prescribed to patients (Lemery et al. 2021; Pärnänen et al. 2019). This scenario has also revealed that the abundance of resistant strains of pathogens was also higher in the Southern part (WHO 2018). As southern parts are generally warmer than their counterparts, it is evident from this example how CC-induced global warming can augment the spread of antibiotic-resistant strains within the biosphere, eventually putting additional economic burden in the face of developing new and costlier antibiotics. The ARG exchange to susceptible bacteria through one of the potential mechanisms, transformation, transduction, and conjugation; Selection pressure can be caused by certain antibiotics, metals or pesticides, etc., as shown in Fig. 5.

Certain studies highlighted that conventional urban wastewater treatment plants are typical hotspots where most bacterial strains exchange genetic material through horizontal gene transfer (Fig. 5). Although at present, the extent of risks associated with the antibiotic resistance found in wastewater is complicated; environmental scientists and engineers have particular concerns about the potential impacts of these antibiotic resistance genes on human health (Ashbolt 2015). At most undesirable and worst case, these antibiotic-resistant genes containing bacteria can make their way to enter into the environment (Pruden et al. 2013), irrigation water used for crops and public water supplies and ultimately become a part of food chains and food webs (Ma et al. 2019; D. Wu et al. 2019). This problem has been reported manifold in several countries (Hendriksen et al. 2019), where wastewater as a means of irrigated water is quite common.

Climate change and vector borne-diseases

Temperature is a fundamental factor for the sustenance of living entities regardless of an ecosystem. So, a specific living being, especially a pathogen, requires a sophisticated temperature range to exist on earth. The second essential component of CC is precipitation, which also impacts numerous infectious agents' transport and dissemination patterns. Global rising temperature is a significant cause of many species extinction. On the one hand, this changing environmental temperature may be causing species extinction, and on the other, this warming temperature might favor the thriving of some new organisms. Here, it was evident that some pathogens may also upraise once non-evident or reported (Patz et al. 2000). This concept can be exemplified through certain pathogenic strains of microorganisms

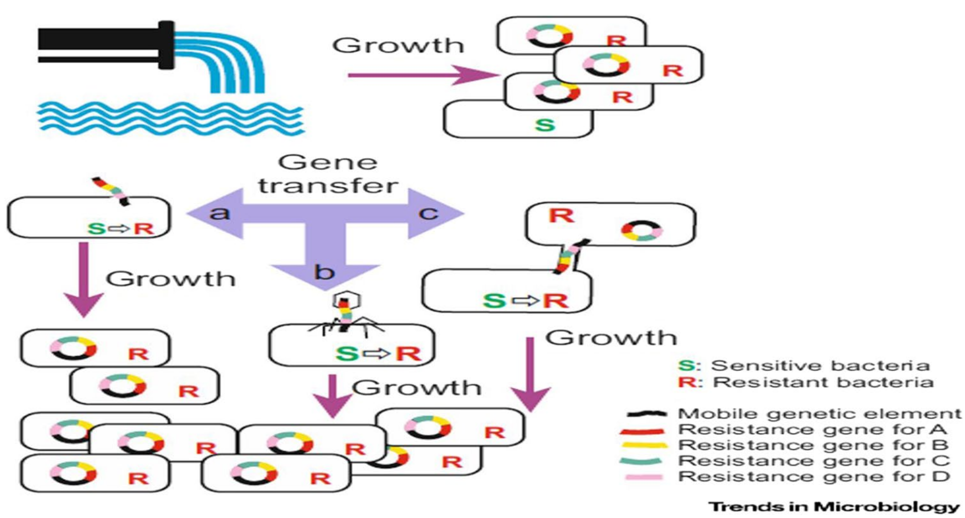

Fig. 5 A typical interaction between the susceptible and resistant strains. **Source:** Elsayed et al. (2021); Karkman et al. (2018)

that how the likelihood of various diseases increases in response to climate warming-induced environmental changes (Table 2).

