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Environment and climate change: Influence on biodiversity, present scenario, and future prospect

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ABSTRACT

Climate change has become a widespread problem in recent years. It is one of the most important global environmental challenges affecting all the natural ecosystems of the world. Various parameters such as increased CO_2 levels, faster glacier melts, and rainfall variability and severe drought have been associated with climate change. Biodiversity is influenced by climate change in different ways including shifts in ranges, changes in relative abundance within species ranges, and subtler changes in activity timing and microhabitat use. Soil properties and water resources are affected by fast changing climate. All these consequences demand for integrated management approaches, proper planning and designing policies to safeguard the biodiversity and hence environment. The present review describes the effect of changing climate on prokaryotic and eukaryotic communities, environment, and economics, the response of communities to such changes and conservation strategies that could be adopted to respond to these changes.

ARTICLE HIGHLIGHTS

- Changing climate is a global challenge
- It is affecting prokaryotic and eukaryotic biodiversity, environment, and economics
- Conservation and mitigation strategies are of global importance
- Framing policies is important to safeguard biodiversity and environment in present scenario of climate change crisis

1. INTRODUCTION

The super challenges of the 21st century are climate change, energy supply, health and disease invasion, and sustainable environment. The world's climate continues to change at a rate expected to be unprecedented in recent human history. The increase of about 0.6°C in global average surface temperature has been observed during the twentieth-century. In recent years, human activity and natural factors have led to rapid increase in greenhouse gas (GHG) emissions. The influence of emitted GHG on future climate is estimated due to its capability of absorbing available infrared radiation and its persistence in the atmosphere [1]. The effects of global warming are broader which may include arctic shrinkage, glacial retreat, and worldwide sea level rise. The changing precipitation patterns will result in more floods and drought. The changes will also occur in agricultural yields, there may be addition of new trade routes, vast extinction of species and increase in disease vectors range [2].

In fact, the climate change is not only an environmental issue nor is it the only threat to global prosperity rather is a threat multiplier for diverse other urgent concerns including global security, disease and habitat loss. Climate change is unique in its scale and enormous risks it poses. Climate change, if remained unchecked, possibly will redraw the map of the planet. It can create global living conditions beyond

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the range, humanity has ever experienced in history. The influence of climatic change is much broader, such as increased frequency of hypoxic events, storm activity, altered rainfall patterns, and flow regimes of freshwater streams and rivers [3]. There is a discernible global pattern of the effects of climate change on crop productivity, which may have implications for food availability. Climate change may jeopardize the stability of entire food systems. The demand for agricultural products has been estimated to increase with increase in global population, which may require a shift toward sustainable intensification of food systems [4].

Rising concentration of atmospheric carbon dioxide is one of the most critical problems as its effects are globally persistent and irreversible on ecological timescales [5]. The primary direct consequences are increasing ocean temperatures [6]. Rising temperatures create additional changes such as increase in ocean stratification, increasing sea levels, reduced sea ice extent, altered ocean circulation patterns, precipitation and freshwater inflows. Acidification is another direct impact of rising CO_2 concentrations on oceans [7]. Climate change also affects global biodiversity in several ways. Movement is an integral part of ecology of many animals, which can affect the fitness of individuals and population survival by enabling foraging and predation, behavioral interactions, and migration [8]. Migration may also be observed in fishes in search of suitable conditions due to increase in temperature. Arrival and hatching date in migrating birds can be strongly affected by global warming [9]. Numerous changes occur in animals due to rising temperature such as increased respiration, decrease in the efficiency of nutrient utilization, decrease in milk production reproductive performance especially in dairy cows [10]. Climate is a major factor determining plant physiology, distribution, and interactions [11]. There might be changes in phenological phases of plants which will lead to prolonged growing season and affect the plant fitness. Evidences are in favor of global climate change and its consequences on different aspects of environment. There is a greater need to develop conservation strategies to respond to such global challenges. This review deals with the influence of climate change on biodiversity and impact on environment.

