International Journal of Integrative Research (IJIR)
Vol.1, No.1, 2023: 1-16

Review on the Impacts of Climate Change on Biodiversity

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A R T I C L E I N F O

Keywords: Adaptation Measure, Climate Change, Mitigation Measure, Biodiversity

Received : 4 December
Revised : 18 December
Accepted: 22 January

A B S T R A C T

Climate change is a significant global issue affecting biodiversity, genetics, species, and ecosystems. Therefore, this study was aimed to review the impact of climate change on biodiversity. Climate change affects terrestrial, marine, and freshwater ecosystems, causing ash conditions and affecting terrestrial ecosystems. To reduce climate change impacts, strategies must be developed through mitigation and adaptation measures. Mitigation measures involve reducing fossil fuel use and increasing carbon storage, while adaptation measures aim to adjust climate change's impact. By combining mitigation and adaptation measures, we can combat climate change's detrimental effects on biodiversity.

INTRODUCTION

Recent years have seen a significant increase in public and scholarly interest in global climate change. According to the Intergovernmental Panel on Climate Change (IPCC), one of the most significant elements influencing disaster risk is climate change (IPCC, 2013). Climate Change Adaptation (CCA) is defined by the United Nations Framework Convention on Climate Change (UNFCCC) as the necessary adjustments made in response to changes in social, ecological, and economic systems related to climate change (Ashe et al., 1999). Greenhouse Gases (GHGs) are released into the atmosphere as a result of tremendous industrialization and economic activity, which causes climate change (WWF, 2020); (IPCC, 2023). Global warming is anticipated to continue, with an increase of 5.8 C by 2100 compared to 1.4 C in 1990, as stated in the Intergovernmental Panel on Climate Change (IPCC) report (IPCC, 2023) . The changing climate may have a variety of implications for environmental resources and habitats for biodiversity as a result of rising temperatures (Bhattarai, 2012). According to (Danovaro et al., 2004), the recently accelerating warming trend has already had noticeable and largely negative effects on important resources, including land, animals, and water.

The phrase "biodiversity" is a general one (Moreno & Rodríguez, 2011). The International Union for Conservation of Nature (IUCN) provided one of the most widely used definitions of biodiversity, stating that "biodiversity is the variability among living organisms from all sources, encompassing terrestrial, marine, and other aquatic ecosystems and the ecological networks of which they are a part; this encompasses diversity among species, between species, and of ecosystems" (IUCN, 2010). Climate change has an impact on biodiversity at various scales, from low-lying areas to high mountains and from little rivers to vast oceans. Some species are now extinct, while others are in danger of going extinct. Extinctions have the potential to interfere with basic ecological (Sodhi, et al., 2011). The loss of snow cover, retreating glaciers, melting permafrost, and increasingly catastrophic events like avalanches and landslides are all signs of climate change in alpine ecosystems (Nepal, 2013).

Similar to how biodiversity loss affects human welfare and the global economy, it is one of the most important components of environmental change on a global scale (Martens & Rotmans, 2005). Even though threatened and endangered animals in fragile areas, including the arctic regions and high mountains, have uncertain lives or existences, they are crucial to maintaining the health and balance of the ecosystems. Numerous investigations on these topics can be found in the scientific and climate change literature. At every level in the hierarchy of ecosystem services, biodiversity is crucial. Provisioning, regulating, cultural, and supporting are the four types of ecosystem services that are offered by an ecosystem's functioning, according to the Millennium Ecosystem Assessment (MEA) (Mace et al., 2012). Over 60% of ecosystem services worldwide were either in decline or already in excess, according to the MEA (Mooney et al., 2009) , and it has been suggested that the influence of recent, accelerating climate change is making matters worse. Global processes of biodiversity migration and extinction have also been sparked by recent climate change. According to recent climatic predictions, there will be more ecological change in the ensuing decades (IPCC, 2013). As we have already observed in the past, species behaviours are changing and disrupting at an excessive rate. This process is still going on today, and it may continue in the future.