A recent example is an outburst of coronavirus (COVID-19) in the Republic of China, causing pneumonia and severe acute respiratory complications (Cui et al. 2021; Song et al. 2021). The large family of viruses is harbored in numerous animals, bats, and snakes in particular (livescience.com) with the subsequent transfer into human beings. Hence, it is worth noting that the thriving of numerous vectors involved in spreading various diseases is influenced by Climate change (Ogden 2018; Santos et al. 2021).

Psychological impacts of climate change

Climate change (CC) is responsible for the rapid dissemination and exaggeration of certain epidemics and pandemics. In addition to the vast apparent impacts of climate change on health, forestry, agriculture, etc., it may also have psychological implications on vulnerable societies. It can be exemplified through the recent outburst of (COVID-19) in various countries around the world (Pal 2021). Besides, the victims of this viral infection have made healthy beings scarier and terrified. In the wake of such epidemics, people with common colds or fever are also frightened and must pass specific regulatory protocols. Living in such situations continuously terrifies the public and makes the stress familiar, which eventually makes them psychologically weak (npr.org).

CC boosts the extent of anxiety, distress, and other issues in public, pushing them to develop various mental-related problems. Besides, frequent exposure to extreme climatic catastrophes such as geological disasters also imprints post-traumatic disorder, and their ubiquitous occurrence paves the way to developing chronic psychological dysfunction. Moreover, repetitive listening from media also causes an increase in the person's stress level (Association 2020). Similarly, communities living in flood-prone areas constantly live in extreme fear of drowning and die by floods. In addition to human lives, the flood-induced destruction of physical infrastructure is a specific reason for putting pressure on these communities (Ogden 2018). For instance, Ogden (2018) comprehensively denoted that Katrina's Hurricane augmented the mental health issues in the victim communities.

Climate change impacts on the forestry sector

Forests are the global regulators of the world's climate (FAO 2018) and have an indispensable role in regulating global carbon and nitrogen cycles (Rehman et al. 2021; Reichstein and Carvalhais 2019). Hence, disturbances in forest ecology affect the micro and macro-climates (Ellison et al. 2017). Climate warming, in return, has profound impacts on the growth and productivity of transboundary forests by influencing the temperature and precipitation patterns, etc. As CC induces specific changes in the typical structure and functions of ecosystems (Zhang et al. 2017) as well impacts forest health, climate change also has several devastating consequences such as forest fires, droughts, pest outbreaks (EPA 2018), and last but not the least is the livelihoods of forest-dependent communities. The rising frequency and intensity of another CC product, i.e., droughts, pose plenty of challenges to the well-being of global forests (Diffenbaugh et al. 2017), which is further projected to increase

Table 2 Examples of how various environmental changes affect various infectious diseases in humans

Environmental modifications	Potential diseases	The causative organisms and pathway of effect
Construction of canals, dams, irrigation pathways	Schistosomiasis	Snail host locale, human contact
	Malaria	Upbringing places for mosquitoes
	Helminthiases	Larval contact due to moist soil
	River blindness	Blackfly upbringing
Agro-strengthening	Malaria	Crop pesticides
	Venezuelan hemorrhagic fever	Rodent abundance, contact
Suburbanization	Cholera	deprived hygiene, asepsis; augmented water municipal assembling pollution
	Dengue	Water-gathering rubbishes Aedes aegypti mosquito upbringing sites
	Cutaneous leishmaniasis	PSandfly vectors
Deforestation and new tenancy	Malaria	Upbringing sites and trajectories, migration of vulnerable people
	Oropouche	upsurge contact, upbringing of directions
	Visceral leishmaniasis	Recurrent contact with sandfly vectors
Agriculture	Lyme disease	Tick hosts, outside revelation
Ocean heating	Red tide	Poisonous algal blooms

Source: Aron and Patz (2001)

soon (Hartmann et al. 2018; Lehner et al. 2017; Rehman et al. 2021). Hence, CC induces storms, with more significant impacts also put extra pressure on the survival of the global forests (Martínez-Alvarado et al. 2018), significantly since their influences are augmented during higher winter precipitations with corresponding wetter soils causing weak root anchorage of trees (Brázdil et al. 2018). Surging temperature regimes causes alterations in usual precipitation patterns, which is a significant hurdle for the survival of temperate forests (Allen et al. 2010; Flannigan et al. 2013), letting them encounter severe stress and disturbances which adversely affects the local tree species (Hubbart et al. 2016; Millar and Stephenson 2015; Rehman et al. 2021).