2. IMPACT OF CLIMATE CHANGE ON BIODIVERSITY

Climate change is increasingly recognized as the serious and widespread threat to biodiversity. The alterations in the environment which will be brought up by the climatic changes will be too rapid for many species to adapt to, and ultimately lead to extensive extinctions. Climate change may lead to migrations which in turn will affect biological diversity at regional and global scales. Stress on populations of whales, ringed seals, and polar bear will continue as a result of changes in critical sea-ice habitat interactions. Crops will fail more often, especially on land at lower latitudes where food supply is scarce [12]. The changes in occurrence of drought, strong winds, and winter storms will bring massive loss to commercial forestry [13]. The species must adapt, move, or face extinction with climate change.

2.1. Animal Biodiversity

Animals had been already subjected to major shifts in the Earth's climate in the past. Some species perished, while others adapted and thrived. Climate change is already having a negative impact on animal life, and the consequences are likely to be disastrous in the future. Climate change is considered a major threat to the survival of many species in changing ecosystems [14-16]. Many studies have taken into account the economic impact of day by day changing climate on livestock production [17]. In general, a combination of rising temperatures and changing rainfall patterns will certainly affect animal husbandry. Feed is an important constraint for livestock production in the tropics, and will continue to be, and crop productivity is a useful proxy for feed availability in most regions. Crop productivity at mid-to high latitudes may increase slightly for local mean temperature increases while at the lower latitudes, it may decrease for even relatively small local temperature increases. In general climate change may affect the animal agriculture in different ways by influencing livestock [18], nammely, the availability and price of feed grain, quality, and production of forage, reproduction, growth and health, as well as distribution of diseases and pests. These changes can lead to redistribution of livestock in an area. There may be shifts in animal types used for instance change from cattle to buffalo, camels, goats, or sheep; there may be genotype shifts which mean the use of breeds which can well handle adverse conditions. Furthermore, there may be changes in housing of animals [17].

Temperature is likely to become hotter in several places and different species due to their physiological differences will show variations in their susceptibility to changing temperatures [19]. Holstein-Friesian dairy cows are primarily susceptible to heat stress as the ambient temperature exceeds 25°C [20]. The first sign of heat stress is an increase in body temperature and rate of respiration ultimately reducing feed intake and milk output [21,22]. Sheep when exposed to high temperatures, weight loss, decrease of average daily gain, growth rate, and total body solids reflected by impaired reproduction have been observed. When the ambient air temperature is high, appetite decreases and growth of pigs is affected [23]. Further, in such changes, some species of animals may expand their ranges whereas others may move towards the poles or upward in elevation. An example of such a shift is population of red fox in Canada which have been advancing north and, on the other hand, population of Arctic fox has been retreating [24]. High temperatures and precipitation have been known to decline the population of British ring ouzel which is a shy species of thrush with a high chirping call.

The decline in Arctic sea ice have a significant impact on Arctic vertebrate populations including polar bears, seals, and walruses which are adapted to live in sea ice for significant periods of the year [25]. If the sea ice breaks and drifts as a result of polar warming, polar bears will have to move north to find a stable platform. Pregnant females will leave the ice to find their preferred land den area have to swim long distances. In case, the pregnancy of malnourished mothers is successful under sub-optimal habitats, the chances of survival of cubs will be greatly reduced [26].

Climate change has a profound impact on the oceans. The upper ocean is warming [27], potentially affecting invertebrate populations including krill, which are important food sources for whales, seabirds, seals, and penguins [28]. Changes in upper ocean temperatures may alter the range of many species, especially marine mammals. Studies show the expansion in the range of common dolphins common in northwest Scotland which are warmer water species whereas contractions in the range of white-beaked dolphins which are a colder water species [29]. Relatively small changes in temperature alter the metabolism and physiology of fishes, affecting their growth, reproduction, feeding behavior, distribution, migration, and abundance [30].

2.2. Bird Biodiversity

Birds are one of the most studied organisms on the planet, and they serve as an important group of indicators for learning about the effects of climate change. The choice of birds for studying climatic changes offer certain advantages such as they are the most well-known kind of organism for climate studies and second, millions of citizen scientists track birds all over the world, contributing to massive datasets [31]. Bird distribution changes have been well described and linked to climate change [32-34]. The vulnerability of species of tropical birds to climate change in particular has been increasingly recognized [35-37]. The weather not only affects the metabolic rate of the birds (e.g., in cold weather where energy expenditure must increase to maintain the body), but also their behavior directly or indirectly [38]. Climate change has been shown to impact breeding. Extreme weather events, such as prolonged freezing spells and droughts, can have catastrophic effects on bird populations, including long-term effects on entire cohorts [39]. The study of Pied Flycatchers *Ficedula hypoleuca* showed increase in their egg size with warmer springs in Germany and Finland [40]. In Siberia, reproductive success in the planktivorous auklets including crested *Aethia cristatella* and parakeet *Cyclorhynchus psittacula* increases at lower sea-surface temperatures. On the other hand, better reproductive success has been observed in the piscivorous puffins such as horned *Fratercula corniculata* and tufted *Lunda cirrhata* at higher, sea-surface temperatures. Long-term changes in sea-surface temperatures can affect the viability of each species' population in different ways and change the seabird population in that area [41].

