Climate Change and its Impact on one Health Triad

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Abstract

Climate change is a pressing global crisis with profound impacts on the environment, human health, and animal well-being. Driven primarily by human activities such as burning fossil fuels and deforestation, it is causing long-term shifts in temperature and weather patterns. These changes are manifesting through rising sea levels, melting glaciers, more extreme weather events, and altered rainfall patterns, threatening ecosystems and biodiversity. The One Health approach, which emphasizes the interconnectedness of human, animal, and environmental health, provides a crucial framework for addressing these complex challenges. Environmental consequences include reduced water availability, declining agricultural productivity, increased pollution, and more frequent natural disasters such as floods and wildfires. Livestock are suffering from heat stress and increased exposure to diseases. Higher temperatures are linked to heat-related illnesses and an increased spread of infectious diseases like malaria, dengue, and zoonoses such as COVID-19. Mental health issues, including trauma and depression, are also rising due to displacement and disaster-related stress. Children and women are especially vulnerable, facing higher risks of physical and psychological harm. Although some regions might benefit from warmer temperatures, the overall consequences are overwhelmingly negative. Addressing these challenges requires urgent, collaborative global action rooted in the One Health perspective.

Keywords: Climate change, Sustainability, Covid-19, Global warming, Temperature, Environment, One Health.

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Introduction

Climate change is a burning issue of recent times that will continue to prevail if not addressed. The World Health Organization (WHO) has termed climate change as one of the biggest threats to global health in the 21st century, with high alert status especially for poor countries near the equator (Marina et al., 2021). According to the United Nations (UN), climate change refers to "the long-term shifts in temperatures and weather patterns". These shifts can be natural, such as any change in the sun's energy, large volcanic eruptions, and a decrease in sea ice. According to a UN report, the average temperature of the Earth's surface at present is elevated by about 1.2°C above what it was in the late 1800s. Increase in the average global temperature, and the frequency of extreme weather events are transforming ecosystems around the world (Ummenhofer et al., 2017). Many plant and animal species are at risk since forests are drying up due to less rainfall and more fires. Climate change is lowering the standard of living by exacerbating impacts on human and animal health (Schuurmans et al., 2021). Human inventions and daily activities are unknowingly damaging nature to a great extent. The increasing levels of greenhouse gas emissions (GHG) and extreme ultraviolet radiation due to the widespread use of fossil fuels, deforestation, overuse of chemical fertilizers, and uncontrolled levels of toxic gases exhaustion from industries are increasing the global average temperature, contributing to the changing climate and weather conditions.

A serious issue of the present times is the increasing temperature of the Earth, which is changing nature and altering the ecosystem, food chain, and most importantly, our environment. It is observed that the Earth's temperature is increasing rapidly (Bosh et al., 2007). As the temperatures of the air and water in our oceans are rising, resulting in the melting of glaciers and ultimately elevating the sea levels and various parts of land near the sea are becoming unavailable for animals and us humans due to an elevation in sea levels. Such increasingly changing climatic conditions are reshaping our environment, where the risk of the spread of unknown diseases is also present (Bonacic et al., 2005).

Taking into account climate change as one of the global suppressors, its impacts on the One Health triad cannot be overlooked. The One Health triad model shows how the health of animals, humans, and the environment is linked to one another. Each element affects and is affected by the others. One Health focuses on disease interactions between wildlife, domestic, environmental, and human health (Clarke et al., 2007). The diseases caused by animals will have an impact on human health, likewise, changes in our surroundings, like pollution and climate change, will affect both animals and humans. The concept of one health has contributed to protecting people, animals, and our environment (Weisheimer et al., 2015). The aim of one health is to improve health and well-being through the prevention of risks and the mitigation of effects of crises that originate at the interface between humans, animals, and their various environments (Figure 1).

One health became a serious topic of discussion after there was an outbreak of severe acute respiratory syndrome, Middle East respiratory syndrome, Ebola, and Zika (Palmer et al., 2005). The spread of such diseases goes uncontrolled with the changing climatic conditions. These diseases have changed human lifestyles immensely. This chapter will thoroughly discuss the impact of climate change on the link between humans, animals, and the environment using a transdisciplinary One Health perspective.

Adverse Effects of Climate Change

Environment

Climate change is a global issue affecting the ecology and socio-political disciplines (Feliciano et al., 2022). With the increase in temperature, diseases, health problems, and normal lifestyle changes are prominent, which appear to continue in the near future (Abbass et al., 2022).