Objective of the review

The objective of this study was to review the impacts of climate change on biodiversity.

LITERATURE REVIEW

Climate Change

A gradual change in the regular weather patterns that have come to define local, regional, and global climates on Earth is referred to as climate change. The phrase is synonymous with a wide variety of observed impacts that these changes have. Because climate and natural ecosystems are interconnected and dependent on one another, it is one of the most significant global environmental issues affecting all natural ecosystems (Bharali & Khan, 2011). Although it has been hypothesized that higher CO2 levels could boost the efficiency of photosynthesis and water utilization, High temperatures and greenhouse gases, on the other hand, will alter rainfall, evaporation runoff, and soil moisture storage, which will hurt growth and production (Vicente-Serrano et al., 2022). The following circumstances are gradually becoming clearer, and there is mounting evidence on a worldwide scale that recent climatic and atmospheric changes are already having an impact on species physiology, distribution, and phenology (Julia, 2014). Regardless, according to the IPCC criteria, there is "very high confidence" that climate change is already having an influence on biodiversity on a global scale (Parmesan & Yohe, 2003). This means that it is believed that more than 95% of observed changes are primarily attributable to climate change.

METHODOLOGY

Climate Change Mitigation and Adaptation Measures

To address the impact of climate change on biodiversity, there are two basic approaches: reducing greenhouse gas emissions and adapting to the effects. The research on climate change adaptation, which is still in its infancy, focuses on anticipating, coping with, and responding to the effects of both current and future climate change (Stein et al., 2013). The distribution of organisms around the world has undergone significant alterations as a result of human-caused changes to the global environment. Ecosystem processes are affected by these changes in biodiversity, which also affect how resilient ecosystems are to environmental change. This has significant ramifications for the ecological services that humans depend on (Chapin et al., 1998). According to the (Jones, 2002), mitigation is the human-made process of reducing greenhouse gas sources or improving sinks. Similar to this, the definition of climate adaptation is "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" and "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2023).

Climate Change Mitigation Measure

Biodiversity is impacted by mitigation efforts (Omann et al., 2009). Among these efforts are decreasing greenhouse gas emissions by using fewer fossil fuels, reducing land-based emissions by preserving vast pools of carbon already present in ecosystems, and speeding up the rate at which ecosystems are absorbing carbon (Kim, 2004). The temporal and spatial scale of various strategies, such as those involving land use and forestry activities like afforestation, reforestation, and land management practices, as well as those involving the use of renewable energy sources (biomass, wind power, solar power, etc.) instead of fossil fuels, can have positive, neutral, or adverse effects (Omann et al., 2009).

Some of these tactics, such as producing biofuel crops or replacing diverse forests with quickly expanding tree plantations to boost carbon uptake, may result in the loss of biodiversity (Puig, 2007). Taxes on emissions, carbon, and/or energy subsidies in favour of renewable energy sources are other common mitigation measures for lowering the use of fossil fuels or improving sequestration by sinks (Omann et al., 2009). Implementing rules and regulations to limit the use of fossil fuel mitigation measures can be made more successful by adding non-tradable permits (Jones, 2002). Lawful implementation of voluntary agreements, technology, and performance standards, assistance with increasing energy efficiency, and road pricing are some other activities (IPCC, 2023). As a way to prevent dangerous interference with the climate system, mitigation policy actions stabilize or lower atmospheric concentrations of greenhouse gases (GHGs) (Kimmel, 2009). Mitigation strategies may aim to maintain the persistence of the present conditions or make it easier to move toward different states, depending on the desired outcome (Stein et al., 2013). Some of the significant climate change mitigation strategies that help preserve biodiversity have already been discussed above.

RESULTS AND DISCUSSION

The relationship between climate change and biodiversity is well known, and it is especially harmful to all types of biodiversity. Both the effects of climate change on biodiversity and the changes in biodiversity that have an impact on climate change are factors in the interconnectedness of the two crises (Pörtner et al., 2021). Ecosystems are under growing pressure from climate change, which can also intensify the consequences of other pressures such as habitat loss, fragmentation, conversion, overexploitation, invasive alien species, and pollution. According to (Richardson and Poloczanska, 2008) there have been 28,586 significant biological changes in terrestrial ecosystems related to climate change, with species extinctions ranking as the most significant one.