Storms and snowpack have a significant impact on the reproductive schedules of birds breeding at high altitudes. Climate change is expected to have an impact on reproduction as well as the entire annual cycle of birds. The species that mainly adjust the annual cycle and multiply according to rainfall, temperature, and food supply will face fewer difficulties as compared to those that coordinate their annual cycle by a rigid Zeitgeber, like photoperiod [42]. Migration in birds is affected by changes in climatic conditions. It is expected that the greater the distance of migration of the species, the more likely one or more aspects of the annual cycle may become mistimed with local weather and food supplies on the summering grounds. An advancement of 14 days over 47 years in the timing of egg laying in *Parus major* population in the United Kingdom due to increased spring temperature has been reported [43].

2.3. Plant Biodiversity

Climate change is also affecting the life cycles and distributions of the world's vegetation. The combination of the changes in air quality and composition and climate are producing new bioclimate for food production systems. There is extensive evidence that plant seasonal biological events have changed in recent decades along with the global climate change [44]. Some medicinal and aromatic plants have begun to flower earlier. In Britain, the first flowering date for approximately 385 plant species advanced by 4.5 days on average over the previous four decades [45]. Temperature range between 45°C and 65°C can cause severe damage and even death of crop plants. For instance, rice is most sensitive to temperature change at anthesis stage. Exposure for few hours at flowering can reduce floral reproduction [46].

In medicinal plants, the damaging effects of climate change may include decrease in availability and most dramatically in the extinction of species [47]. A study reported extinction of about 600 plant species in the past 250 years [48].Valuable medicinal plants are likewise one of those species that experience dramatic phenological change [49]. In addition to endangering population growth, phenological changes may have an impact on the predictable or consistent availability of medicines to those who rely on them [50,51]. The medicinal plants of arid zone may also be at special risk. The nival or subnival species in montane ecosystems are most vulnerable to habitat loss [52], and future climate change is expected to be most severe in northern latitude mountains [53]. Alpine meadows are once again among the most threatened plant communities [54], and they are shrinking due to warming-induced upslope shrub encroachment [55]. It is thought that species growing at the highest altitudes are most vulnerable to extinction because they will have nowhere to go if they are outcompeted by lower elevation species that are now expanding their ranges to higher elevations [56].

In a survey of plant distribution in Arizona mountains local extinction of 15 species of plants including *Muhlenbergia porter, Quercus gambelii* and *Urochloa arizonica*, in comparison with 50 years earlier has been observed [57]. In the alpine Himalayas of Sikkim 75 species of plants, including *Rhododendron nivale*, *Potentilla fruticosa* and *Lepidium capitatum* were observed to be locally extinct in comparison with 1850 [58].

Deserts and arid shrublands are expected to experience the fastest rates of climate change, making compensatory migration difficult [59]. For instance, a significant degradation has been observed in the desert steppe habitat of one of the most widely used wild medicinal plants *Glycyrrhiza uralensis*, attributed to increasing climate change and anthropogenic disturbance [60]. Sea grasses are declining globally at a rate of about 7% per year, and global climate change is expected to have a negative impact on them, posing a pressing challenge for coastal management [61]. Water temperature greatly influences the physiology, growth rates and reproduction in sea grasses and determines their geographic distribution based on their temperature tolerance [62]. The species of tropical sea grasses including *Thalassia testudinu*m and *Syringodium filiforme* in the Gulf of Mexico showed reduction in their productivity when summer temperatures were higher [63]. In an investigation in Australia, the leaf growth rates of *Thalassia hemprichii, Halodule uninervis,* and *Cymodocea rotundata* were reduced at water temperature above 40°C [64].

