

HUMAN ACTIVITIES AND CLIMATE CHANGE: A REVIEW ASSESSING THE IMPACT ON GLOBAL BIODIVERSITY AND ECOSYSTEM RESILIENCE

***Anosike, Joy Chizoba and Obiudu Kenneth**

Department of Chemical Sciences, Godfrey Okoye University, Enugu, Nigeria.

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Abstract: Human activities and climate change are significantly impacting on global biodiversity and ecosystem resilience. The natural world is facing unprecedented threats, including habitat destruction, pollution, overexploitation of resources, and climate change. These impacts are having far-reaching consequences on ecosystems worldwide, leading to species extinction, ecosystem disruption, and loss of ecosystem services. Biodiversity is essential for maintaining healthy and resilient ecosystems. Ecosystems provide a range of services, including clean air and water, soil formation, and climate regulation, which are essential for human well-being. However, human activities and climate change are driving biodiversity loss and ecosystem disruption at an unprecedented rate. This review aims at assessing the effects of habitat destruction, pollution, overexploitation of resources, and climate change on ecosystems worldwide. Consequences of these impacts on species extinction, ecosystem disruption, and the loss of ecosystem services will be examined. The findings of this review will provide insights into the complex relationships between human activities, climate change, and biodiversity loss, and will inform strategies for mitigating these impacts and promoting sustainable ecosystem management. It will also provide recommendations for policymakers and practitioners on how to promote sustainable ecosystem management and plausible means of mitigating the impacts of human activities and climate change on biodiversity and ecosystems.

Keywords: Biodiversity, Ecosystem, Climate change, Natural disasters, Species extinction

Introduction

Climate change has been defined as long-term changes in local, global or regional temperature and weather resulting from human activities. For 1000s of years, the nexus between life forms and the weather have been in a delicate balance conducive for the existence of all life forms on this Planet. After the industrial revolution (1850) this balance is gradually declining and the change has become apparent from the middle of the twentieth century. And thus this has become a major threat to the wellbeing of humans and

the sustainability of biodiversity. Major indicators of climate change include average global temperature, extreme and unpredictable weather. And these have now acquired the importance of global emergency. Human-induced climate change, according to the report of the latest Intergovernmental Panel for Climate Change (AR6 Climate Change 2021), is prevalent now and appears to be unprecedented at least in the last 2000 years, intensifying its effect across the regional globe. In this review the causes of climate change, its impact on human wellbeing and

biodiversity, and mitigation measures deployed at global level are briefly reviewed.

Causes of climate change

Green-house gases emission

Human activities increasingly cause steady increase of emission of greenhouse gases (GHGs) which is a cause of climate change. The major greenhouse gases are carbon dioxide (76%), methane (16%), and to a limited extent nitrous oxide (2%). Until recent decades, atmospheric temperature was maintained within a reasonable range as some of the sunlight that hits the earth was reflected back into the space while the rest converts to heat that keeps the earth and the atmosphere warm enough for the sustenance of life forms (Zattara and Aizen 2021). Combined accumulation of greenhouse gases and water vapour forms a transparent layer in the atmosphere that traps infrared radiation (net heat energy) emitted from the Earth's surface and reradiates it back to Earth's surface, thus contributing to the increasing temperature (greenhouse effect). Comparatively, Methane is 25 times and nitrous oxide 300 times more potent than CO₂ in trapping heat. Countries like US, UK, European Union, Canada, Australia, Japan and Russia were the major CO₂ producers and were responsible for 61% of world's emissions. However, in the recent times, China generates the maximum amount of CO₂ (27%) followed by USA (11%) and India (6.6%); on per capita basis, with India ranking ninth (Beckman et al. 2020).