Due to rapid industrialization climate issue has increased drastically (Leppänen et al., 2014). The latest study reveals that the challenges faced by humans due to climate change include less energy, damaged infrastructure, death due to heat, increasing industrial losses, and shortage of food and water (Gasper et al., 2011). Damages to the economy make it very difficult to make ends meet, so, as a result, issues like hunger and poverty increase to a great level. At the same time, different activities of the cities make them more vulnerable to climate change impacts.

By looking at the changing climatic conditions of the world, it is clear that drought has become a major issue, consequently affecting major crops like cotton (Zafar et al., 2022). Drought has always been an enemy for crops, yet how it affects our major crops like maize, along with several cofactors, remains unclear. Recent data from peer publications shows that drought, along with climatic factors, has significantly decreased the yields of cotton and maize. Our food source depends on cereals a lot, whose materials are literally destroyed by drought (Daryanto et al., 2016).

The ozone layer present in the stratosphere acts as a protective shield for the Earth's surface, containing a high concentration of ozone (O). This layer absorbs 94-99% of the sun's harmful ultraviolet (UV) radiation, which could otherwise damage life on Earth (Albritton and Daniel, 1998). The major and most common sources of climate change due to human activities are the emissions of greenhouse gases, particularly CO_2, which is resulting in an increase in atmospheric temperatures (Zafar et al., 2018). The ongoing climatic condition of the Mediterranean Sea has been studied. A key climatic factor here is precipitation. So, a reduction in rainfall can seriously affect human beings. Precipitation, along with increasing temperature, can result in drought (Adger et al., 2005).

The kind of climatic changes that are occurring have the potential to cause irreversible, drastic changes on Earth. This is fully dependent on the type of climatic change that will occur, and these changes have not been calculated so far. A prime example of this is the major slowing of the ocean transportation of warm water in the North Atlantic. If this kind of change continues to occur, it will lead to major concerns (Ahmed et al., 2020). Prime factors to deal with changes and to survive are money, innovations, skills, infrastructure, access to resources, and effective policies. The reach of citizens to these sources varies a lot. Developed countries can overcome these issues somehow or another other but underdeveloped countries will have to suffer a lot (Waqas et al., 2021). Many areas that are under the effect by climate change are also affected by other factors like intense population growth, limited resources, and poverty.

The climate effect on flowing water and underground water differs in different regions, with precipitation as a major factor. The increase in stream flow in Southeast Asia, the decrease in Central Asia, and unknown results in mid latitudes due to the rainfall factor show climatic effects (Hussain et al., 2018). A significant portion of the world population lives in water-stressed areas. The greatest drawback is likely to be the unmanaged water due to false policies and not being able to manage it. Flood threats can increase many times in the future due to precipitation as the main factor. The factors like increased carbon dioxide are no doubt beneficial for plant growth, but overall, other changing climatic conditions seriously affect crops and soil (Leal Filho et al., 2021). Research has revealed that increasing temperature of global temperature will result in a shortening of the food supply in the world due to a lack of ambient temperature for the growth of crops (Battisti et al., 2009).

Changes in climate have led to increased surface levels of ozone, resulting in smog all over plain regions, drastically affecting our daily life activities, and respiratory diseases have become common. Atmospheric pollutants, industrial runoff, and agricultural waste have led to severe climatic conditions. These substances ultimately run off into water, leading to marine pollution, which is a serious issue worldwide affecting marine life (Adger et al., 2005). Sea levels are rising every year many times. The main components of sea rise are glacier melting and thermal expansion. This increase in sea level will cause the intrusion of soil into aquifers. Pollution in marine water is causing increased oxygen consumption by organisms and thus decreasing the salinity oxidation conditions of seas.

Soil moisture is a big factor for crops. It is directly affected by climatic conditions. For example, soil moisture was reduced recently in the northern hemisphere mid-latitude summers. However, soil moisture in local regions is not directly affected by climatic conditions; instead, it largely depends on the quality and characteristics of the soil of that region. Lastly, the effect of human activities on climate and environment varies from year to year and decade to decade. A study shows that in the near future, human activities will have a larger impact on climatic conditions than natural ones, ultimately affecting the environment.