Climate change impacts on forest-dependent communities

Forests are the fundamental livelihood resource for about 1.6 billion people worldwide; out of them, 350 million are distinguished with relatively higher reliance (Bank 2008). Agro-forestry-dependent communities comprise 1.2 billion, and 60 million indigenous people solely rely on forests and their products to sustain their lives (Sunderlin et al. 2005). For example, in the entire African continent, more than 2/3rd of inhabitants depend on forest resources and woodlands for their alimonies, e.g., food, fuelwood and grazing (Wasiq and Ahmad 2004). The livings of these people are more intensely affected by the climatic disruptions making their lives harder (Brown et al. 2014). On the one hand, forest communities are incredibly vulnerable to CC due to their livelihoods, cultural and spiritual ties as well as socio-ecological connections, and on the other, they are not familiar with the term "climate change." (Rahman and Alam 2016). Among the destructive impacts of temperature and rainfall, disruption of the agroforestry crops with resultant downscale growth and yield (Macchi et al. 2008). Cruz (2015) ascribed that forest-dependent smallholder farmers in the Philippines face the enigma of delayed fruiting, more severe damages by insect and pest incidences due to unfavorable temperature regimes, and changed rainfall patterns.

Among these series of challenges to forest communities, their well-being is also distinctly vulnerable to CC. Though the detailed climate change impacts on human health have been comprehensively mentioned in the previous section, some studies have listed a few more devastating effects on the prosperity of forest-dependent communities. For instance, the Himalayan people have been experiencing frequent skin-borne diseases such as malaria and other skin diseases due to increasing mosquitoes, wild boar as well, and new wasps species, particularly in higher altitudes that were almost non-existent before last 5–10 years (Xu et al. 2008). Similarly, people living at high altitudes in Bangladesh have experienced frequent mosquito-borne calamities (Fardous; Sharma 2012). In addition, the pace of other waterborne diseases such as infectious diarrhea, cholera, pathogenic induced abdominal complications and dengue has also been boosted in other distinguished regions of Bangladesh (Cell 2009; Gunter et al. 2008).

Pest outbreak

Upscaling hotter climate may positively affect the mobile organisms with shorter generation times because they can scurry from harsh conditions than the immobile species (Fettig et al. 2013; Schoene and Bernier 2012) and are also relatively more capable of adapting to new environments (Jactel et al. 2019). It reveals that insects adapt quickly to global warming due to their mobility advantages. Due to past outbreaks, the trees (forests) are relatively more susceptible victims (Kurz et al. 2008). Before CC, the influence of factors mentioned earlier, i.e., droughts and storms, was existent and made the forests susceptible to insect pest interventions; however, the global forests remain steadfast, assiduous, and green (Jactel et al. 2019). The typical reasons could be the insect herbivores were regulated by several tree defenses and pressures of predation (Wilkinson and Sherratt 2016). As climate greatly influences these phenomena, the global forests cannot be so sedulous against such challenges (Jactel et al. 2019). Table 3 demonstrates some of the particular considerations with practical examples that are essential while mitigating the impacts of CC in the forestry sector.

Climate change impacts on tourism

Tourism is a commercial activity that has roots in multidimensions and an efficient tool with adequate job generation potential, revenue creation, earning of spectacular foreign exchange, enhancement in cross-cultural promulgation and cooperation, a business tool for entrepreneurs and eventually for the country's national development (Arshad et al. 2018; Scott 2021). Among a plethora of other disciplines, the tourism industry is also a distinct victim of climate warming (Gössling et al. 2012; Hall et al. 2015) as the climate is among the essential resources that enable tourism in particular regions as most preferred locations. Different places at different times of the year attract tourists both within and across the countries depending upon the feasibility and compatibility of particular weather patterns. Hence, the massive variations in these weather patterns resulting from CC will eventually lead to monumental challenges to the local economy in that specific area's particular and national economy (Bujosa et al. 2015). For instance, the Intergovernmental Panel on Climate Change (IPCC) report demonstrated that the global tourism industry had faced a considerable decline in the duration of ski season, including the loss of some ski areas and the dramatic shifts in tourist destinations' climate warming.