The emission of GHGs is to large extent due to the Burning of fossil fuels (coal, oil and natural gas) for automobiles and industries which produces carbon emissions during their extraction as well as consumption. Atmospheric concentration of CO₂ by before the advent of the industrial revolution is estimated to be around 280 ppm and now it has

increased to 412 ppm (as of 2019). Increase in the atmospheric temperature also leads to an increase in the temperature of the ocean. The oceans, in turn, play a vital role in the global carbon, absorbing about 25% of the carbon dioxide emitted by human activities. Further, some CO₂ dissolves in the ocean water, releasing carbonic acid which increases the acidity of the sea water. Rising ocean temperatures and acidification reduce their capacity to act as carbon sinks as well as affect ocean ecosystems and the populations that rely on them.

Increasing demand for meat and dairy product has led to a significant increase in livestock population and conversion of enormous amount of the land to pasture and farm land to raise livestock. Large amounts of methane are produced by ruminant animals (largely cows, buffaloes and sheep) which invariably adds to the greenhouse gases in the atmosphere (Sejiyan et al. 2016). More so, anaerobic fermentation of livestock manure also generates methane.

Microbial activities are the major sources of nitrous oxide released to the atmosphere (60%) upon their infestation on nitrogen-based organic material from uncultivated soil and waste water (Leeming, 2021). Human activities through agro-related activities particularly agriculture provides the remaining nitrous oxide deposit; deployment of nitrogen-based fertilizers to crop plants is a routine practice to increase yield; many of the farmers tend to apply more than the required amount. This ultimately leads to emission of nitrous oxide emissions from the soil through nitrification and denitrification processes aided by microbes. Similarly, synthetic and organic fertilizers increase nitrogen availability in the soil for microbial action resulting in release of nitrous oxide. Organic fertilizers, however, release nitrogen more slowly than synthetic ones so that most of it gets

absorbed by the plants as they become available (Lenzen et al. 2012). Synthetic fertilizers release nitrogen rapidly which cannot be used by plants right away, thus making the excess nitrogen available to microbes to convert to nitrous oxide. Presently CO₂ concentration in the atmosphere is higher than at any time in at least 2 million years, and methane and nitrous oxide are higher than at any time in the last 800,000 years (AR6 Climate Change 2021).

Rampant in the arctic regions of Siberia, Canada, Greenland, Alaska, and Tibetan plateau is Permafrost (permanently frozen soil), containing large quantities of organic carbon in the top soil leftover from dead plants which has propensity to decompose or rot away due to the cold. Global warming-induced thawing of permafrost initiates decomposition of this material by microbes thus releasing additional amount of carbon dioxide and methane to the atmosphere.

Deforestation

In the early part of human civilization, deforestation appeared to be as a result of subsistence farming with farmers mowing down trees for purposes of growing crops for consumption of their families and local population. In preindustrial era also, a considerable balance existed between the amount of CO₂ emitted through various processes and the amount absorbed by the plants. Forests are the main sinks of atmospheric CO₂. After the industrial revolution, the trend began to change; increasing proportion of deforestation is being driven by the demands of urbanization, industrial activities and large-scale agriculture. A new satellite map has indicated that field crops have been extended to one million additional km² of land over the last two decades and about half of this newly extended land has replaced forests and other ecosystems (Potapov et al., 2021).

In recent decades the demands on forest to grow plantation crops such as oil palm, coffee, tea and rubber, and for cattle ranching and mining have increased enormously thus reducing the forest cover. According to the World Wildlife Fund (WWF), over 43 million hectares of forest was lost between 2004 and 2017 out of 377 million hectares monitored around the world (Pacheco et al., 2021). Amazon Rain Forest is the largest tropical rain forest of the world and covers over 5 million km². It is undergoing extensive degradation and has reached its zenith in recent years. Report by National Geographic revealed that about 17% of Amazon rain forest has been destroyed over the past 50 years and is increasing in recent years; during the last 1 year it has lost over 10,000 km². In most of the countries the forest cover is less than 33%, considered necessary. For example, India's forest and tree cover is only about 24.56% of the geographical area (Indian State Forest Report 2019).