Livestock

Climate change has both direct and indirect effects on animals. Direct effects include changes in the physical surroundings of animal populations, while the indirect effects involve the migration of animals, including aquatic fauna, which leads to changes in the animals' hunting patterns and their competition within the population for survival (Leal Filho et al., 2021). Agriculture and livestock are the most paramount sectors which is affected by climate change. The overall health of an agricultural system and the production of livestock in that agriculture can be influenced significantly by any changes in their climate (Clarke et al., 2007). Furthermore, the demand for livestock is expected to increase twice, particularly for developing countries, and about 70% worldwide (Alexandratos et al., 2012). It is important to increase the production of livestock. There are many mechanisms that can be used to increase the production of livestock. Coping mechanisms can be used for the growth of livestock (Clarke et al., 2007). Coping mechanisms are strategies or techniques used to manage and mitigate stress and adversity. There is a need to educate our farmers about the coping mechanisms. By understanding coping mechanisms, farmers can improve animal welfare, growth, and the ratio of stress-related diseases

Dairy and Meat

It is expected that climate change will have negative effects on animal production, especially in areas where people heavily depend on livestock for a living. Many environmental factors can worsen the already existing issues in the growth and health of livestock, and the production of milk and meat for human consumption. These factors include air, temperature, humidity, and wind speed. Any changes in these

factors can adversely affect animal growth and reproduction (IPCC, 2007). Further, animal products can be affected significantly, that is, milk, meat, and wool production, and the overall quality of these products. Additionally, oxidative stress can also lead to various health problems in animals that not only affect their productivity but also affect their overall health (Lykkesfeldt & Svendsen, 2007).

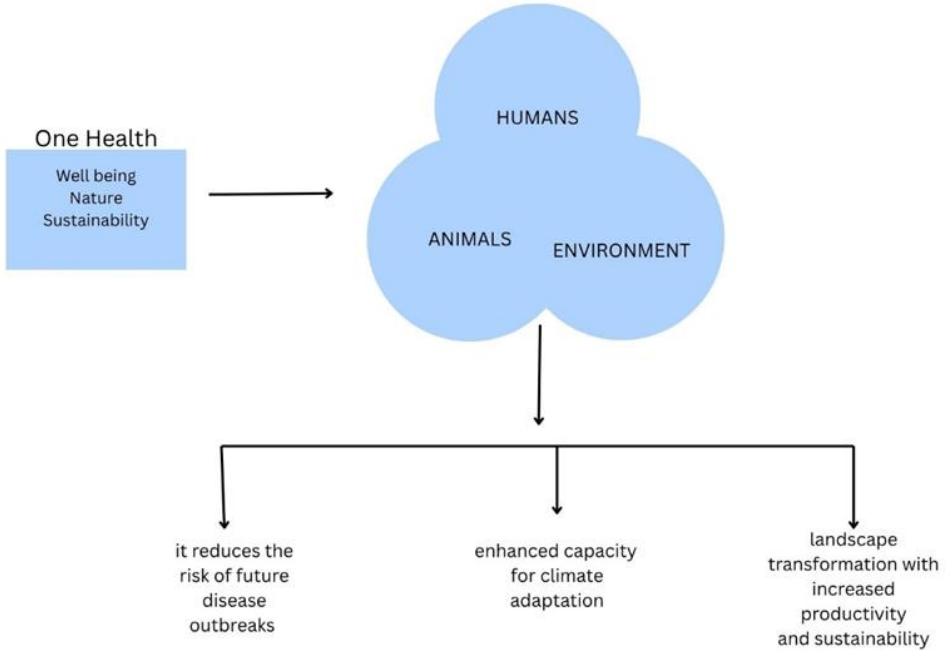

Fig. 1: Impact of One Health model on development achievements

Another negative effect of climate change is a decline in conception rate and thus resulting in less milk production. With this negative impact, the reproduction rate will be influenced, leading to a decline in meat production. Under intensifying changes in climate, vulnerability among animal populations can elevate, increasing the risk of infectious diseases, followed by an increase in the rate of death (Bonacic et al., 2005). It is observed that an increase in temperature and humidity can affect dairy farms. Researchers have shown a direct relation between milk production and temperature-humidity index (THI) (IPCC, 2001). The optimum temperatures for high milk yield of dairy cows range from 5°-15°C. When the temperature rises from 15°C, these animals work to regulate their body heat, and if the temperature exceeds 25°C, it elevates the sweating and animals struggle to maintain a healthy body heat balance (IAEA, 2017). The livestock is directly affected by meteorological conditions that are not suitable for them. The animals that are kept outside and are exposed to the environment directly have a negative effect on their growth parameters, such as weight gain, feed intake, and feed digestion, potentially due to unpleasant weather conditions (Jourdain et al., 2010).

