

Climate Change: Acting Now May Already Be Too Late

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Abstract

Climate change refers to long-term shifts in temperatures and weather patterns. The imbalance between incoming and outgoing radiation in the atmosphere is responsible for the climate change. The shifts in temperatures and weather patterns may be natural (e.g., through variations in the solar cycle) but since the early 20th century, human activities have been the main driver of climate change (e.g., through increased greenhouse gas emissions). Climate is changing in an accelerating pace. By 2100, the global mean temperatures may increase by up to 5.4°C. Climate change is a serious threat to ecosystem and health. It causes alterations to the physical environment of the planet Earth and impacts life of humans, animals, and plants. In humans, climate change creates water and food insecurity, increased morbidity/mortality, and population movement. Climate change disproportionately affects the vulnerable subjects (e.g., children, elderly, indigenous, and poor). Preventive measures are urgently needed to avoid irreversible consequences.

Keywords: Adaptation; Awareness; Climate change; Ecosystem; Global warming; Health; Prevention; Survival; Vulnerable populations

Abbreviations

AZ: Arizona

C: Celsius

COVID-19: Coronavirus Disease 2019

e.g.: Exempli gratia

IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC: Intergovernmental Panel on Climate Change

LLC: Limited Liability Company

MD: Medical Doctor

USA: United States of America

Introduction

Climate change includes warming and side effects of warming. It results from an imbalance between incoming and outgoing radiation in the atmosphere. The most important cause of climate change is related to human activities. Humans have caused a net accumulation of carbon dioxide and other heat-trapping greenhouse gases (e.g., methane, nitrous oxide, fluorinated gases, and water vapor) in the atmosphere during the last several decades. The current rapid rate and important magnitude of climate change are of great concern. It is expected that by 2100, the rise in global mean temperatures can be up to 5.4°C [1-5].

Climate change is a serious threat to ecosystem and health, causing alterations to the physical environment of the planet Earth, and affecting life of humans, animals, and plants around the globe (Figure 1) [1-31].



Figure 1: Climate change has a global impact on life around the globe.

It is urgent to implement preventive measures to control and limit climate change. Otherwise, long-term damages will be irreversible.

Causes of Climate Change

Climate change is the consequence of an imbalance between incoming and outgoing radiation in the atmosphere. The increase in heat-trapping greenhouse gases in the atmosphere raises Earth's mean surface temperature. With the increase of the temperature, more water evaporates from the oceans and other water sources into the atmosphere, causing additional increase of the temperature [1-5].

The atmospheric carbon dioxide has two primary sources: natural and anthropogenic (human-induced). Natural sources of carbon dioxide include most animals which exhale carbon dioxide as a waste product. Anthropogenic sources of carbon dioxide have been primarily driven by human activities since the early 20th century (industrial revolution), mainly fossil fuel burning (e.g., burning coal, oil, and natural gas), but also agricultural emissions and deforestation (non-exhaustive list). Deforestation of the Amazon in Brazil, mainly for agricultural purposes, has been a significant contributing factor to climate change. The top five countries responsible for emissions of carbon dioxide are China, United States of America (USA), India, Russia, and Japan (Table 1) [4]. The Coronavirus Disease 2019 (COVID-19) pandemic did produce a drop in carbon dioxide emissions, but the drop was temporary, and emissions have climbed back to the pre-pandemic levels.

Countries	Carbon Dioxide Emissions (Metric Tons)	Contribution (%)
China	10.06 billion	28
USA	5.41 billion	15
India	2.65 billion	7
Russia	1.71 billion	5
Japan	1.16 billion	3

Table 1: Top five countries contributing to carbon dioxide emissions in 2018.

The increase in atmospheric methane results from activities such as mining, agriculture, raising livestock, and decomposing garbage. The increase in nitrous oxide concentrations is due to several causes including burning of fossil fuel and using fertilizers. Fluorinated gases (e.g., hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride) are synthetic and powerful greenhouse gases that are emitted through a variety of paths including industrial processes (e.g., aluminum and semiconductor manufacturing). Water vapor, which is the most abundant greenhouse gas, is mainly enhanced by the surface warming caused by the increases in the other greenhouse gases.

Consequences of Climate Change

Climate change is a serious threat for our planet, causing multiple side effects for the physical environment of the planet Earth. It affects the life of humans, animals, and plants. Although most consequences of climate change are deleterious, some health benefits may occur. For example, warmer winters can reduce the number of temperature-related morbidities and death.