Table 3 Essential considerations while mitigating the climate change impacts on the forestry sector

Attributes		Description	Forestry example
Purposefulness	Autonomous	Includes continuing application of prevailing information and techniques in retort to experienced climate change	Thin to reduce drought stress; construct breaks in vegetation to Stop feast of wildfires, vermin, and ailments
Timing	Preemptive	Necessitates interactive change to diminish future injury, jeopardy, and weakness, often through planning, observing, growing consciousness, structure partnerships, and ornamental erudition or investigation	Ensure forest property against potential future losses; transition to species or stand erections that are better reformed to predictable future conditions; trial with new forestry organization practices
Scope	Incremental	Involves making small changes in present circumstances to circumvent disturbances and ongoing to chase the same purposes	Condense rotation pauses to decrease the likelihood of harm to storm Events, differentiate classes to blowout jeopardy; thin to lessening compactness and defenselessness of jungle stands to tension
Goal	Opposition	Shield or defend from alteration; take procedures to reservation constancy and battle change	Generate refugia for rare classes; defend woodlands from austere fire and wind uproar; alter forest construction to reduce harshness or extent of wind and ice impairment; establish breaks in vegetation to dampen the spread of vermin, ailments, and wildfire

Source: Fischer (2019)

Furthermore, different studies (Neuvonen et al. 2015; Scott et al. 2004) indicated that various currently perfect tourist spots, e.g., coastal areas, splendid islands, and ski resorts, will suffer consequences of CC. It is also worth noting that the quality and potential of administrative management potential to cope with the influence of CC on the tourism industry is of crucial significance, which renders specific strengths of resiliency to numerous destinations to withstand against it (Füssel and Hildén 2014). Similarly, in the partial or complete absence of adequate socio-economic and socio-political capital, the high-demanding tourist sites scurry towards the verge of vulnerability. The susceptibility of tourism is based on different components such as the extent of exposure, sensitivity, life-supporting sectors, and capacity assessment factors (Füssel and Hildén 2014). It is obvious corporality that sectors such as health, food, ecosystems, human habitat, infrastructure, water availability, and the accessibility of a particular region are prone to CC. Henceforth, the sensitivity of these critical sectors to CC and, in return, the adaptive measures are a hallmark in determining the composite vulnerability of climate warming (Ionescu et al. 2009).

Moreover, the dependence on imported food items, poor hygienic conditions, and inadequate health professionals are dominant aspects affecting the local terrestrial and aquatic biodiversity. Meanwhile, the greater dependency on ecosystem services and its products also makes a destination more fragile to become a prey of CC (Rizvi et al. 2015). Some significant non-climatic factors are important indicators of a particular ecosystem's typical health and functioning, e.g., resource richness and abundance portray the picture of ecosystem stability. Similarly, the species abundance is also a productive tool that ensures that the ecosystem has a higher buffering capacity, which is terrific in terms of resiliency (Roscher et al. 2013).

Climate change impacts on the economic sector

Climate plays a significant role in overall productivity and economic growth. Due to its increasingly global existence and its effect on economic growth, CC has become one of the major concerns of both local and international environmental policymakers (Ferreira et al. 2020; Gleditsch 2021; Abbass et al. 2021b; Lamperti et al. 2021). The adverse effects of CC on the overall productivity factor of the agricultural sector are therefore significant for understanding the creation of local adaptation policies and the composition of productive climate policy contracts. Previous studies on CC in the world have already forecasted its effects on the agricultural sector. Researchers have found that global CC will impact the agricultural sector in different world regions. The study of the impacts of CC on various agrarian activities in other demographic areas and the development of relative strategies to respond to effects has become a focal point for researchers (Chandioet al. 2020; Gleditsch 2021; Mosavi et al. 2020).