Biodiversity

The term "biodiversity" serves as a catch-all for the breadth of nature's variety or variation within the natural system both in terms of frequency and number. The diversity of plants, animals, and microorganisms, the genes they carry, and the ecosystems they create are frequently used to explain it. The biodiversity we observe today is the product of billions of years of evolution, influenced by both natural forces and, to a greater and greater extent, by human activity. It creates the web of life, of which we are a vital part and wholly reliant (Rawat & Agarwal, 2015).

About 2.1 million species have so far been recognized, mainly tiny animals like insects. Although, according to UNEP estimates, there are 9.0 to 52 million species on Earth, scientists believe that there are about 13 million species (Mora et al., 2011). Genetic variations within each species—such as those between different crop kinds and livestock breeds—are also a part of biodiversity. The distinctiveness of each person and each species is determined by their chromosomes, genes, and DNA, the components of life. The diversity of ecosystems, including those found in deserts, forests, marshes, mountains, lakes, rivers, and agricultural landscapes, is yet another characteristic of biodiversity. Every ecosystem has a community of living things, including humans, who interact with one another as well as the air, water, and soil around them. Thus, there are three main levels of biodiversity:

Genetic diversity: is the variety of genetic material found in each unique organism, including plants, animals, and microorganisms found in populations of a particular species.

The diversity of species, or living things, is referred to as species diversity. It is evaluated using the number of species in a given area is referred to as the area's species richness. The relative numbers of different species are referred to as species abundance.

Ecosystem diversity: refers to the range of biotic populations, habitats, and ecological processes present in the biosphere. On Earth, biodiversity is not dispersed uniformly. It is the most prosperous in the tropics. The highest levels of terrestrial biodiversity are typically found close to the equator which appears to be a result of the region's warm environment and high primary productivity (Gaston, 2000). In all oceans, the mid-latitudinal belt is where marine biodiversity is most prevalent and where sea surface temperature is highest along the shores of the Western Pacific (Rodionov, 1994). According to (Tittensor et al., 2010), there is a latitudinal gradient in species diversity. Biodiversity has been growing throughout time but it is anticipated to slow down in some years, since it tends to congregate in hotspots (Myers et al., 2000).

Impacts of Climate Change on Different Ecosystem Levels

This section discusses the effects of climate change on biotic species in terrestrial, marine, and freshwater systems and correlates their adaptive responses based on studies of pertinent papers on climate change, biodiversity, and ecosystem services. The marine, terrestrial, and freshwater systems are all significantly impacted by climate change and fluctuation. There appears to be a consequence for biodiversity alterations as a result of climate change. As a result, many species' ranges and patterns of distribution alter, as do the quantity, accessibility, and calibre of resources that support human populations (Xu et al., 2009).

This will affect how forests, protected areas, and resources for fish, wildlife, and fisheries are managed and safeguarded. Marine, terrestrial, and freshwater communities are already being impacted by species migration brought on by disturbance and competition from predatory species (Bayden et al., 2011). The populations of iconic wildlife species, including the polar bear (Ursus maritimus), ringed seals (Pusa hispida), great white sharks (Carcharodon carcharias), and blue whales (Balaenoptera musculus), will continue to decline and eventually vanish due to a lack of resources and significant changes in the interactions between sea ice habitat and species (Harley et al., 2006). Urban areas, rural areas, and communities all around the world are already experiencing the effects of human-induced climate change (Bayden et al., 2011).

Millions of people's access to fresh water, hydropower, and mountain snowfall are all at risk due to climate change. Agriculture and food security will be impacted by changes to the climate and precipitation patterns. The most difficult conditions are expected to affect populations that are already at risk from food insecurity and sea level rise. Climate change poses a hazard to human infrastructure in the form of encroaching coasts, strain on the electricity system, and shifting structures as a result of permafrost melting (Parry & Palutikof, 2007).

