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Chapter

Impact of Climate Change on Life

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Abstract

Climate is changing in an accelerating pace. Climate change occurs as a result of an imbalance between incoming and outgoing radiation in the atmosphere. The global mean temperatures may increase up to 5.4°C by 2100. Climate change is mainly caused by humans, especially through increased greenhouse gas emissions. Climate change is recognized as a serious threat to ecosystem, biodiversity, and health. It is associated with alterations in the physical environment of the planet Earth. Climate change affects life around the globe. It impacts plants and animals, with consequences for the survival of the species. In humans, climate change has multiple deleterious consequences. Climate change creates water and food insecurity, increased morbidity/mortality, and population movement. Vulnerable populations (e.g., children, elderly, indigenous, and poor) are disproportionately affected. Personalized adaptation to the consequences of climate change and preventive measures are key challenges for the society. Policymakers must implement the appropriate strategies, especially in the vulnerable populations.

Keywords: climate change, global warming, ecosystem, animal survival, human health, vulnerable populations, adaptation, prevention

1. Introduction

Climate change has always happened on Earth but its rapid rate and important magnitude occurring now are of great concern. Climate change occurs as a result of an imbalance between incoming and outgoing radiation in the atmosphere. The global warming associated with climate change is different from past warming in its rate. It is anticipated that there will be a rise in global mean temperatures of up to 5.4°C by 2100. There is overwhelming evidence showing that human activities have contributed to climate change over the past century while changes in solar activity and volcanic eruptions have played a minor role. Over the last several decades, humans have engaged in large-scale transformation of natural systems causing a net accumulation of carbon dioxide in the atmosphere [1–5].

Climate change is recognized as a serious threat to ecosystem, biodiversity, and health. It is associated with alterations in the physical environment of the planet Earth and affects life around the globe [1–37].

Adaptation to the consequences of climate change and prevention of aggravation of climate change are key challenges for the society. Policymakers must implement personalized strategies, especially in the vulnerable populations [1, 2, 5, 30–32, 35–37].

2. Climate

Climate, from Ancient Greek “*klima*” (meaning inclination), is defined as the weather averaged over a long period (the standard period is 30 years).

The instrumental record of climate change is based on thousands of temperature and precipitation recording stations around the world.

3. Climate change versus global warming

Climate change and global warming are often used interchangeably but have distinct meanings and refer to different physical phenomena. Climate change includes warming and side effects of warming (e.g., heavy precipitation and increased wind speeds) while global warming refers only to long-term Earth's rising global mean surface temperature.

4. Climate change causes

Climate change occurs as a result of an imbalance between incoming and outgoing radiation in the atmosphere. The increase in heat-trapping greenhouse gases (e.g., carbon dioxide, methane, and nitrous oxide) in the atmosphere raises Earth's mean surface temperature. The levels of greenhouse gases are higher now than at any time in the last 800,000 years. As temperature increases, more water evaporates from the oceans and other water sources into the atmosphere, causing further increase of the temperature [1–5].

Atmospheric carbon dioxide comes from 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. The top 5 countries responsible for emissions of carbon dioxide are China, United States of America (USA), India, Russia, and Japan [4]. In 2017, the USA emitted approximately 5.1 billion metric tons of energy-related carbon dioxide for a global worldwide emission of approximately 32.5 billion metric tons. Deforestation of the Amazon in Brazil (loss of the equivalent of almost one million soccer fields of forest cover each year), mainly for agricultural purposes, is significantly contributing to climate change.

5. Climate change consequences

Climate change causes a cascade of side effects for the physical environment of the planet Earth and the living organisms on the globe (**Figure 1**). All the changes in the physical planet Earth's environment affect the life of plants, animals, and humans. Coral reefs, forests, and coastal human communities are particularly vulnerable to climate change. Some of the effects of climate change may be through the enhancement of the susceptibility to chemical pollution [1–37].