Planet Earth

Climate change has multiple negative impacts on the physical planet Earth's environment (e.g., impact on the frequency and severity of extreme events and natural disasters).

The current climate change is associated with increased Earth's temperature (land surfaces and upper layers of the ocean) [1,4]. Over the past 70 years, the Earth's temperature has increased by approximately 0.7°C [4]. In the past 20 years, Earth's lowest air temperature was -94.7°C (recorded in Antarctica in 2010) and hottest air temperature was 70.7°C (recorded in Iran's Lut Desert in 2005). The average global temperature for the past five years was among the highest on record. The present global mean

temperature is around 15.0°C. Currently, the surface temperatures are rising by approximately 0.2°C per decade [6]. According to the Intergovernmental Panel on Climate Change (IPCC) and based on different emissions scenarios, by 2100, there will be a rise in global mean temperatures of 0.9 to 5.4°C [4]. Warming is more pronounced at higher latitudes. The North Pole and Northern Hemisphere have warmed much faster than the South Pole and Southern Hemisphere. Springs occur earlier. Greater temperature increases are happening in winter compared to summer and in nighttime compared to daytime.

Mountain glaciers are melting. Lakes are freezing less and for a shorter duration. In few decades, thousands of lakes may lose their winter ice cover.

There is a rise in sea levels. Since 1900, global mean sea level has increased by approximately 0.20 meter. Based on different emissions scenarios, by 2100, sea levels may rise between 0.40 and 1.50 meters [4]. This can cause the disappearance of several islands and flooding with invasion of cities by water (Figure 2). The continued sea-level rise is irreversible over hundreds to thousands of years.



Figure 2: Climate change through rise in sea levels can cause invasion of cities by water.

The salty ocean water causes salination of freshwater supplies and loss of productive farmlands and challenges native animals and plants [7].

The warmer ocean water temperature is responsible for more dangerous hurricanes and heavier rainstorms [4,8]. The proportion of Category 4 and 5 hurricanes has increased at a rate of 25-30% per 1.0°C of global warming [8]. Hurricane Katrina (Category 5, New Orleans, USA, 2005) was one of the deadliest hurricanes in recent USA history. The total number of direct or indirect fatalities following hurricane Katrina was 1,833. The 2020 North Atlantic hurricane season had thirteen hurricanes (including six major hurricanes, e.g., Category 3 or higher). In August 2021, sixteen years after hurricane Katrina, hurricane Ida (Category 4) made

landfall in New Orleans. It had enough power to reverse the flow of the Mississippi River. Most casualties of hurricane Ida occurred in Northeast of the USA where the hurricane caused catastrophic flooding and more than fifty deaths.

Wildfires are more frequent. The dry, hot weather has increased the intensity and destructiveness of forest fires in different countries (e.g., Brazil, USA, and Australia) [9,10]. Wildfires cause deforestation, property damage, exposure of many people to prolonged periods of polluted and toxic air with potential health impacts (e.g., respiratory diseases), and death. In recent years, devastating autumn wildfires occurred in California, USA [10].

More frequent and severe droughts are happening [4,11]. This can cause misery, hunger, starvation, and population movement.

The surface waters of the oceans become more acidic due to the increased amount of carbon dioxide in the atmosphere [4]. The acidification of the oceans can alter marine ecosystems, damaging coral reefs, fish, and other aquatic species [4,12].

Humans

Through multiple paths, climate change leads to increased morbidity and mortality in humans.

Increased temperature causes physiological reactions with increased risks of morbidity and mortality (e.g., reduced performance and work productivity, behavioral changes, heat exhaustion, heat stroke, respiratory failure, myocardial infarction, stroke, and death) [5,13-15]. Without adaptation, the economic losses of reduced work productivity could be more than 20% of the gross domestic product by 2100. Children, elderly people, poor people, outdoor workers, workers required to wear protective clothing and/or personal protective equipment, and subjects with chronic health conditions are at higher risk when facing heat stress. The annual heat-related death in the USA is around 1,500. The European heat wave during the summer of 2003 caused approximately 70,000 deaths. On the positive side, increased temperatures can lower the incidence and mortality of some winter-related events (e.g., myocardial infarction and stroke). The incidence of some infectious diseases (e.g., malaria) can also be reduced by hotter and drier conditions.