Warming is occurring quickly in the Arctic [65]. The fluctuations in ranges of temperature and changes in ice covers and snow patterns are affecting the distribution of Arctic vegetation. It has been observed that the changes in climate possibly will affect the chemical constituents and thus the survival of the aromatic and medicinal plants in Arctic. Certain reports have revealed the impact of the temperature fluctuations on bioactive compounds of the plants [66,67].

2.4. Microbial Biodiversity

Microbes inhabiting soil play significant roles in nutrient cycling and protecting plants from environmental stresses [68]. The organisms inhabiting the soil interact with each other and plants in many ways that shape and maintain the ecosystem. Climate change is altering the distribution and diversity of species and at the same time affecting the interactions between organisms [69,70]. Numerous studies have shown that changes in species interactions in response to climate change chain alter biodiversity and function of terrestrial ecosystems [24,71]. There are some reports on soil microbial communities (SMCs) and their diversity and distribution during climatic change [72,73]. Alterations in relative abundance and function of soil communities due to climatic changes has been observed as the members of SMCs vary in their physiology, temperature sensitivity, and growth rates [74,75]. A study observed changes in the relative abundances of soil bacteria and increased the bacterial to fungal ratio of the community due to warming by 5°C [76]. Further, the acceleration in fermentation, methanogenesis and respiration among the microbial communities has also been observed in response to increase in temperature. The microbial community composition (MCCs) of soil constantly changes as they respond to changing resource availability. Certain communities grow quickly and utilize the resources as they are available and some communities adapt and grow slowly and utilize more chemically complex substrates. Guo *et al*. [77] carried out study on climate warming accelerates temporal scaling of grassland soil microbial biodiversity. The study suggested that the strategies of soil biodiversity preservation and ecosystem management may need to be adjusted in a warmer world. The study of Wu *et al*. [78] concluded detrimental effects of biodiversity loss might be more severe in a warmer world. Recently, a study has been conducted to measure the effect of climate change in Antarctic microbial communities. The study proposed that climate change studies in Antarctica should consider descriptive studies, short-term temporary adaptation studies, and long-term adaptive evolution studies and concluded that this will help in understanding and managing the effects of climate change on the Earth [79].

A study investigated the effect of temperature on microbes in dry land soil, boreal, temperate, and tropical soil and response of microbial communities to different temperatures. The study concluded that the rates of respiration per unit biomass were lower in the soils collected from the environments having higher temperature and suggested that thermal adaptation of the microbial communities may lessen positive climate feedbacks [80]. Another study reported increased soil biomass and fungal abundance with higher atmospheric CO_2. The study showed a limited effect on bacterial diversity with higher atmospheric CO_2 [81]. Drought conditions have been shown to influence fungi and bacteria, but fungi are known to be more sensitive than bacteria. It has been observed that during drought fungal growth increases [82].

Another study observed the effects of elevated levels of CO_2 and precipitation on soil microorganisms. The study suggested that bacterial growth was negatively affected whereas fungal biomass was observed to show an increase with increasing precipitation [83]. On the other hand, it has been suggested that global warming increases the abundance of bacteria and fungi and leads to the alteration of the soil food web. The rise in temperature also makes changes in the physiology of decomposing microorganisms also [84]. Climate change is known to favor the growth of cyanobacteria [85]. Many bloom-forming cyanobacteria grow at high temperatures [86]. The growth of *Microcystis* sp. has been observed to increase at elevated CO_2 levels [87]. Generally as the environmental conditions change, the resident microbial communities either adapt, become dormant or die [88].