Although most impacts of climate change are likely to be adverse, some health benefits may result in some regions. For example, warmer winters may reduce the number of temperature-related health events and death.



Figure 1.
Climate change causes global changes of the planet (Picture downloaded from the internet “Google Images”).

5.1 Physical planet Earth’s environment

According to the core accretion theory, planet Earth formed around 4.54 billion years ago (approximately one-third the age of the universe) by accretion from the solar nebula [38].

Planet Earth has faced climate change throughout its long history. The current climate change has multiple negative impacts on the physical planet Earth’s environment. It affects the frequency and severity of extreme events and natural disasters [1, 4, 6–13, 19].

5.1.1 Temperature

Temperature records from modern thermometers (with temperature scales) have been available only since early 18th century. By studying indirect parameters (chemical and structural signatures), scientists can infer past temperatures.

At the creation of the universe, the temperature of the universe at 10^{-35} second old was around 1 octillion°C. Within less than 2 minutes, the universe temperature cooled down to around 1 billion°C. Over at least the last several million years, planet Earth shifted between ice ages facing long cold periods (glacial) and warm periods (interglacial), on 100,000-year cycles.

The current climate change is associated with increased Earth’s temperature (land surfaces and upper layers of the ocean) (**Figure 2**) [1, 4]. Land surfaces are heating faster than ocean surfaces. A warmer atmosphere can hold more water vapor, leading to increased overall average precipitation [4]. Over the past 70 years, the Earth’s temperature has increased by approximately 0.7°C [4]. Since 1950, the number of cold days and nights has decreased while the number of warm days and nights has increased. Since 1976, the rate of warming has been greater than at any other time during the last 1,000 years. For any given period, there are extreme temperatures. 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 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, there will be a rise in global mean temperatures of 0.9 to 5.4°C by 2100 [4].



Figure 2.

Climate change is associated with increased Earth's temperature (Picture downloaded from the internet "Google Images").

The rise in global mean temperature is not the same everywhere. There are regional variations in Earth's temperature. Some areas will not even get warmer and may actually get cooler in the short term [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. Greater temperature increases are expected in winter compared to summer and in nighttime versus daytime. Springs occur earlier and winters are milder.

5.1.2 Mountain glaciers and lakes

Climate change causes mountain glaciers to melt and accelerates the rate of ice loss on Earth in Greenland and Antarctica (**Figure 3**). Some glaciers are sites of



Figure 3.

Climate change causes melting of mountain glaciers (Picture downloaded from the internet "Google Images").

powerful sacred and symbolic meanings for local communities (e.g., in the Peruvian Andes, the Nepalese Himalayas, and the Chinese Meili Snow Mountains) [7].

Lakes around the world are freezing less and for a shorter duration. In few decades, thousands of lakes may lose their winter ice cover.

5.1.3 Sea levels

Climate change triggers rise in sea levels. The sea levels rise following either an increase in the volume of the water already in the ocean as water warms and expands or an increase in the mass of the water in the ocean mainly due to melting glaciers [4]. Since 1900, global mean sea level has increased by approximately 0.20 meter [4]. Over the last 25 years, the global mean sea level rose on average by 0.003 meter per year [8]. By 2100, based on different emissions scenarios, sea levels are predicted to rise between 0.40 and 1.50 meters [4]. The sea-level rise will lead to disappearance of some islands and flooding with invasion of cities by water, leading to homelessness and population movement (**Figure 4**).

The salty ocean water will challenge native plants and animals to adapt to the changing conditions. For humans, it causes salination of freshwater supplies and loss of productive farmlands [8]. Low-income countries (e.g., Bangladesh) are particularly impacted.



Figure 4.
Climate change triggers rise in sea levels (Picture downloaded from the internet “Google Images”).

