Review Article

Effects on Biodiversity in Climate Change Scenario

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Abstract | Climate changes and subsequent loss of biodiversity are threatening human existence. Due to its significance in ecosystem functioning, biodiversity is very important but difficult to replenish and recover when eroded. A severe threat to the anthropological system was the loss of biodiversity that took place over the planet. Climate change has the opposite effect on habitat fragmentation and contributes to the loss of biological diversity at the habitat, genetic, and species levels in a synergistic way. Land and aquatic biodiversity greatly influenced, some species are exhibiting different responses to these changing climatic factors like behavioral, morphological, phenological, reproductive, and genetic changes. After all these responses there are many species that are endangered and extinct. This review illustrates that climate change is a severe environmental concern that is affecting land (plants, soil, microbes, animals, and arthropods) and aquatic biodiversity (waterbodies, phytoplankton, coral reefs, and fishes) drastically.

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1. Introduction

Climate change, a serious global concern, is caused by human activity and poses a variety of hazards to all living things. Increasing anthropogenic activities are responsible for the global warming that has happened during the last five decades. Global warming could have several consequences, including increased temperature, rising atmospheric CO_2 concentrations in the and precipitation (Betts, 2011). There would be an increase in 1.4–5.8°C temperature rise from 1990 to 2100 (Collins *et al*., 2013). In the atmosphere, the carbon level has risen from 280 ppm before the Industrial Revolution to 420 ppm presently, with 900 ppm expected by end of the century (Lindsey, 2020). A considerable increase in CO_2 levels in the atmosphere would have both direct and indirect global climate effects.

Biodiversity is essential for ecosystem structure and function, as well as the wide range of commodities and services derived from natural ecosystems for humankind (Naeem *et al*., 2009; Leadley, 2010). Ecosystem services account for at least 40% of global GDP and 80% of GDP in less-developed countries (Li and Fang, 2014). The loss of biodiversity, ability to function in human society resulting in irreversible alterations of ecosystems, culminating in a worldwide crisis. However, little is known about the functional role of biodiversity in a system. As a result, it is

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critical to learn more about the connections between ecosystem services and biodiversity, as well as how risks to biodiversity from climate change are affecting different ecosystems (Urban *et al*., 2016). Biodiversity is inextricably linked to climate changes it may lead to a sharp increase in extinction rates.

Climate change is already having an impact on biodiversity and will continue to do so in the future. Climate change is among the main direct drivers impacting ecosystems, according to the Millennium Ecosystem Assessment. Changes in distribution, increasing extinction rates, variations in reproductive timings, and changes in the length of growing seasons for plants are all effects of climate change on biodiversity (Dias *et al*., 2018). As a result of these changes and human activity, 83 % of wild mammal biomass and half of plant biomass will become extinct (Behera *et al*., 2021). The effect of climate-driven factors on plants, soil, animals, arthropods, and aquatic biodiversity is briefly discussed in this paper.

1.1 Impact on plant biodiversity

Due to climate change, variations in global vegetation cover occur in the borders of the biomes. Global warming influenced the plant phenology like some species showed the 2-3 days advancement per decade in the time of phonological activities like breeding or flowering, shrinking body sizes an evolution of various life-history traits, and new variants for phenological traits (Franks and Weis, 2008; Sheridan and Bickford, 2011; Vigouroux *et al*., 2011). Drought caused numerous alterations of the characteristics of life history, including a shift to earlier blooming, higher skew of the flowering schedule, and reduced peak flowering by comparing the ancestors with their descendants (Franks and Weis, 2008). In Finland, the timberline increases 200m higher in the Atlantic thermal period. In the future, if the global conditions persist then montane cloud forest will grow at the place of the species-rich tropic alpine vegetation (Mantyka-pringle *et al*., 2012).