Impacts of climate change

Increase in atmospheric temperature has serious impact on biodiversity and ecosystems, and human wellbeing. The most important evidences of climate change is the long term data available on the CO₂ levels, global temperature and weather patterns. The impacts of climate change in the coming decades are evidenced on published models on the basis of the analysis of the available data. Comparative analysis of the performance of climate models published between 1970 and 2007 in projecting global mean surface temperature and associated changes with actual observations have shown that the models were consistent in predicting global warming in the years after publication (Hausfather et al., 2019). This correlation between predicted models and actual data points to the fact that the models are indeed reliable in

accurately predicting the global warming and its impacts on weather pattern in the coming decades and their consequences on biodiversity and human welfare.

Weather pattern and natural disasters

Extreme and unpredictable weather, coupled with increase in the frequency and intensity of natural disasters are major changes observed in recent years. Brazil's south central region saw one of the worst droughts in 2021 with the result many major reservoirs reached < 20% capacity, seriously affecting farming and energy generation (Getirana et al., 2021). In earlier decades, it was possible to predict with reasonable certainty annual weather pattern including the beginning and ending of monsoon rains; farmers could plan sowing periods of their crops in harmony with the prevailing weather. Now the weather pattern is changing almost every year and the farmers are suffering huge losses. Similarly the extent of annual rainfall and the locations associated with heavy and scanty rainfall appears not to be predictable with certainty. Many areas which were associated with scanty rainfall have started getting much heavier rains and the extent of rainfall is getting reduced in areas traditionally associated with heavy rainfall. Similarly the period and the extent of snowfall in temperate regions have also become highly variable.

Increase in the frequency and intensity of natural disasters such as floods and droughts, cyclones, hurricanes and typhoons, and wildfires have become very obvious. Japan, Philippines, Germany, Madagascar and India were among the top five countries affected by climate change in 2021. And this came in with death of a large number of humans and other animals, and to say the least, economic losses suffered by both urban and rural populations have been enormous. Deadly floods and landslides during

2020 rendered about 12 million people homeless in India, Nepal and Bangladesh. World Meteorological Organization's comprehensive report published in August 2021 (WMO-No.1267), revealed that climate change related disasters have increased by a factor of five over the last 50 years; although, the number of deaths and economic losses were reduced to 2 million and US\$ 3.64 trillion respectively, due to improved warning and disaster management. More than 91% of these deaths happened in developing countries. Largest human losses were brought about by droughts, storms, floods and extreme temperatures. The report highlights that the number of weather, climate and water-extremes will become more frequent and severe as a result of climate change.

Global warming elicits the drying of organic matter in forests, thus increasing the risks of wildfires. Wildfires have become rampant, with Western United States, Southern Europe and Australia heavily invaded by this. They have become frequent in India also and some sub-Sahara African countries. European Space Agency, has before now reported that fire affected an estimated four million km² of Earth's land each year. Wildfires also release large amounts of carbon dioxide, carbon monoxide, and fine particulate matter into the atmosphere causing air pollution and consequent health problems. In 2021, wildfires around the world, emitted 1.76 billion tonnes of carbon (European Union's Copernicus Atmospheric Monitoring Service). In Australia, more than a billion native animals reported to have been killed during 2020 fires, and some species and ecosystems may never recover (OXFAM International 2021).

Sea level rise

Global warming contributes to rising of sea level rise in two ways. On one hand, the melting of the glaciers,

the polar ice cap and the Atlantic ice shelf are adding water to the ocean and on the other hand the volume of the ocean is expanding as the water warms. Incomplete combustion of fossil fuels, biofuels and biomass releases tiny particles of carbon ($< 2.5 \mu\text{m}$), referred to as black carbon. While suspended in the air, black carbon particles absorb sun's heat 1000s of times more effectively than CO_2 thus contributing to global warming (Sodhi and Ehrlich 2010). Upon deposition of black particles on snow, glaciers or ice caps, they enhance their melting further adding to the rise in sea level. Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years. Between 2006 and 2016, it been reported that the rate of sea-level rise was 2.5 times faster than it was for almost the whole of the twentieth century (OXFAM International 2021). Precise data gathered from satellite radar measurements reveal an accelerating rise of 7.5 cm from 1993 to 2017, an average of 31 mm per decade (WCRP Global Sea Level Budget Group 2018).