5.1.4 Hurricanes and rainstorms

Climate change promotes more dangerous hurricanes and heavier rainstorms due to warmer ocean water temperature (**Figure 5**) [4, 9]. The proportion of Category 4 and 5 hurricanes has increased at a rate of 25–30% per 1.0°C of global warming [9]. 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 (reports from state and local officials in five states). The 2019 North Atlantic hurricane season had six hurricanes (including three major hurricanes, e.g., Category 3 or higher).



Figure 5.

Climate change promotes more dangerous hurricanes (Picture downloaded from the internet “Google Images”).

5.1.5 Wildfires

Climate change causes more frequent wildfires. The dry, hot weather has increased the intensity and destructiveness of forest fires in several countries (e.g., Brazil, USA, and Australia) (**Figure 6**) [10, 11]. Wildfires can cause deforestation, serious property damage, exposure of large populations to prolonged periods of polluted and toxic air with potential health impacts (e.g., respiratory diseases), and death. Amazon (Brazil) has become more flammable and vulnerable to wildfires during recent droughts [10]. California (USA) has experienced devastating autumn wildfires in recent years [11]; over 100 fatalities were directly attributed to the most destructive and deadliest wildfires that occurred in 2017 and 2018.



Figure 6.

Climate change causes more frequent wildfires (Picture downloaded from the internet “Google Images”).

5.1.6 Droughts

Drought is a complex and multivariate phenomenon influenced by diverse physical and biological processes. Drought is among the most expensive natural disasters. Climate change is responsible for more frequent and severe droughts (especially in subtropical regions), promoting the expansion of deserts (**Figure 7**) [4, 12]. This will lead to misery, hunger, starvation, and population movement.



Figure 7.
Climate change is responsible for more frequent and severe droughts (Picture downloaded from the internet “Google Images”).

5.1.7 Ocean acidity

The ocean provides most of the life-supporting environment on planet Earth. The abundance of carbon dioxide in the atmosphere is causing the surface waters of the oceans to become more acidic as some carbon dioxide dissolves into ocean water forming carbonic acid [4]. Ocean acidification can alter marine ecosystems with damage to coral reefs (source of many benefits for human communities), fish, and other aquatic species [4, 13].

5.2 Plants

Climate change impacts plant phenology. Different climate change components are involved including atmospheric carbon dioxide level, temperature, sea level, rainfall, weeds, and pests or microbes [14–19].

5.2.1 Survival

Plant survival is affected by climate change (**Figure 8**) [14–16]. The increased land surface temperature with the resulting mild winters promoting pest proliferation (e.g., allowing more pine beetles to survive), the invasion of farmlands by salty water, the wildfires, and the droughts compromise life of plants and lead to destruction of forests and damage to human agriculture. According to some reports,



Figure 8.

Climate change challenges plant survival (Picture downloaded from the internet “Google Images”).

agriculture is the most endangered activity adversely affected by climate change. The decreased farming activity will lead to food insecurity.

5.2.2 Blooming, pollination, and fructification

Plant growth, blooming, pollination, and fructification are impacted by climate change [17–19]. With the occurrence of shorter winters and warmer springs, plants bloom earlier for a shorter period and die younger (**Figure 9**). Winter chill is essential for several fruit-producing trees. Insufficient chilling due to climate change can affect the productivity of fruit trees (e.g., less fruits, smaller fruits, and changes in color, texture, and taste of fruits) [17, 18]. Around 75% of the production of seeds and fruits for human consumption depend on pollinators. Pollinators, especially bees, are facing unprecedented challenges for survival. With the lack of synchrony between plants and pollinators due to shift in seasons and the decline in the number of pollinators, the production of fruits is decreasing while the cost is significantly increasing.



Figure 9.

Climate change is responsible for earlier blooming time of plants (Picture downloaded from the internet “Google Images”).