Plant stoichiometry is typically driven in opposite directions by increased CO_2 and N availability (Novotny *et al*., 2007), but productivity in the same direction (Luo *et al*., 2006). Increases in nitrogen availability have been shown in several studies to reduce plant diversity (Clark and Tilman, 2008; Hautier *et al*., 2009). Similarly, increased eCO_2 reduces plant diversity (Reich *et al*., 2006). Total 16 grasslands were planted under a long-term (10 years) outdoor experiment in different combinations of elevated N (eN) and ambient N (aN), and ambient CO_2 (aCO_2), and elevated (eCO_2). Results exhibited that 16% for aCO_2, 8% for eCO_2, and eN reduces the richness of the species. As a result, eCO_2 has alleviated the damaging effects on species diversity of N enrichment (Reich, 2009).

The world's agricultural countries are currently dominated by only 150 plants (out of 250,000 known plant species), whereas 12 crops make up 80 percent of world food production (Motley *et al*., 2006). Changes in climate, might cause rapid shifts in species distribution, with some species expanding into new favorable areas and others declining in more hostile environments (Kelly and Goulden, 2008). The impact of climate change on wild cowpea (*Vigna* spp.), potato (*Solanum* spp.), and peanut (*Arachi* spp.) Most of these species are expected to lose over half of their geographic range and become extremely fragmented, with about 16–22% of these going to be extinct (Jarvis *et al*., 2008). The extinction of 64 vascular plants occurs in the Netherlands during the previous years. Direct human impact and change in climate both affect the ecosystem to trigger the species distribution pattern (Van der Putten *et al*., 2010).

1.2 Impact on soil biodiversity

Soil biodiversity is greater than that of the overground biodiversity and is vital for agroecosystem long-term viability. It is made up of microflora (bacteria and fungi), macrofauna (earthworms and termites), microfauna (nematodes and protozoans), and mesofauna (microarthropods like mites and springtails). Soil organisms undertake a number of important tasks, including the decomposing and degradation of plants' litter and nutrient biological processes. The transformation of atmospheric nitrogen into organic form and the remineralization of mineral nitrogen resulting in gaseous nitrogen production. Land use patterns and soil pollutants, especially those caused by N enrichment, modify soil biodiversity in addition to the impact on soil desertification (Pritchard, 2011).

The biodiversity of soil organisms fluctuates by climatic factors like temperature and precipitation, as well as climate-driven changes in plant production and species composition (increasing atmospheric CO_2 and temperature). The microfauna and microflora abundance increased with eCO_2. CO_2 effects differed between field and greenhouse experiments, with the former being less prominent and the latter being more so (Blankinship *et al*., 2011). Soil moisture variations have higher effects on microarthropod communities like changes in precipitation and outcome of warming or eCO_2 (Kardol *et al*., 2011). Rui *et al.* (2015) concluded that a multifactor climate change experiment has led to change in bacterial and fungal abundance and to a higher impact on community composition, precipitation leads to climate change causes and their interactions. According to Bardgett (2011), there is enough evidence to suggest that carbon transfer from roots to soil can mitigate climate change. The content and structure of the soil microbial community has been changed due to eCO_2 concentrartions (Deng *et al*., 2012).

1.3 Impact on animal biodiversity

Climate change has a direct impact on terrestrial animals because it is a primary driver of diversification and extinction processes. The greater cause of species extinction is global warming according to international studies. In this century it is approximated that a 1.5 °C average rise in the temperature causes 20-30% of species at extinction risk (Hannah *et al*., 2002). Not only individual species lost but the ecosystem completely damages with an increase in temperature. Many animals will be threatened when their habitat is disturbed such as iconic animals (Bellard *et al*., 2012).

Temperature changes may cause behavioral responses to climate change, which begin from population to species levels, like range shifts and decrease in population (Beever *et al*., 2017). Changing feeding time, modulating circadian and altering site, hibernation, and migration (McCann *et al*., 2018). More complex evaluations of behavioral changes, such as reproductive, foraging, and phenological changes (Beever *et al*., 2016), are also being provided through research, like rat snake predation increased by rising temperature. Responding to rapid variations in precipitation and temperature, *Canis. simensis* has already extended its geographic distribution to higher elevations (Sintayehu, 2018).