3. BIODIVERSITY RESPONSES TO CLIMATE CHANGE

Climate change is expected to change the diversity of species, the distribution of human pathogens, and ecosystem services around the world. Estimating these changes and designing suitable management strategies for future ecosystem services will need a predictive model that includes the most basic biological responses. One of the key questions in the debate over climate change's ecological impact is whether species can adapt quickly enough to keep up with the rapid pace of climate change [89,90]. Species can, in theory, change in response to climate change, and changes have already been observed. The species can track and follow suitable conditions in space, which is typically accomplished through dispersion. Spatial movement of species tracking appropriate climatic conditions on a regional scale is the best documented response from palaeontological records and recent observations. Over 1000 species of marine invertebrates, insects, and birds have already shown latitudinal and altitudinal range shifts [91], resulting in a decrease in range size, primarily in mountain top and polar species [92]. Furthermore, in order to keep up with abiotic factors that represent cyclic variation, such as on a daily or yearly basis, species may respond to changes by shifting time from daily to seasonal. A meta-analysis of a wide range of plant and animal species found that the average response to climate change was a shift in key phenological events occurring 5.1 days earlier per decade over the last 50 years [93]. The advancement in flowering by more than 10 days per decade has also been observed in some species [91]. Another approach is species may adapt themselves to the changing climate in their local range. Thus, there are multiple responses of the species to cope up with the changing climatic conditions and unable to adapt to new conditions, the species may go extinct either locally or globally [94].

4. GLOBAL BIODIVERSITY SCENARIO FOR THE YEAR 2100

As a result of numerous human-caused changes in the global environment, global biodiversity is changing at an unprecedented rate [95,96]. Quantitative scenarios are emerging as tools to assess the impact of future socio-economic development pathways on biodiversity and ecosystem services. Global marine, freshwater, and terrestrial biodiversity scenarios are analyzed through different measures including change in the abundance of the species, habitat loss, extinction, and distribution shifts [97]. The risk of species extinction address the irreversible component of biodiversity change [98,99]; however, species extinctions have weak links to ecosystem services and respond less rapidly to global change than other factors. Quantitative global extinction scenarios for freshwater and marine organisms are, however, uncommon. According to one of the proposed models based on the relationship between fish diversity and river discharge, 4–22% extinction of fish by 2070 in about 30% of the world rivers, due to reduced river discharge from climate change and increased water withdrawals [100]. Habitat loss and degradation in terrestrial ecosystems encompass a wide range of human-caused changes in natural and semi-natural ecosystems. The distribution shifts are expected to cause the reorganization of ecosystems, including the establishment of novel communities [96]. Scenarios constantly indicate the decline of the biodiversity over the 21st century. The most important factors identified so far to induce changes in biodiversity at global scale includes the changes in the concentration of carbon dioxide, land use, deposition of nitrogen, and on purpose or accidental introduction of alien animals, plants, and microbes in an ecosystem [101].

5. CONSERVATION OF BIODIVERSITY IN CHANGING CLIMATE

The changing temperature and precipitation patterns are expected to interact with other drivers to influence an array of biological processes and distribution of species. Alarming predictions about the potential consequences of future climate change are prompting policy responses ranging from the local to the global [102]. To date emission of greenhouse gases are driving earth to significant climate change in the coming decades [103]. The annihilation of evolutionary potential, possible loss of biodiversity and disturbance of ecological services must be taken seriously. Many countries have conservation plans for threatened species, but these plans have generally been developed without taking into account the potential impacts of climate change. Climate change is greatly influencing the biodiversity and represents a significant future challenge for biodiversity conservation strategies [94].The interaction between climate and land use provides opportunities for adaptation to climate change that increase the ability of species to adapt [104]. Preventing detrimental consequences for biodiversity requires immediate action and strategic conservation plans for years and decades to come [105]. Integration of different approaches and perspectives is required for more accurate information on which species and habitats, which places and how conservation managers can make the most of natural systems' adaptive capacity. In many cases, existing conservation policies and practices are already encouraging measures to reduce vulnerability to climate change such as restoration or creation that improves the functional connectivity of landscapes and habitat management. The assessment of impact of climate change on biodiversity has been especially based on empirical niche models [106]. These models for most species indicate large geographic displacements and widespread extinction. Assessing the biodiversity consequences of climate change is really a multifaceted issue and all aspects of vulnerability such as adaptive capacity, exposure, and sensitivity must be considered for implementation of conservation strategies [Figure 1] [107].

6. IMPACT OF CLIMATE CHANGE ON ENVIRONMENT

In recent years, extensive efforts have been made to monitor and predict climate change in response to fears of global warming. Attention has been focused on the diverse environments including soil and water, and the imminent socio-economic and environmental consequences of rising global temperatures. The fluctuations in temperature will leave a negative impact on organic matter of soil, and diverse physical and chemical properties of soil. Water resources will be greatly affected under changing climate [Figures 2 and 3].