5.3 Animals

Climate change exposes animals to a variety of stressors, influencing metabolic and endocrine functions, with potential consequences for the survival of species [14, 20–28]. With climate change, more animal species are going extinct every year. Approximately 700 mammals and birds are impacted. The degree of vulnerability varies by the type of animal and different species will be affected in different ways. Species with low tolerance for rising temperature are vulnerable to extinction. The vulnerable/endangered animals include polar bears, koalas, elephants, sea turtles, cheetahs, panda bears, and penguins (non-exhaustive list).

Species affected by climate change 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). If unable, they may perish and become extinct.

5.3.1 Habitat

Climate change can cause habitat degradation or loss for several species (e.g., polar bears, koalas, and birds). Polar bears are dependent on sea ice. The increased temperature is causing the arctic sea ice to melt, damaging the polar bears' habitat (**Figure 10**) [23]. Koalas are dependent on eucalyptus tree. The increased temperature and drought are causing wildfire, destroying the koalas' habitat [24]. Lake Urmia (Iran) is a bird habitat and used to be a popular tourist destination. The lake is drying up mainly because of climate change.



Figure 10.
Climate change causes loss of habitat for polar bear (Picture downloaded from the internet “Google Images”).

5.3.2 Nutrition

Survival of species can be affected by water/food availability/quality beyond those that species can tolerate. Unpredictability/shortage of water and food caused by climate change may lead to greater prevalence of torpor and hibernation in small mammals and hypometabolism in large mammals.

Polar bears will have trouble finding food as the sea ice thins and melts earlier. With limited food supply, the polar bears rely on their stored fat. They have to swim longer distances in the water and many young cubs die because of their inability to swim. Koalas' main food source is eucalyptus leaves. Each koala eats

approximately 1 kg of eucalyptus leaves per day. Climate change reduces the amount of water in the eucalyptus tree. The increased carbon dioxide level causes decrease protein levels in the tree affecting plant nutritional quality. All these changes create dehydration, malnutrition, and starvation. Koalas are risking their lives by climbing down from their trees in search of water and food. This leaves them vulnerable to predators and the risk of being hit by cars. Koalas' population has declined by more than 30% over their last three generations (**Figure 11**) [24]. Elephants require 150–300 liters of water per day for drinking in addition to the amount needed for bathing and playing. Droughts can cause population decline (**Figure 12**) [25].



Figure 11.

Climate change is responsible for dehydration and malnutrition of koala (Picture downloaded from the internet “Google Images”).



Figure 12.

Climate change causes decline in elephant population (Picture downloaded from the internet “Google Images”).

5.3.3 Migration, breeding, and gender determination

Warmer springs have promoted advanced timing of migration and breeding in most avian species in the last decades (**Figure 13**) [26]. Rising sea levels threaten the sea turtle eggs as most turtles lay their eggs on beaches. Climate change can affect sex determination in several animals [27, 28]. The sex of the sea turtles is determined by the nest temperatures. Cool temperatures produce more males while warm temperatures produce more females. Climate change alters the sea turtles' gender population (females outnumbering males). Certain areas could end up producing only female turtles, with the possibility of local species extinction since there will be no mating partners for female turtles (**Figure 14**).



Figure 13.
Climate change promotes early avian migration (Picture downloaded from the internet “Google Images”).



Figure 14.
Climate change leads to female sea turtle overpopulation and domination (Picture downloaded from the internet “Google Images”).

5.4 Humans

Climate change is a major threat to human existence. It has multiple deleterious health consequences leading to increased morbidity and mortality [1–3, 5, 8, 29–37].

5.4.1 Temperature

The human core temperature averages 37.0°C and is tightly controlled within a range of 33.2°C and 38.2°C to ensure optimal physiological function. Extreme deviations from the normal core temperature, i.e., a decrease below 27.0°C (hypothermia) or an increase above 42.0°C (hyperthermia) can be fatal [5]. Climate change is resulting in increased exposures to intense heat in many parts of the world. With increase temperature, there are physiological reactions in humans creating risks for some organs and exposing individuals to increased morbidity and mortality (e.g., reduced performance and work productivity, behavioral changes, heat exhaustion, heat stroke, respiratory failure, myocardial infarction, stroke, and death) (**Figure 15**) [5, 29–31]. The reduced work productivity (up to 10% in some hot areas) has large economic consequences. 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. In the USA, the annual heat-related death is approximately 1,500. The European heat wave during the summer of 2003 caused as many as 70,000 deaths.