Changes in body size are commonly associated with morphological changes. In North American migratory birds, an increase in summer temperatures has been linked to smaller bodies and longer wings (Weeks *et al*., 2020). Warmer temperatures may increase growth but reduce the body size of ectotherms, the metabolic rate of which is temperature-sensitive (Gardner *et al*., 2011). With comprehensive data on early migration, migratory birds provide unequivocal evidence of earlier breeding (Lany *et al*., 2016), phenological changes (Lehikoinen *et al*., 2019), and respond to shifting precipitation and rising temperatures on birds (DeGregorio *et al*., 2015).

Visser and Both (2005) reported that breeding is year-round for African elephants (*Loxodonta africana*), in dry season subordinate males mate whereas during the wet season dominant males mate. Changes in the severity or duration of wet vs dry seasons change the genetic patterns and relative breeding rates in African elephant populations. This penguin lives most of their life in the Antarctic so known as true Antarctic penguins. Due to an increase in temperature reduction in the quantity of ice occurs in regions of the continent. Their basic food is breeds and krill that are under the sea ice. Reduction of ice means the food shortage of Adelie penguins occurs (Kumar and Chopra, 2009). Increased temperatures can impact livestock's behavior and metabolism (internal body processes), resulting in lower food intake and lower productivity (Thornton *et al*., 2009).

1.4 Impact on arthropod biodiversity

Arthropod populations have been impacted by climate change for a long time. It will have a direct impact on arthropods' growth and development, as well as indirect effects on host plants. While CO_2, on the other side, would have an indirect effect on arthropod herbivores via host plants. The anthropogenic activities identified contribute significantly to regional and global climate change (Houghton *et al*., 2001). Jump and Penuelas (2005) reported that due to climate change, insect species relative abundance fluctuates fast, and species that are unable to cope with the stressors become extinct. Zaller *et al.* (2014) reported that extinction rates are now (100–1000) times higher than they were previously, and daily (45–275) species going extinct. The impact of forecasted rains in Austria is expected to diminish spider abundance -47%, beetles -52%, leaf beetles -64%, cicadas, and leafhoppers -39%, springtails -58%, ground beetles -41 %, lacewings -73%, and true flies -73%, but the snails spp increases +69 % (Zaller *et al*., 2014).

Phenology shifts cause the dispersal of a huge number of Microlepidoptera which is also due to climate change. Arthropod survival, dispersion, development, and population size could all be affected by rising temperatures. Heat can also hasten the loss of metabolic reserves in creatures that hibernate for lengthy periods without eating (David, 2009). Insects with a long life-cycle will more likely be adapted over time for temperature swings, whereas plant pests with a "stop-and-go" temperature development strategy develop faster during periods of favors for the environment. The rise in temperatures improves the growth of insects and causes more generations of agricultural harm, ultimately (Diku and Mucak, 2010). Carlson and Rowe (2009) discovered that scorpions with striped bark scorpions, *Centruroides vittatus*, exhibited significantly faster sprint speeds (defensive repertoire) when the temperature was higher. Males were noticeably quicker than females. Latency was higher, while at lower temperatures the sting rate was lower. Females seem to be able to sting at an exciting rate higher than males. Desiccated Scorpions were able to run more quickly than (hydrated) scorpions due to weight loss (Carlson and Rowe, 2009)

Changes in the phenology of host plant diseases lead to imbalances in insect and tritrophic interactions, hence eCO_2 has an indirect influence on insect groups. The bionomics of insect pests are altered by both warmer weather and increased CO_2 (Carlson and Rowe, 2009). Insects exhibited narcoleptic and behavioral alterations in response to increased CO_2 levels (Ziska and Runion, 2007). When compared to aphids in plants cultivated in aCO_2, high CO_2 levels significantly lowered *Myzus persicae* adult weight (Himanen *et al*., 2008). Changes in crop patterns affect the distribution of arthropods. Major insect pests such as pod borers and cereal borers, as well as sucking pests like aphids and whiteflies, may relocate to milder climates, causing more harm to field and horticulture crops. Host plant resistance, natural enemies, transgenic plants, bio pesticides, and synthetic chemicals will all be less effective as a result of global warming (Sharma, 2010).