Impacts of Climate Change on Freshwater Ecosystems

Freshwater ecosystems are being impacted by climate change on both a temperature and water flow regime level. The pattern of flow variability is referred to as the "flow regime." Statistical low and high flows, daily to inter-annual fluctuation, long-term annual and monthly means, and flow timing are some characteristics that determine flow regimes (Däll & Zhang, 2010).

Numerous studies have demonstrated that flow regimes are crucial in determining the biotic composition, structure, function, and diversity within river ecosystems and that changes in river flow (and the ensuing changes in water storage, such as in wetlands) may have a significant effect on freshwater ecosystems (Poff & Zimmerman, 2010). Abiotic aspects of freshwater ecosystems, such as water quality, sediment transport, and water temperature, are also impacted by changes in river flow that have an impact on how well species fare. As a result, analyses of potential freshwater ecosystem changes brought on by altered river flow due to climate change should be included in climate impact assessments (Kernan et al., 2011).

The majority of evaluations of temperature variations' effects on freshwater ecosystems due to climate change (Mace et al., 2012; Pedrono et al., 2016) concentrated on this issue. As a substitute variable for river flows, some people have looked at variations in mean precipitation (Rochard &Lassall, 2009). Changes in water flows were rarely taken into account in assessments. In a review of some publications, (Kundzewicz et al., 2007) discussed the effects of reduced ice jam flooding on the availability of habitat, the effects of a shallower water column on salmon spawning, and the effects of reduced runoff on water bird breeding grounds. These studies dealt with the effects of climate change-induced river flow alterations on freshwater ecosystems. (Scheurer et al., 2009) that climate change-induced increases in river discharge and sediment loads in winter and early spring could be particularly harmful to brown trout reproduction and the development of young life stages. This was part of a review on the impact of climate and land use change on Alpine brown trout. (Erwin, 2009) discussed the difficulties in maintaining and restoring wetlands in the face of climate change, emphasizing the necessity to lessen non-climate stressors and monitor, in particular, invasive species that are favoured by climate change. He cautioned that many wetlands, particularly the drier-end wetlands, might vanish as a result of climate change. (Partridge & Finlayson, 2022) identified semi-arid and arid regions as being particularly vulnerable when assessing the effects of climate change on aquatic birds that depend on inland freshwater systems.

Impacts of Climate Change on Marine Ecosystems

Marine ecosystems are among the largest aquatic ecosystems on earth and are crucial to the general health of both marine and terrestrial environments (Townsend et al., 2003). As a result, they are of utmost significance to the biology of the planet. Furthermore, marine habitats are regarded as being well-resistant to invasive species since they often have a high level of biodiversity. But marine ecosystems are suffering greatly as a result of climate change (Chandravanshi et al., 2019). The possible effects of anthropogenic climate change are a major source of concern for coastal marine environments because of their importance on a worldwide scale (Bayden et al., 2011). According to recent studies, ocean systems are currently being driven toward conditions that have not existed for millions of years, raising the possibility of fundamental and irreversible ecological change (Hoegh-guldberg, 2010). This is due to the rapidly increasing concentration of greenhouse gases in the atmosphere.

Ocean ecosystems are being affected by climate change, which is fundamentally altering them (Harley et al., 2006), despite much uncertainty around the regional and temporal specifics. Global warming has had a significant negative impact on marine ecosystems; it has resulted in habitat loss, the introduction of invasive plant and animal species, warming, acidification, toxins, and a significant amount of fertilizer runoff into the ocean (Mooney et al., 2009). The number of marine species is rapidly falling, as evidenced by several studies included in this study, and this trend has only been going on for the past 20 years. According to research by (Jackson, 2008), changes in climatic variability and weather patterns have contributed to the extinction of 80% of the largest species, including sharks and blue whales; 90% of oysters; 65% of seagrass; and 67% of wetlands in coastal estuaries. In a similar work had been done by (Richardson, and Poloczanska, 2008) who found that the ocean's oligotrophic waters had grown by 6.6 million km2 over the past 20 years as a result of global warming.