With the rapid growth of global warming since the 1980s, the temperature has started increasing globally, which resulted in the incredible transformation of rain and evaporation in the countries. The agricultural development of many countries has been reliant, delicate, and susceptible to CC for a long time, and it is on the development of agriculture total factor productivity (ATFP) influence different crops and yields of farmers (Alhassan 2021; Wu 2020).

Food security and natural disasters are increasing rapidly in the world. Several major climatic/natural disasters have impacted local crop production in the countries concerned. The effects of these natural disasters have been poorly controlled by the development of the economies and populations and may affect human life as well. One example is China, which is among the world's most affected countries, vulnerable to natural disasters due to its large population, harsh environmental conditions, rapid CC, low environmental stability, and disaster power. According to the January 2016 statistical survey, China experienced an economic loss of 298.3 billion Yuan, and about 137 million Chinese people were severely affected by various natural disasters (Xie et al. 2018).

Mitigation and adaptation strategies of climate changes

Adaptation and mitigation are the crucial factors to address the response to CC (Jahanzad et al. 2020). Researchers define mitigation on climate changes, and on the other hand, adaptation directly impacts climate changes like floods. To some extent, mitigation reduces or moderates greenhouse gas emission, and it becomes a critical issue both economically and environmentally (Botzen et al. 2021; Jahanzad et al. 2020; Kongsager 2018; Smit et al. 2000; Vale et al. 2021; Usman et al. 2021; Verheyen 2005).

Researchers have deep concern about the adaptation and mitigation methodologies in sectoral and geographical contexts. Agriculture, industry, forestry, transport, and land use are the main sectors to adapt and mitigate policies(Kärkkäinen et al. 2020; Waheed et al. 2021). Adaptation and mitigation require particular concern both at the national and international levels. The world has faced a significant problem of climate change in the last decades, and adaptation to these effects is compulsory for economic and social development. To adapt and mitigate against CC, one should develop policies and strategies at the international level (Hussain et al. 2020). Figure 6 depicts the list of current studies on sectoral impacts of CC with adaptation and mitigation measures globally.