Animal Health

Rising temperature, changing rainfall patterns, and humidity levels are climate changes that can affect the spread of disease-carrying agents. Climate has a direct effect on ectothermic vectors (Arthropods), which are cold-blooded and sensitive to temperature, rainfall patterns, and wind (Bonacic et al., 2005). An increase in temperature can boost the production and growth rate of disease-carrying agents, making the disease transmission more likely. Heat stress and drought will weaken animals' ability to fight diseases (Bonacic et al., 2005). Animals that are already struggling with diseases can become worse due to changes in climate conditions. Diseases that are spread by insects due to change in climate can also be increased because insects are sensitive to changes in the environment. It will cause great risk when the disease spreads in the new population (Walther et al., 2002).

Climate shapes where the animals live, and it influences the plants and animals they depend upon in a shared climate (Kadzere et al., 2002). During extreme weather conditions, there is also an increase in the death rate of animals, unfortunately (Hahn et al., 2002). A study has shown that the animals are more likely to die in the hottest month of the year (Dechow & Goodling, 2008). The risk of death and serious illness increases when the heat waves are extreme. An increase in temperature and humidity can make things worse (McCarthy et al., 2001). Researchers should develop strategies that may help the animals tolerate harsh climate conditions. That results in an increase production of livestock.

Human Health

Climate change and its deteriorating effects on human health have become prevalent over time. Its impact on human health is observed and recorded across countries and on all continents, depending on their geographical positions and exposures to related factors that contribute towards climate change. According to WHO, approximately 250,000 deaths are expected between 2030 and 2050, due to climate change and its resultant impact on human health (Abbass et al., 2022). Health care professionals fear that if immediate steps in mitigating climate change are not taken and considered, human health will suffer significantly.

Many researchers and health-care professionals have reported that certain meteorological factors, such as temperature and humidity, are closely associated with infections and other harmful health outcomes (Rhea et al., 2021). According to the report of the Lancet Countdown on

Health and Climate Change (2022), the environmental changes caused by climate change are also causing a shift in geographic patterns of climate-responsive diseases such as malaria and dengue. Heat can affect health through a variety of direct and indirect mechanisms (Botkin et al., 2007). With the continuous increase in temperature and prolonged exposure to heatwaves, many diseases such as acute kidney injuries, cardiovascular and respiratory diseases have become common. Heat can affect health indirectly by restricting physical activity. With little to no physical activity, the human body can succumb to heat illness and can increase vulnerability to a number of diseases. It is estimated that only a 2°C rise in environmental temperature increases the annual death rate from heatwaves in many countries by approximately twofold, including Africa, South America, and Southeast Asia (McMichael & Lindgren, 2011).

Changing weather patterns influence respiratory diseases. Many known human diseases are found to be exacerbated by Climate Change (Mora et al., 2022), mainly zoonotic diseases that originate in animals and vector-borne diseases, as we all witnessed COVID-19 lately. According to the WHO (2020), zoonotic diseases are infections transmitted from non-human species to humans. Any changes in climate, particularly elevating temperatures, can facilitate the transmission of pathogens from wild animals to humans (Rupasinghe et al., 2022). Other factors that can be involved in accelerating the transmission of zoonotic diseases are deforestation, urban expansion, and habitat loss. These factors lead to changing conditions, which means more animals move towards humans. Climate-related exposures, such as floods and hurricanes, have major impacts on health. A study shows that after Hurricane Laura hit the Gulf coast in 2020, the average number of COVID-19 hospitalizations increased (Tracey et al., 2022). Breathing in tiny airborne pollutants results in high vulnerability to COVID-19 (Pozzer et al., 2020). Areas that experienced extreme drought and lack of access to clean water showed greater COVID-19 occurrence (Rodriguez-Lonebear et al., 2020). Figure 2 below shows that climate change alters the geographic range of diseases and increases the potential for novel pathogens to spread quickly. The intensifying weather conditions and escalating natural disasters have major impacts on the overall well-being of humans.