Extreme weather conditions can lead to breakdowns in the physical barriers between outdoor and indoor spaces of homes and buildings, promoting the growth of indoor fungi and mold with subsequent health consequences (e.g., headaches, red eyes, skin rashes, and asthma).

Humans are exposed to water and food insecurity with significant impact on hygiene, nutrition, and food safety [1]. Without adequate desalination of drinking water following increased salinity due to sea-level rise, the high exposure to salt

through drinking water, food, and bathing can cause several health issues (e.g., hypertension and skin diseases) [7]. With the rise in ocean temperature, several fish populations may move to higher latitudes, affecting dietary protein supplies of millions of people. In 2020, up to 811 million people in the world faced hunger. This number was approximately 161 million more than in 2019 (Figure 3).



Figure 3: Climate change promotes food shortage leading to hunger.

There is a spread of some infectious diseases (e.g., malaria, dengue, and Lyme disease) through variations in temperature, precipitation/humidity, wind, and solar radiation [3,16].

The unsuitable living conditions created by climate change (e.g., desertification, sea-level rise, decline in freshwater availability, food shortage, and health issues) will move many people (forced displacement, planned resettlement, migration), especially in poor communities. It is estimated that up to several hundred million individuals will be moved by 2050 [17]. Population movement will expose countries to multiple health, social, and financial challenges and generate violent conflicts.

Vulnerable populations including children, elderly, indigenous groups, poor individuals, outdoor workers, remote populations, and subjects with pre-existing conditions are disproportionately affected [1,2,5,14,15,17-20]. Indeed, the mortality of the European heat wave of 2003 affected mainly the elderly and the global mortality due to climate change in 2004 was around 141,000 of which 85% were children.

Animals

Climate change has consequences for the survival of several species [26]. Approximately 700 mammals and birds are affected by climate change. Species will either need to move to more

suitable locations (e.g., higher elevations and latitudes) or to adapt to changes at their current locations (e.g., habitat, feeding and breeding patterns). Otherwise, the species may perish and become extinct. These endangered animals include polar bears, koalas, elephants, sea turtles, cheetahs, panda bears, and penguins (non-exhaustive list).

Several species face habitat damage (e.g., polar bears, koalas, and birds). Polar bears depend on sea ice. The increased temperature is causing the arctic sea ice to melt, affecting their habitat (Figure 4) [21]. Koalas are dependent on eucalyptus tree. The increased temperature and drought are generating wildfire and destroying the koalas' habitat [22]. Lake Urmia (Iran), a bird habitat, is drying up mainly due to climate change.

Species survival is impacted by changes in water/food availability/quality. Polar bears will have trouble finding food as the sea ice thins and melts earlier. Koalas' main food source is eucalyptus leaves. There is a reduction in the amount of water in the eucalyptus tree. The increased carbon dioxide level by decreasing protein levels in the tree affects plant nutritional quality. These changes create dehydration, malnutrition, and starvation. Over their last three generations, Koalas' population has declined by more than 30% [22]. Elephants require 150-300 liters of water per day for drinking in addition to the amount needed for bathing and playing. Droughts may lead to elephants' population decline [23].



Figure 4: Climate change causes melting of sea ice and impacts polar bear's habitat.

Warmer springs have caused advanced timing of migration and breeding in most avian species [24]. Rising sea levels threaten the sea turtle eggs on beaches. The nest temperatures impact sex determination of the sea turtles. Cool temperatures produce more males while warm temperatures produce more females. There is an unbalanced sea turtles' gender population with the risk of species extinction as certain areas produce only female turtles [25].

Plants

Climate change, through atmospheric carbon dioxide level, temperature, sea level, rainfall, weeds, and pests or microbes, impacts plants.

Plant survival is affected [26-28]. The increased temperature promotes pest proliferation. The invasion of farmlands by salty water, the wildfires, and the droughts lead to destruction of forests (Figure 5). Plant growth, blooming, pollination, and fructification are impacted [29-31]. With shorter winters and warmer springs, plants bloom earlier for a shorter period and die younger. Insufficient chilling affects the productivity of fruit trees leading to less fruits, smaller fruits, and changes in color, texture, and taste of fruits [29,30]. The absence of synchrony between plants and pollinators due to shift in seasons and the decrease in the number of pollinators cause a reduction in the production of fruits.