On the upside, increased temperatures by allowing milder winters can lower the incidence and mortality of some winter-related events such as myocardial infarction and stroke. Also, hotter and drier conditions can reduce the incidence of some infectious diseases (e.g., malaria).



Figure 15.

Climate change through heat wave can cause increased morbidity and mortality (Picture downloaded from the internet “Google Images”).

5.4.2 Nutrition

Climate change creates water and food insecurity/shortage with significant impact on hygiene, nutrition, and food safety in several countries (**Figure 16**) [1, 8, 32, 33]. In the absence of proper desalination of drinking water impacted by increased salinity following sea-level rise (especially in low-income countries

like Bangladesh), the high exposure to salt through drinking water, food, and bathing can lead to several health problems (e.g., hypertension and skin diseases) [8]. In many regions, food production systems are negatively impacted by climate change [1]. According to the International Rice Research Institute in the Philippines, 1.0°C rise in night-time temperature can reduce rice yields by 10%. With the ocean temperature rise, several fish populations may move to higher latitudes, affecting dietary protein supplies of millions of people.



Figure 16.
Climate change can create human undernutrition (Picture downloaded from the internet “Google Images”).

5.4.3 Infection

Climate change through variations in temperature, precipitation/humidity, wind, and solar radiation influences the spread of some infectious diseases since these variations may impact the survival, reproduction, and distribution of disease pathogens and vectors/hosts as well as their transmission environment. Several infectious diseases are involved including malaria, dengue, and Lyme disease (**Figure 17**) [3, 34].



Figure 17.
Climate change favors spread of infectious diseases (Picture downloaded from the internet “Google Images”).

5.4.4 Population movement

Climate change by creating unsuitable living conditions (e.g., desertification, sea-level rise, decline in freshwater availability, food shortage, health issues) will move many people (forced displacement, planned resettlement, migration). Poor communities are particularly impacted by the human movement. It is estimated that by 2050, up to several hundred million persons will be moved (**Figure 18**) [32]. Population movement will expose countries to multiple challenges (e.g., social, health, and financial consequences and violent conflicts).



Figure 18.

Climate change causes population movement (Picture downloaded from the internet “Google Images”).

5.4.5 Vulnerable populations

Overall, children, elderly, indigenous groups, poor individuals, outdoor workers, remote populations, and subjects with pre-existing conditions are disproportionately affected by climate change (**Figure 19**) [1, 2, 5, 30–32, 35–37].

Low-income and geographically vulnerable countries (e.g., Bangladesh) are most affected by the health consequences of climate change (at least in its earlier stages). However, in higher-income countries (e.g., USA), there is also a high



Figure 19.

Climate change disproportionately impacts vulnerable populations (Picture downloaded from the internet “Google Images”).

vulnerability in some ethnic and socio-economic groups as demonstrated by the Chicago heatwave of 1995 and the New Orleans hurricane Katrina of 2005. According to the World Health Organization, the global mortality in 2004 as a result of climate change was around 141,000 of which 85% were children. The mortality of the European heat wave of 2003 affected mainly the elderly.

6. Climate change adaptation in animals

Adaptive evolution of phenotypes to climate change has been the subject of several investigations [26, 39].

Animals react to climate change in three ways: to move, to adapt, or to die. Moving to a new territory is not always a simple solution and can create new challenges (e.g., interaction with unfamiliar species and more competition for food).