Anything that is found on the bottom of a body of water is referred to as "benthic" (Bertness & Ewanchuk, 2002). The animals and plants that reside on the bottom are known as the benthos. According to (Danovaro et al., 2008), benthic systems have a significant role in the photic zone and the regulation of the climate. The top layer of a body of water is known as the photic zone. There is sufficient light for photosynthesis by living things. In the ocean, this region contains about 90% of all living things. However, the main ocean-derived ecosystem services used by humans, such as tourism, fisheries, and nursery habitats, are all at risk due to the adverse consequences of climate change on marine systems (Mooney et al., 2009). The most significant effects of climate change on the oceans are on species that serve as habitats, including corals, sea grass, mangroves, salt marsh grasses, and oysters (Harley et al., 2006). These animals provide a home for millions of other species in marine ecosystems.

For instance, Megabats (Pteropodidae), which spend the daytime in mangroves and fly out at night to hunt in nearby forests, Pied Imperial Pigeons (Ducula sialorrhea), which fly to coastal rainforests during the day to feed, can also find roosting places in mangroves at night (Epstein et al., 2009). Anomaly warm sea temperatures are contributing to a decline in coral reef ecosystems by increasing the frequency of coral bleaching and coral mortality. The outcome of rising temperatures, which have also decreased the diversity and density of coral reef fish and other organisms, is mass coral bleaching and mortality. Along with the slowing of reef accretion caused by the effects of ocean acidification, these impacts are compounded by regional effects like habitat loss and food shortages. By 2050, complex coral reef ecosystems are probably going to become less common (Ateweberhan et al., 2013).

Impacts of Climate Change on Terrestrial Ecosystems

Human activity and climate change have significantly impacted Earth's terrestrial systems. According to research by the Millennium Ecosystem Assessment, human activity has altered approximately 75% of the Mediterranean and temperate forests, while five out of the thirteen biomes examined indicated an average conversion rate of 50% (Mooney et al., 2009). Climate change may make forests more prone to wildfires and drought.

According to predictions, there will be more conversion in the future of tropical and semi-tropical grasslands and forests, which contain a rich diversity of species important for regulating water, storing carbon, providing food and timber, and many other ecosystem services (Harley et al., 2006). Climate change has now had an impact on tundra and boreal forests, which are not suited for agriculture and are consequently not used by humans. Spring leaf emergence and fruit ripening trends changed over 30 years by 2.5 and 2.4 days every decade, respectively. Due to the environment and climate changes, fewer land animals and bird species are present. One in eight species is currently in danger of extinction on a worldwide scale, and approximately 150 bird species have disappeared in the previous 500 years (Mooney et al., 2009). Songbird migration patterns have also been shown to evolve. In a study by (Bonebrake & Mastrandrea, 2010), 78 species of birds were studied over a 46-year evaluation period. While the spring migration was discovered to be earlier, the fall migration appeared unaffected.

As a result of their ecology and evolutionary traits, some species of plants, birds, and mammals have reacted to climate change in different ways than others (Dawson et al., 2011). High-elevation species are shown to be rebuilding community interactions, whereas lowland species are found to be expanding their elevation distribution (Woodward et al., 2010). Terrestrial species can change their distribution if they have high dispersion skills and a wide range of thermal tolerances; however, iconic species are susceptible due to habitat fragmentation and unfavourable climatic conditions (Mooney et al., 2009). Similarly to this, marine ecosystems are also significantly impacted by global climate change (Harley et al., 2006).