Figure 5: Climate change increases the frequency and intensity of wildfires resulting in destruction of forests.

Adaptation and Prevention for Climate Change

Adaptation to deleterious consequences of climate change and prevention of aggravation of climate change are key actions [1-3,5,15,17-20,28,30,32].

Adaptation (spontaneous or planned) protects people from higher temperatures, rising in sea levels, more acidic oceans, more dangerous hurricanes, and heavier rainstorms. Personalized adaptive strategies should be implemented, especially in the vulnerable populations. This requires coordinated international policy.

Prevention (long-term strategies) is an important approach. It is urgent to reduce the greenhouse gas emissions as soon as possible. Low-carbon energy technologies, policies to reduce fossil fuel burning, forest preservation, and reforestation should be promoted. Carbon sequestration, by capturing and storing atmospheric carbon dioxide, can decrease the amount of carbon

dioxide in the atmosphere and reduce climate change. Alternative energies from sun, wind, and waves for more energy-efficient homes and vehicles are needed. Societies should promote use of public transportation, cycling, walking, and consumption of plant-based meals.

To avoid irreversible damages, IPCC recommended to keep the global warming below 1.5°C. In some countries, there are important political lobbying denying the contribution of humans to climate change and creating political barrier to pro-environmental policies. All United Nations countries negotiated the Paris Agreement in 2015 that aimed to keep global warming well below 2.0°C, preferably to 1.5°C [33]. One hundred ninety-seven countries (including the USA) signed the treaty. In 2017, the USA under Trump administration decided to withdraw from the Paris Agreement but in 2021, the Biden administration rejoined the Paris Agreement. Since the Paris Agreement was signed, there have been several signs of progress. The world started to shift away from fossil fuels to clean energy and the projected temperature rise by the end of the century has fallen.

Cost of Climate Change

Climate change has a very high cost for the society and significantly affects the economic growth of each country. According to AccuWeather estimates, the economic impact of hurricane Katrina was around \$320 billion (costliest hurricane) and the damage caused by hurricane Ida may cost up to \$95 billion (7th costliest hurricane). The cost of California wildfires of 2017 and 2018 was more than \$40 billion. It is estimated that by 2090, the cost of climate change for the USA economy can reach hundreds of billions of dollars a year.

Action against climate change (e.g., adaptive and preventive strategies) requires significant financial investments but inaction is more expensive. According to October 2019 data from the World Bank, the world will need to make significant investment in infrastructure over the next 15 years (around \$90 trillion by 2030). It is essential that industrialized countries fulfil their commitment by providing \$100 billion a year to developing countries so they can adapt and implement greener economies. It is estimated that shifting to a green economy can generate a direct economic gain of \$26 trillion through 2030 with over 65 million new green jobs.

Future of Life on Planet Earth with Climate Change

Climate change is a serious threat for our planet. It significantly affects the viability of many plant and animal species, and human health. Climate change may become one of the major drivers of species extinction in the 21st century. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reports found that biodiversity is declining in every region of the world, endangering economies,

livelihoods, food security, and quality of life. In the words of the IPBES chair, “the time for action was yesterday or the day before”.

According to experts, we have approximately a decade to keep carbon dioxide from reaching catastrophic levels that can cause irreversible damages. Without efficient preventive action, by the year 2050, 15 to 37% of existing plant and animal species may become extinct, and by the year 2100, half of all species may experience extinction.

Conclusion

Climate change is widespread, rapid, and intensifying. The most important cause of climate change is related to human activities over the past century through increased greenhouse gas emissions. Energy, industry, transport, buildings, agriculture, and land use are the main emitters. Climate change is affecting every aspect of life and is recognized as a serious threat to ecosystem, biodiversity, and health. Climate change is a pressing issue that needs to be addressed.

All nations, big or small, should work together to fight climate change. Adaptation to health consequences of climate change and prevention of aggravation of climate change are key challenges for the society. The health sector should promote research, education, and information on climate change and its consequences.

Adaptation requires multiple measures at various levels. Personalized adaptive strategies, especially in the vulnerable populations, should be implemented. Climate change impacts can be mitigated by reducing greenhouse gas emissions and by enhancing the capacity of Earth’s land surface to absorb greenhouse gases from the atmosphere. Long-term investment in renewable energy and energy efficiency is urgently needed.

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