1.5 Impact on aquatic biodiversity

An increase in sea level causes a change in the temperature of the ocean which leads to several events. As ocean temperatures rise, oxygen levels drop, potentially reducing fish body size on an average of 14–24% by 2050 (Cheung *et al*., 2013). Rising temperature, changes in ocean acidification, and sea ice cover are responsible for range changes in the arctic marine environment, marine mammals, and arthropods (Mecklenburg *et al*., 2016). Enhanced temperature causes an increase in the level of CO_2 so the ocean becomes more acidic (Hijmans and Graham, 2006). This acidity affects marine organisms especially fish. Marine phytoplankton can respond quickly to environmental changes, which results in a wide range of flowering times (Wasmund *et al*., 2019), as a result, secondary consumers may not match, leading to a change in the food web structure (Wasmund *et al*., 2019).

Many studies have documented changes in fish populations, trophic interactions, recruitment success, and migratory patterns due to climatic factors (Hays *et al*., 2005). Coral reefs are also facing risk due to a decrease in oxygen that causes bleaching and ultimately death of the coral (Bellard *et al*., 2012). Higher warmth causes Zooxanthellae to be expelled, resulting in coral bleaching, leading to the extent that 16% of the corals of the globe have been extinguished (Goldberg and Wilkinson, 2004). Climate change is thought to be threatening the extinction of up to a third of coral species and coral death triggers the extinction of many tropical fish species (Weidel *et al*., 2008).

Climate change affects extreme rainfall patterns, drought, and flooding. That enhances the pressure on the lakes and rivers which provides the water for animals and people (Byg and Salick, 2009). Rising stream temperatures will have a deleterious impact on some harvested species in freshwater systems (Crozier *et al*., 2019). Melting of glaciers in the mountain regions has an impact on the freshwater ecosystem. Himalayan glaciers fall in Asian rivers such as Indus, Mekong, Yangtze, Yellow, and Ganges (Harley, 2011). A great number of people depend on the glaciers for sanitation, hydroelectric power, drinking water, and agriculture.

Conclusions and Recommendations

Climate change has emerged as the decade's most serious environmental issue. It is becoming one of the most serious threats to biodiversity, putting additional pressures on species, genetic resources, and populations. The mitigation strategies include biodiversity protection and sustainable development. Despite the fact that adequate efforts have been made around the world to address environmental concerns, the negative effects of climate change are still growing, and the global rate of biodiversity loss is ongoing. If we take action now to control climate change then we can get many benefits, as well as the reduction in biodiversity, which can be minimized. Continuity in climate change causes a reduction in 50% of animal and plant species which destroy the ecosystem globally. Reducing carbon and greenhouse gas emissions from the energy, industrial and transportation sectors by reducing fuel consumption and increasing the use of renewable/ green energy is receiving a lot of attention. However, as countries seek mitigation and adaptation techniques, natural habitat protection is a critical component of climate change strategies. Strengthened support for protected areas and more sustainable resource management can help with strategy development as well as biological resource and ecosystem protection.

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Novelty Statement

Climate change has emerged as the most significant environmental concern of the decade. It is now one of the most severe biodiversity concerns; putting additional pressure, species extinction, genetic resources, and populations. This review will helpful for formation of mitigation strategies include sustainable development and biodiversity protection.

Author's Contribution

Hasnain Raza, Kaynat Ahmed, Iqra Tariq and Qurat-ul-Ain: Wrote the portion of Plant and Soil Biodiversity of the manuscript.
Huda Bilal, Sana Sarfaraz and Sanaullah: Wrote the Portion of Animal and arthropod Biodiversity.
Maryam Maqsood and Ali Raza: Reviewed this article and gave fruitful suggestions. Hasnain Raza and **Huda Bilal:** Formatted the manuscript according to the journal.

Conflict of interest
The authors have declared no conflict of interest.

Ethical approval
This manuscript does not contain any studies involving human participants and/or animals.

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