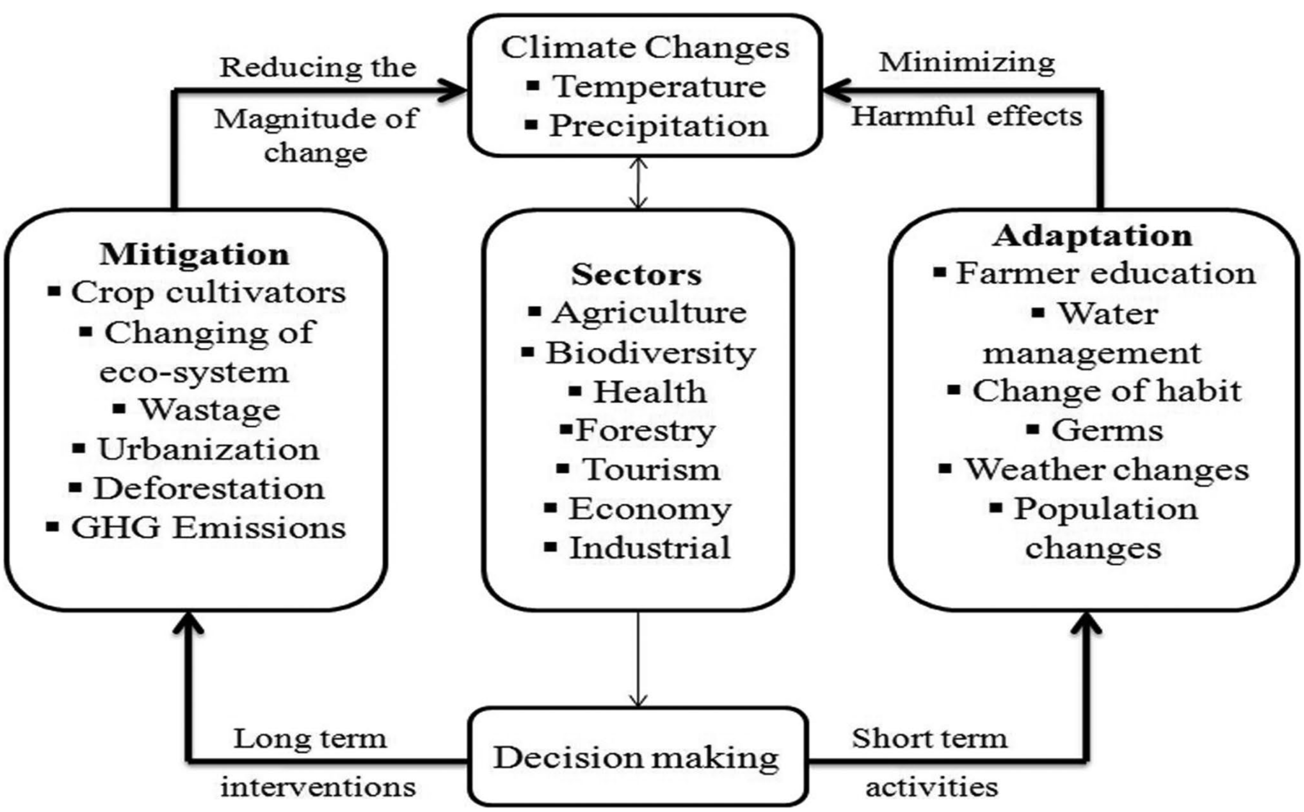

Fig. 6 Sectoral impacts of climate change with adaptation and mitigation measures. **Source:** constructed by authors

Conclusion and future perspectives

Specific socio-agricultural, socio-economic, and physical systems are the cornerstone of psychological well-being, and the alteration in these systems by CC will have disastrous impacts. Climate variability, alongside other anthropogenic and natural stressors, influences human and environmental health sustainability. Food security is another concerning scenario that may lead to compromised food quality, higher food prices, and inadequate food distribution systems. Global forests are challenged by different climatic factors such as storms, droughts, flash floods, and intense precipitation. On the other hand, their anthropogenic wiping is aggrandizing their existence. Undoubtedly, the vulnerability scale of the world's regions differs; however, appropriate mitigation and adaptation measures can aid the decision-making bodies in developing effective policies to tackle its impacts. Presently, modern life on earth has tailored to consistent climatic patterns, and accordingly, adapting to such considerable variations is of paramount importance. Because the faster changes in climate will make it harder to survive and adjust, this globally-raising enigma calls for immediate attention at every scale ranging from elementary community level to international level. Still, much effort, research, and dedication are required, which is the most critical time. Some policy implications can help us to mitigate the consequences of climate change, especially the most affected sectors like the agriculture sector;

1. *Seasonal variations and cultivation practices*
   Warming might lengthen the season in frost-prone growing regions (temperate and arctic zones), allowing for longer-maturing seasonal cultivars with better yields (Pfadenhauer 2020; Bonacci 2019). Extending the planting season may allow additional crops each year; when warming leads to frequent warmer months highs over critical thresholds, a split season with a brief summer fallow may be conceivable for short-period crops such as wheat barley, cereals, and many other vegetable crops. The capacity to prolong the planting season in tropical and subtropical places where the harvest season is constrained by precipitation or agriculture farming occurs after the year may be more limited and dependent on how precipitation patterns vary (Wu et al. 2017).
2. *New varieties of crops*
   The genetic component is comprehensive for many yields, but it is restricted like kiwi fruit for a few. Ali et al. (2017) investigated how new crops will react to climatic changes (also stated in Mall et al. 2017). Hot temperature, drought, insect resistance; salt tolerance; and overall crop production and product quality increases would all be advantageous (Akkari 2016). Genetic mapping and engineering can introduce a greater spectrum of features. The adoption of genetically altered cultivars has been slowed, particularly in the early forecasts owing to the complexity in ensuring features are expediently expressed throughout the entire plant, customer concerns, economic profitability, and regulatory impediments (Wirehn 2018; Davidson et al. 2016).
3. *Changes in management and other input factors*
   To get the full benefit of the CO_2 would certainly require additional nitrogen and other fertilizers. Nitrogen not consumed by the plants may be excreted into groundwater, discharged into water surface, or emitted from the land, soil nitrous oxide when large doses of fertilizer are sprayed. Increased nitrogen levels in groundwater sources have been related to human chronic illnesses and impact marine ecosystems. Cultivation, grain drying, and other field activities have all been examined in depth in the studies (Barua et al. 2018).
4. *The technological and socio-economic adaptation*