Snow is known to accounts for almost all current precipitation in the Arctic region. However, it continues to warm four times faster than the rest of the world as the melting ice uncovers darker land or ocean beneath, which absorbs more sunlight causing more heating. The latest projections indicate more rapid warming and sea ice loss in the Arctic region by the end of the century than predicted in previous projections (McCrystall et al. 2021). It also indicates that the transition from snow to rain-dominated Arctic in the summer and autumn is likely to occur decades earlier than estimated. In fact this transition has already begun; rain fell at Greenland's highest summit (3216 m) on 14 August 2021 for several hours for the first time on record and air temperature remained

above freezing for about 9 h (National Snow and Ice Sheet Centre Today, August 18, 2021).

Researchers Have warned that rapid melting and deterioration of one of western Antarctica's biggest glaciers, roughly the size of Florida, Thwaites (often called as Doomsday Glacier), could lead to ice shelf's complete collapse in just a few years (annual meeting of the American Geophysical Union, 13 December 2021). It holds enough water to raise sea level over 65 cm. Thwaites glacier which is holding the entire West Antarctic ice sheet is facing undermining from underneath by warm water linked to the climate change. Melting of Thwaites could eventually lead to the loss of the entire West Antarctic Ice Sheet, which locks up 3.3 m of global sea level rise (Voosen 2021). If this happens, its consequences on human tragedy and biodiversity loss are beyond imagination.

The Himalayan mountain range is estimated to hold the world's third largest amount of glacier ice after Arctic and Antarctic regions. It is considered as Asian water tower (Immerzeel et al. 2020); the melt water from the Himalayan glaciers provide the source of fresh water to nearly 2 billion people living along the mountain valleys and lowlands around the Himalayas. These glaciers are melting at unprecedented rates. Recently King et al. (2021) studied 79 glaciers close to Mt. Everest by analysing mass-change measurements from satellite archives and reported that the rate of ice loss from glaciers consistently increased since the early 1960s. This loss is likely to increase in the coming years due to further warming. In another study, a tenfold acceleration in ice loss was observed across the Himalayas than the average rate in recent decades over the past centuries (Lee et al. 2021). Melting of glaciers also results in drying up of perennial rivers in summer leading to the water scarcity for billions of humans and animals, and food

and energy production downstream. See level rise and melting of glaciers feeding the rivers could lead to migration of huge population, creating additional problems. Even when the increase in global temperature rise is limited to 1.5 °C (discussed later), it generates a global sea-level rise between 1.7 and 3.2 feet by 2100. If it increases to 2 °C, the result could be more catastrophic leading to the submergence of a large number of islands, and flooding and submergence of vast coastal areas, saltwater intrusion into surface waters and groundwater, and increased soil erosion. A number of islands of Maldives for example, would get submerged as 80% of its land area is located less than one meter above the sea level. The biodiversity in such islands and coastal areas becomes extinct. China, Vietnam, Fiji, Japan, Indonesia, India and Bangladesh are considered to be the most at risk. Sundarbans National Park (UNESCO world heritage Site), the world's largest Mangrove Forest spread over 140,000 hectares across India and Bangladesh, is the habitat for Royal Bengal Tiger and several other animal species. The area has already lost 12% of its shoreline in the last four decades by rising sea level; it is likely to be completely submerged. Jakarta in Indonesia is the fastest sinking city in the world; the city has already sunk 2.5 m in the last 10 years and by 2050, most of it would be submerged. In Europe also, about three quarters of all cities will be affected by rising sea levels, especially in the Netherlands, Spain, Belgium, Greece and Italy. The entire city of Venice may get submerged (Anonymous 2018). In USA, New York City and Miami would be particularly vulnerable.