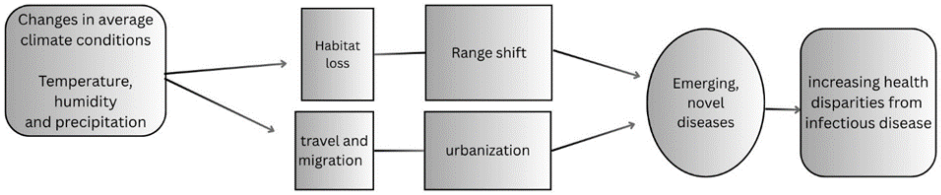

Fig. 2: Climate change exacerbates infectious disease risk and increases health disparities.

Child Health

Although climate change affects all communities indiscriminately, children are the most vulnerable due to their unique behavior patterns, developing organ systems, and physiology (Samantha et al., 2023). Young adults and children residing in low-lying areas are prone to natural disasters such as floods. The possible harms from hurricanes and floods include fractures, puncture wounds from projectile objects, drownings, and poisonings**.** Exertional heat illness (EHI) affects young athletes and children more often as they adjust more slowly to changes in air temperature (Zachary et al., 2020). Exertional heat illnesses cause thousands of devastating health outcomes annually. Due to exposure to such disasters, children experience signs of mental trauma, post-traumatic stress disorder (PTSD), anxiety, etc. Moreover, child malnutrition is often seen due to changing weather patterns. A Survey was carried out in the US, where 1000 children and young people expressed their worry about the changing climate conditions and their impact

Women Health

Gender inequality, coupled with the climate crisis, is one of the greatest challenges of our time. A review of census information on the effects of natural disasters across 141 countries conducted by the WHO showed that although disasters create hardships for everyone, on average, they kill more women than men, or kill women at a younger age than men (Parmesan, 2006). According to the UN Environment, when extreme weather conditions such as floods and hurricanes hit and force people to displace and migrate, 80% of people affected are women and girls experiencing a high risk of violence and poverty. The consequential weather extremes, such as droughts, heat waves, and floods, cause forced migrations, increased rates of gender-based violence, limited availability of clean water, and food insecurity (Afifi et al., 2024). Women suffer more due to limitations in healthcare services. When displaced women are not in their native location, they are less likely to have access to relief aid than the usual residents of the area or country (Michelle et al., 2023). The Drought in Kenya in 2022 has highlighted how women were affected the most by malnutrition and dehydration. The nature of women's physiology makes them highly susceptible. Pregnant women have been found to suffer the most as a result of exposure to heat, poor air quality, and ventilation (Emily et al., 2024). The rising air temperature, air pollution, and heat exposure target the maternal health, complicating pregnancies and causing issues like gestational diabetes. According to UN Women, extreme heat increases the chances of stillbirth, and climate change is increasing the spread of vector-borne illnesses such as malaria, dengue fever, and Zika virus, which are associated with worsening maternal and neonatal outcomes.

Mental Health

Changing weather patterns have taken a toll on the mental health of people. THE forced displacements, migration, and a loss of sense of place or belonging due to the extreme weather conditions have resulted in mental and spiritual harm (Shultz et al., 2019). Through investigations, it is said that climate change is the biggest threat to mental health in the 21st century (Lawrence et al., 2022). Many reports by the American Academy of Pediatrics have found climate change and its resultant increase in heat to have an impact on mental health and disturbed sleeping patterns, with reduced cognitive functions and impaired learning. Those facing the greatest climate impacts, often the least responsible for emissions, are more vulnerable and less resourced to access mental health support, aggravating mental health inequalities. The gap between those who can access mental health support and those who cannot is widening, leading to greater inequity (Donatella et al., 2021).

Studies have shown that rising temperatures correlate with higher suicide rates, increased aggression, and worsening symptoms of psychiatric disorders.

This chapter has thoroughly explained how climate change affects all organisms. The need of the hour is to make policies that work for the mitigation of climate change and the protection of future generations.

Health Risks

Human health is at risk when it comes to changes in climatic conditions. The health risks caused by climate include various types of infectious diseases, poor nutritional quality, lower food yields, and reduced water flow (Coope, 1994). The changing conditions like heatwaves, increased humidity in the air, and polluted air can elevate heat-related deaths and illness episodes in urban areas, mostly targeting elderly people. The areas at risk of increased flooding will cause drowning, more respiratory and diarrheal diseases, leading to malnutrition and hunger in third-world countries (Davis & Zabinski, 1992). In the upcoming decades, the impact of climate change on human health will be more evident. Most commonly spreading diseases are vector-borne. These are mostly transmitted by ticks or insects, and these organisms are sensitive to temperature, humidity, rainfall patterns, and wind. With climate change, they undergo mutations and adaptations that can cause severe diseases to human health (Kovats et al., 2000). These organisms are not static but also change their geographical distribution, causing greater damage to human life (Figure 3) (Huntley 1991). The climate difference is visible in the equatorial and poleward regions, which results in the evolution and adaptation of genes in species.