Climate Change Adaptation Measure

Discussions about the implications of adaptation efforts are frequently brought up in the literature on biodiversity and climate change (Bonebrake & Mastrandrea, 2010); Dawson et al., 2011). This is in contrast to the success of mitigation measures. By limiting negative effects and maximizing opportunities, adaptation is the process of responding to or tolerating climate change-induced impacts (Njoroge, 2014). To strengthen the resilience of our physical, social, and natural ecosystems, adaptation responses are fundamentally planned or unplanned policy measures (Kimmel, 2009). Actions taken to lessen hazards and take advantage of possibilities related to global climate change are referred to as planned adaptation to climate change (Füssel, 2007). Several national and international authorities, corporations, scientific research institutes, non-governmental organizations, and conservation unions are also making significant efforts to identify the potential threats and opportunities of climate change (Susannah et al., 2013) have suggested important policy approaches for mitigation and adaptation. This is in line with (Njoroge, 2014) view that adaptation is becoming an increasingly important public policy response. Since many species and related ecosystem services depend on them for survival, it is therefore imperative to take urgent action to recognize the hazards of climate change and provide adaptive alternatives to deal with them (Heller & Zavaleta, 2008)

At this time, adaptation is essential since climate change is making the planet's ecosystems and biodiversity more susceptible. The adaptation actions, however, must be properly planned and taken into account, as they call for a multimodal approach (Jones & Phillips, 2009). It is possible to make a broad distinction between measures that implement operational adaptation decisions and actions that frequently entail the development of laws or regulations to increase adaptive capability (Barnett & Adger, 2007). Similarly, taking advantage of a developing set of adaptation principles, techniques, and planning procedures, natural resource managers and policymakers are increasingly incorporating climate considerations into their planning and management (Stein et al., 2013).

Adaptation can be seen from two perspectives: autonomous and designed. Species may be able to adapt to climate change on their own by dispersing to suitable habitats, changing their phenotype through phenotypic plasticity without changing their genotype, and modifying their genetic makeup gradually over several generations (Urban et al., 2007). According to (Toby Kiers et al., 2010), some species will be able to adapt better than others based on generation times, dispersal abilities, and reliance on other species, such as pollinators, hosts for parasites, and symbiosis. Time gaps between the change and the reaction, as well as genetic variation loss, could be further barriers to evolutionary adaptations to climate change (Paterson et al., 2008). It is generally acknowledged that many species and ecosystems won't be able to adapt to climate change naturally over the time scales expected and that deliberate adaptation strategies will be necessary.

As a result, actions for adaptation and conservation management are under pressure to deal with several issues related to climate change, such as how to resolve the conflict between the need for action now and the lack of clarity surrounding the type and scope of climate change in a particular region. According to (Paterson et al., 2008), further complexity factors include possible management consequences, likely reactions of species and ecosystems, and the interaction between various responses. (Stein et al., 2013) note that a large portion of the adaptation work is still grounded in ecological reasoning rather than in-depth research and case studies because there is still only a limited amount of concrete scientific evidence regarding the efficacy of various management strategies for climate change. There is a need for proactive management strategies in the face of these uncertainties that can quickly adapt to new situations and shifting conservation priorities; these will call for institutional coordination, incorporating climate change scenarios into planning, and making efforts to address multiple threats at once (Heller & Zavaleta, 2008).

CONCLUSIONS

Climate change is one of the most serious recent issues in the world. It mostly has an impact on the biodiversity of the world by decreasing the quality of the biodiversity. Not only this, but it can also slow down genetics, species, and ecosystems. Therefore, climate change is the variation of the atmospheric temperature caused by either anthropogenic or natural causes; in this case, the change may increase the atmospheric temperature. Biodiversity refers to the available forms of life on the earth's surface when there is a climate change. They are vulnerable to the ash condition. Climate change can affect different ecosystem levels: especially the terrestrial ecosystem, which should be affected when the temperature rises, and also the marine and freshwater ecosystems, which could also be affected by climate change. However, we need to develop strategies that can reduce the impacts of climate change, especially through mitigation and adaptation measures. In the case of mitigation measures, we can reduce the impact of greenhouse gas emissions simply by reducing fossil fuel use and increasing carbon storage, or carbon sequestration. In adaptation measures, we need to adjust the climate change impact. In this case, the impacts of climate change can be combated by using both mitigation and adaptation measures to reduce the impacts of climate change on biodiversity.

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