Crop productivity and human health

Many studies have shown that climate change is driving increasing losses in crop productivity (Zhu et al. 2021). The models on global yield loss for wheat,

maize and rice indicate a rise in yield losses by 10 to 25% per degree Celsius warming (Deutsch et al. 2018). Bras et al. (2021) reported that heat-wave and drought roughly tripled crop losses over the last 50 years, from -2.2% (1964–1990) to -7.3% (1991–2015). Overall, the loss in crop production from climate-driven abiotic stresses may exceed US\$ 170 billion year⁻¹ and shows a major threat to global food security (Razaq et al. 2021). Analysis of annual field trials of common wheat in California from 1985 to 2019 (35 years), during which the global atmospheric CO₂ concentration increased by 19%, showed that the yield decreased by 13% (Bloom and Plant 2021). Apart from crop yield, climate change is reported to result in the decline of nutritional value of food grains (Jagermeyr et al. 2021). For instance, rising atmospheric CO₂ concentration reduces the amounts of proteins, minerals and vitamins in rice (Zhu et al. 2018). This may be true in other cereal crops also. As rice supplies 25% of all global calories, this would greatly affect the food and nutritional security of predominantly rice growing countries. Climate change would also increase the prevalence of insect pests adding to the yield loss of crops. The prevailing floods and droughts also affect food production significantly. Global warming also affects crop productivity through its impact on pollinators. Insect pollinators contribute to crop production in 75% of the leading food crops (Rader et al. 2013). Climate change contributes significantly to the decline in density and diversity of pollinators (Shivanna 2020; Shivanna et al. 2020). Under high as well as low temperatures, bees spend less time in foraging (Heinrich 1979) adding additional constraints to pollination efficiency of crop species.

The IPCC Third Assessment Report (Climate change 2001: The scientific basis – IPCC) resolved that the

poorest countries would be hardest hit with reductions in crop yields in most tropical and sub-tropical regions due to increased temperature, decreased water availability and new or changed insect pest incidence. Both rising ocean temperatures and ocean acidification affect marine ecosystems. Loss of fish habitats is modifying the distribution and productivity of both marine and freshwater species thus affecting the sustainability of fisheries and populations dependent on them (Salvatteci, 2022).

Air pollution is considered as the critical environmental risk of climate change because its impact on public health resulting in increasing morbidity and mortality (Manisalidis 2020). Key indicators such as particulate matter, carbon monoxide, nitrogen oxide, and sulphur dioxide are the major air pollutants. Not only do they cause respiratory problems such as asthma and bronchiolitis and lung cancer, recent studies have shown that exposure to air pollution is linked to methylation of immunoregulatory genes, altered immune cell profiles and increased blood pressure in children (Prunicki et al. 2021). In another study wildfire smoke has been reported to be more deleterious to humans than automobiles emissions (Aquilera et al. 2021). Stubble burning (intentional incineration of stubbles by farmers after crop harvest) appears to be a common practice in some parts of South Asia particularly in India; it emits large amount of toxic gases such as carbon monoxide and methane and elicits serious damage to the environment and health (Abdurrahman et al. 2020). It equally affects soil fertility by destroying the nutrients and microbes of the soil. Attempts are on gear to use alternative methods to circumvent this practice.

Diseases such as zika fever, dengue and chikungunya are spread by Aedes mosquitoes and are now largely

limited to the monsoon season. Global warming supports their transmission in time and space thus exposing new populations and regions for extended period to these diseases. Lyme disease caused by a bacterium is transmitted through the bite of the infected blacklegged ticks. A common disease in the US, Lyme disease has tripled in the past two decades. Recent studies have suggested that variable winter conditions due to climate change could increase tick's activity thus increasing the infections (Pennisi, 2022).