Some animals can adapt to changing conditions. An interesting example of adaptation to climate change is the case of polar bears. With the change in climate, polar bears who usually used seal pubs and other marine mammals as food, have started hunting animals available on land (e.g., snow geese and caribou). However, there is no proof that the change in diet can support the polar bear population in the long run. Another example of adaptation to climate change is with migrating birds. As spring arrives earlier, insects emerge earlier. Some migrating birds are laying their eggs earlier to match insect availability for their young.

7. Climate change adaptive and preventive strategies

Adaptation to deleterious consequences of climate change and prevention of aggravation of climate change are important components of the global response of the society [1–3, 5, 16, 18, 31, 32, 35–37, 40].

Adaptation (spontaneous or planned) is especially important in developing countries. Policymakers must implement personalized adaptive strategies, especially in the vulnerable populations. The risk control to population health cannot be implemented efficiently at the local level alone. It requires coordinated international policy. Human beings rely on biodiversity and functioning ecosystems for water, food, and health. If other species are unable to adapt to climate change, the consequences for humans could be extremely serious. Adaptive strategies require investment and skills. Society needs to implement strategies to help wildlife adapt to the impacts of climate change (e.g., wildlife overpass and drinking stations). Identification of traits contributing to resilience and vulnerability of species will allow the development of efficient conservation action plans.

Prevention (long-term strategies) is a key approach. To spare species and protect humans, the greenhouse gas emissions should be reduced as soon as possible. If we drastically reduce greenhouse gas emissions, our climate may reach a new and potentially acceptable equilibrium. Development and deployment of 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. More energy-efficient homes and vehicles using alternative energies from sun, wind, and waves are needed. Increased use of public transportation, cycling, and walking should be promoted. It is also helpful if humans could reduce the consumption of animal-based food (red meat) and switch to plant-based diet (fruits and vegetables). This type of dietary change can have multiple health, environmental, and economic benefits.

Numerous countries work together under the umbrella of the United Nations Framework Convention on Climate Change. The recommendation of the IPCC is to keep the global warming below 1.5°C to avoid irreversible damages. Unfortunately, in some countries, extensive political lobbying denying the contribution of humans to climate change and creating political barrier to pro-environmental policies has emerged. In 2015, all United Nations countries negotiated the Paris Agreement aiming to keep global warming well below 2.0°C [41]. Almost all countries signed the treaty. However, in 2017, the USA decided to withdraw from the Paris Agreement.

8. Climate change cost

Climate change, through its multiple consequences, has a very high cost for the society and significantly affects the economic growth.

The estimates of total direct damage of hurricane Katrina were up to \$125 billion and the cost of California wildfires of 2017 and 2018 exceeded \$40 billion. It is estimated that the cost of climate change for USA economy can reach hundreds of billions of dollars a year by 2090.

Adaptive and preventive strategies need important financial investments. The cost of halting global warming and reducing greenhouse gas emission to very low levels by 2050 will be around \$50 trillion. At the current greenhouse gas emission rate, the budget for keeping the global warming below 1.5°C would be exhausted by 2028.

9. Climate change and future of life on planet Earth

Climate change is a serious threat for our planet. The number of relatively undisturbed ecosystems is decreasing rapidly. Climate change seriously 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) releases regular reports on biodiversity written by hundreds of experts from all regions of the world. The 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 scientists, we have approximately a decade to keep carbon dioxide from reaching catastrophic levels that can cause irreversible damages. If no efficient preventive action is undertaken, by the year 2050, 15 to 37% of existing plant and animal species are predicted to become extinct and by the year 2100, half of all species may experience extinction.

10. Conclusions

It is widely accepted that the climate is changing in an accelerating pace. Climate change is affecting every aspect of life. It is recognized as a serious threat to ecosystem, biodiversity, and health.

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 (for health personnel), and information (for public and policymakers) on climate change and its consequences.

Adaptation requires multiple measures at various levels. Policymakers must implement personalized adaptive strategies, especially in the vulnerable populations.

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.

Conflict of interest

The author declares no conflict of interest.

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