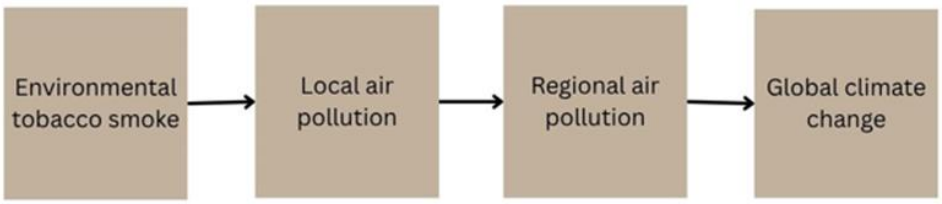

Fig. 3: Pollution in one area spreads eventually to a wider locality and contributes to the overall environmental health

Natural System

Climate change can cause severe weather conditions that disturb the overall habitat. The severe drought or downpour is an effect of a warming climate, and it will set the trend that some areas will experience heavier rainfall than expected scale and some will face drought as overall rainfall decreases (Huber & Gulledge, 2011). In very recent times in Pakistan, i.e., in April 2025, the climatic changes caused a hailstorm including hailstones that damaged the properties and vehicles, therefore disturbing the day routine of citizens. As compared to that, many other cities are deprived of rainfall and facing severe heat waves. The rising temperature is one concern, and the shortage of water reservoirs is another. Water shortage affects agriculture, marine, forestry, human health, and energy (Kiers et al., 2010). One-third of the world's population lives in water-stressed countries. With the increasing population rate, the streamflow and groundwater are expected to decrease. The demand is increasing, but the level of resources is decreasing. Agriculture and food security is also affected by climate change. The increased level of CO_2 is affecting the yield. Another factor that gets damaged and affects yield production is the soil quality. By changes in climate, wildlife, population density, population size, and behaviors of species are also affected. This also affects vegetation and marine life, putting them at risk (Michelle et al., 2023).

The climatic changes are also causing natural disasters like wildfires due to hotter temperatures, longer periods of dry seasons, and lightning storms that ignite fires. Floods are also caused by the rising temperature, which causes the glaciers to melt, raising the sea level. Warmer sea surface temperature, rising sea levels, and slower-moving storms are strongly associated with disasters like hurricanes, cyclones, and typhoons (Afifi et al., 2024).

Future Impacts of Climate Change

Climate change, which used to be a distant theory, has become a factor that is undoubtedly contributing to reshaping the planet with changes in biodiversity and habitats. Climate change is expected to affect biodiversity through natural selection and migration at different stages, starting from an organism to a whole biome level. Migration of the animal populations, including aquatic fauna, reflects the incapacity of the biotic component of our environment against climate change to withstand and function properly. All the living organisms are very responsive to any changes in their climate, and respond in three non-exclusive axes, i.e., time, style, and space. Further, the response of one individual affects the other related individual in a shared environment. For example, climate change caused changes in flowering plants that also affected the insect pollinators, resulting in the disturbance of the plant-pollinator network of a population. The species thus introduces adaptations for survival through various mechanisms.

The species that fail to adapt according to one or all three axes of change undergo extinction either at the local level or the global level. Few of the taxa have become extinct due to climatic changes in the Quaternary period. Over time, due to these changes, we are facing a loss of biodiversity that cannot be overlooked.

Conclusion

Climate change is a concerning issue globally because rising temperatures, gases, wastewater, and pollution are affecting the health of our ecosystem. The risk of the spread of viral diseases becomes high with an elevation in temperatures and pollution. Similarly, the melting of glaciers is also a notable phenomenon observed with increasing temperature. Water scarcity is a global challenge because of climate change. To restore natural resources, and improve agricultural and environmental health and ultimately human health, considerable measures need to be taken at national levels where cutting excessive use of energy use and carbon footprint can help ensure improved One Health.

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