Biodiversity

In nature, biodiversity and associated ecoservices are the minimum requirements for human livelihood and for sustenance of ecological balance. Record keeping of biodiversity, and its accelerating loss and urgent need for its conservation have become the main worry for humanity since several decades (Wilson and Peter 1988; Wilson 2016; Heywood 2017; IPBES 2019; Genes and Dirzo 2021; Shivanna and Sanjappa 2021). Analysis of loss of biodiversity exclusively due to climate change is difficult as other human-induced environmental changes such as habitat loss and degradation, overexploitation of bioresources and introduction of alien species also interact with climate change and affect biodiversity and ecosystems. In recent decades there has been a massive loss of biodiversity leading to initiation of the sixth mass extinction crisis due to human-induced environmental changes (Raven 2020).

Measures for Mitigation of Climate Change

Measures aimed at mitigating climate change are multifaceted; they development of systemic framework to reduce greenhouse gas emission, circumvention of deforestation, and increase in the forest cover., extensive use of coal and fossil fuels should be controlled in other to reduce greenhouse gas emission. As climate change is a global challenge,

local solutions confined to one or a few countries will be insufficient; global efforts are highly solicited. Several attempts are being made to achieve these objectives at the global level since many decades (Soroye et al. 2020). Mitigation strategies are largely at the level of diplomatic negotiations involving states and international organizations, Governments and some nongovernmental organizations. The Intergovernmental Panel on Climate Change (IPCC) was put together by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988. The purpose was to provide political leaders with periodic scientific assessments concerning climate change, its implications and risks, and also to put forward adaptation and mitigation strategies (Shivanna 2020). By 1992 more than 1700 World scientists, including the majority of living Nobel laureates gave the first Warning to Humanity about climate change and accompanying problems. They expressed concern about potential damage to the Planet Earth by human-induced environmental changes such as climate change, continued human population growth, forest loss, biodiversity loss and ozone depletion. Conference of Parties (COP) of the UN Convention on Climate Change was equally established in 1992 under the United Nations Framework Convention on Climate Change (UNFCCC) to discuss global response to climate change. Its first meeting (COP 1) was held in Berlin in March 1995 and is being held every year since then. The Fifth Assessment Report of the IPCC, released in November 2014, predicted an increase in the mean global temperature of 3.7 to 4.8 °C by 2100, relative to preindustrial levels (1850), in the absence of new policies to mitigate climate change; it highlighted that such an increase would have serious consequences. This prediction

compelled the participating countries at the COP 21 held in Paris in December 2015 to negotiate effective ways and means of reducing carbon emissions. In this meeting the goal to limit global warming to well below 2 °C, preferably to 1.5 °C, compared to preindustrial levels was accepted by 196 participating countries as a legally binding treaty on climate change. It also agreed for a review of progress every 5 years and the development of a fund containing \$100 billion by 2020, which would be replenished annually, to help developing countries to adopt non-greenhouse-gas-producing technologies (Wagner, 2020).

In 2017, after 25 years after the first warning, 15,354 world scientists from 184 countries posited a 'second warning to humanity'. They insisted that with the except for stabilization of stratospheric ozone layer, humanity will be faced with insufficient progress in solving these environmental challenges, and alarmingly, most of them would be worse off (Ripple et al. 2017). Analysis of Warren et al. (2018) on a global scale on the effects of climate change on the distribution of insects, vertebrates and plants revealed that even with 2 °C temperature increase, approximately 18% of insects, 16% of plants and 8% of vertebrates species are expected to lose >50% geographic range; this falls to 6% for insects, 8% for plants and 4% for vertebrates when temperature increase is reduced to 1.5 °C.

UN Report on climate change (prepared by >90 authors from 40 countries after examining 6000 scientific publications) released in October 2018 in South Korea also gave serious warning to the world. Some of the salient features of this report were: Overshooting 1.5 °C will be disastrous, with damaging effects on ecosystems, communities and economies. By 2040 there could be global food

shortages, the inundation of coastal cities and an unprecedented refugee crisis.