The policy consequence of the causative conclusion is that as a source of alternative energy, biofuel production is one of the routes that explain oil price volatility separate from international macroeconomic factors. Even though biofuel production has just begun in a few sample nations, there is still a tremendous worldwide need for feedstock to satisfy industrial expansion in China and the USA, which explains the food price relationship to the global oil price. Essentially, oil-exporting countries may create incentives in their economies to increase food production. It may accomplish by giving farmers financing, seedlings, fertilizers, and farming equipment. Because of the declining global oil price and, as a result, their earnings from oil export, oil-producing nations may be unable to subsidize food imports even in the near term. As a result, these countries can boost the agricultural value chain for export. It may be accomplished through R&D and adding value to their food products to increase income by correcting exchange rate misalignment and adverse trade terms. These nations may also diversify their economies away from oil, as dependence on oil exports alone is no longer economically viable given the extreme volatility of global oil prices. Finally, resource-rich and oil-exporting countries can convert to non-food renewable energy sources such as solar, hydro, coal, wind, wave, and tidal energy. By doing so, both world food and oil supplies would be maintained rather than harmed.

IRENA's modeling work shows that, if a comprehensive policy framework is in place, efforts toward decarbonizing the energy future will benefit economic activity, jobs (outweighing losses in the fossil fuel industry), and welfare. Countries with weak domestic supply chains and a large reliance on fossil fuel income, in particular, must undertake structural reforms to capitalize on the opportunities inherent in the energy transition. Governments continue to give major policy assistance to extract fossil fuels, including tax incentives, financing, direct infrastructure expenditures, exemptions from environmental regulations, and other measures. The majority of major oil and gas producing countries intend to increase output. Some countries intend to cut coal output, while others plan to maintain or expand it. While some nations are beginning to explore and execute policies aimed at a just and equitable transition away from fossil fuel production, these efforts have yet to impact major producing countries' plans and goals. Verifiable and comparable data on fossil fuel output and assistance from governments and industries are critical to closing the production gap. Governments could increase openness by declaring their production intentions in their climate obligations under the Paris Agreement.

It is firmly believed that achieving the Paris Agreement commitments is doubtlful without undergoing renewable energy transition across the globe (Murshed 2020; Zhao et al. 2022). Policy instruments play the most important role in determining the degree of investment in renewable energy technology. This study examines the efficacy of various policy strategies in the renewable energy industry of multiple nations. Although its impact is more visible in established renewable energy markets, a renewable portfolio standard is also a useful policy instrument. The cost of producing renewable energy is still greater than other traditional energy sources. Furthermore, government incentives in the R&D sector can foster innovation in this field, resulting in cost reductions in the renewable energy industry. These nations may export their technologies and share their policy experiences by forming networks among their renewable energy-focused organizations. All policy measures aim to reduce production costs while increasing the proportion of renewables to a country's energy system. Meanwhile, long-term contracts with renewable energy providers, government commitment and control, and the establishment of long-term goals can assist developing nations in deploying renewable energy technology in their energy sector.

Author contribution KA: Writing the original manuscript, data collection, data analysis, Study design, Formal analysis, Visualization, Revised draft, Writing-review, and editing. MZQ: Writing the original manuscript, data collection, data analysis, Writing-review, and editing. HS: Contribution to the contextualization of the theme, Conceptualization, Validation, Supervision, literature review, Revised drapt, and writing review and editing. MM: Writing review and editing, compiling the literature review, language editing. HM: Writing review and editing, compiling the literature review, language editing. IY: Contribution to the contextualization of the theme, literature review, and writing review and editing.

Availability of data and material Data sources and relevant links are provided in the paper to access data.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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