Even 1.5 °C warming would rise sea levels by 26–77 cm by 2100; 2 °C would add another 10 cm which would affect another 10 million people living in coastal regions. Coral reefs are projected to decline 70–90% even at 1.5 °C. At 2 °C, 99% of the reefs would be ravaged. Storms, floods, droughts and forest fires would increase in intensity and frequency. The world has already warmed by about 1 °C since preindustrial times and we are currently heading for about 3–4 °C of warming by 2100. Unless rapid and deep reductions in CO₂ and other greenhouse gas emissions occur in the coming decades, achieving the goals of the 2015 Paris Agreement will be beyond reach.

To keep 1.5 °C target, coal's share of global electricity generation must be cut from the present 37% to no more than 2% by 2050. Renewable power must be greatly expanded. Net CO₂ emissions must come down by 45% (from 2010 levels) by 2030 and reach net zero (emissions of greenhouse gases no more than the amount removed from the atmosphere) around 2050.

The afore-mentioned report sensitized the world Governments about the seriousness of the climate change. The COP 26 meeting which was to be held in 2020 had to be postponed due to Covid-19 pandemic. The first part of the sixth report of IPCC was released in August 2021 (AR6 Climate Change 2021), just before the postponed COP 26 meeting was to be held; it highlighted that the threshold warming of 1.5 °C (the target of keeping the warming by the end of the century) would reach in the next 20 years itself and if the present trends continue, it would reach 2.7 °C by the end of the century (Negrutiu et al. 2020). Under this predicted climate emergency, COP 26 meeting

was held in Glasgow, Scotland between October 31 and November 12, 2021. Nearly 200 countries participated in this meeting. The main aim of the COP 26 was finalization of the rules and procedures for implementation of the Paris agreement to keep the temperature increase to 1.5 °C. A number of countries including USA and European Union pledged to reach net zero carbon emission by 2050 (Ripple et al. 2020). China pledged to reach net zero emissions by 2060 and India by 2070. India also committed to reduce the use of fossil fuels by 40% by 2030. More than 100 countries committed to reduce worldwide methane emissions by 30% (of 2020 levels) by 2030 and to end deforestation by 2030. The average atmospheric concentration of methane reached a record 1900 ppb in September 2021; it was 1638 ppb in 1983 (US National Oceanic and Atmospheric Administration), highlighting the importance of acting on pledges made at the COP 26.

One of the limitations of COP meetings has been non-adherence of the commitment made by developed countries at Paris meeting to transfer US \$100 billion annually to developing and poor countries to support climate mitigation and loss of damage, through 2025; only Germany, Norway and Sweden are remitting their share. Several experts feel that the adoption of the Glasgow Climate Pact was weaker than expected. According to the assessment of Climate Action Tracker, a non-profit independent global analysis platform, emission reduction commitments by countries still lead to 2.4 °C warming by 2100. However, a positive outcome of the meeting was that it has kept alive the hopes of achieving the 1.5 °C goal by opening the options for further discussion in the coming COP meetings. Apart from implementation of mitigation pledges made by countries, it is also important to pay attention to climate adaptation since

the negative effects of climate change will continue for decades or longer (AR6 Climate Change 2021). Investment in early warning is an important means of climate adaptation, which is lacking in many parts of Africa and Latin America.

Conclusion

Human activities, particularly greenhouse gas emissions, are significantly accelerating climate change, leading to widespread biodiversity loss and diminishing ecosystem resilience through altered habitats, extreme weather, and disrupted natural

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processes. The review highlights an alarming increase in species extinction rates, the destabilization of ecosystems, and a reduced ability of natural systems to provide vital services to human society. Addressing this multifaceted crisis requires integrated approaches, including reducing greenhouse gas emissions, protecting and restoring habitats, implementing sustainable resource management, and fostering research to better predict and adapt to inevitable changes.

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