6.1. Soil Health and Fertility

Healthy soil is the foundation of agriculture and a basic resource for meeting human needs in the twenty-first century. It is a critical component of ecosystems and earth system functions that helps to deliver primary ecosystem services [108]. The most recent report of the intergovernmental panel on climate change point outs the average rise in the global temperature between 1.1 and 6.4°C by 2090–2099. The changes in the climate will have impact on precipitation patters at global level and will alter both the amount of precipitation received and the distribution of precipitation over the course of an average year in many locations [109]. Each of these factors will affect soil which is of major importance for the food security [110-112]. Food security will be threatened through its effects on soil processes and different properties [113].

Soil moisture is another important component of the hydrological cycle that regulates precipitation partitioning between runoff, evapotranspiration, and deep infiltration [114]. Fluctuations in temperature will influence moisture content of the soil which in turn may impact infiltration and runoff amounts and rates [115]. Further, as a link between the biosphere and the edaphic zone, soil water is fundamental requirement for the terrestrial ecosystems which determines plant growth. Water stress occurs when the soil water level falls below a critical species-specific threshold, which will then lead to morphological and physiological disturbances in plants [116].

Soil erosion is another phenomenon experienced in different parts of the world under changing climate. It is one of the major threats to the economy and society affecting agriculture. The most common reason predicted for soil erosion is the change in the erosive power of rainfall and changes in plant biomass [117]. Although soil erosion is a natural and inevitable process, the accelerated rates of soil loss, is really a serious environmental issue. The

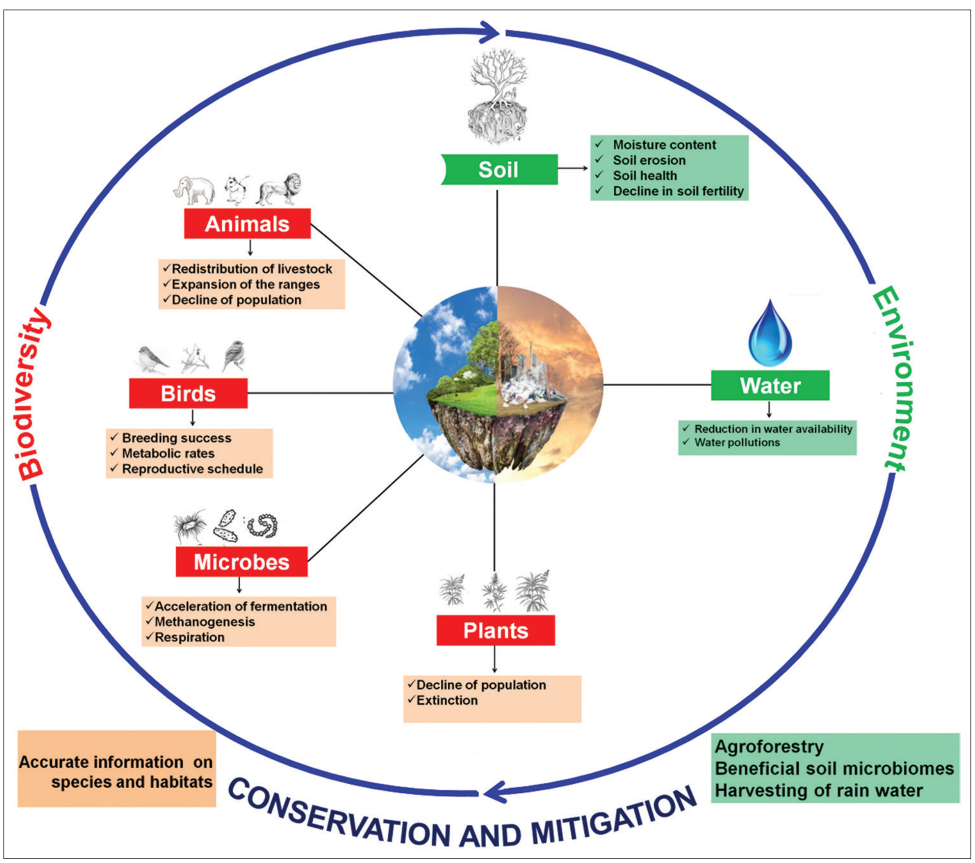

Figure 1: Depicts the effect of climate change on biodiversity and environment and their conservation/mitigation strategies.

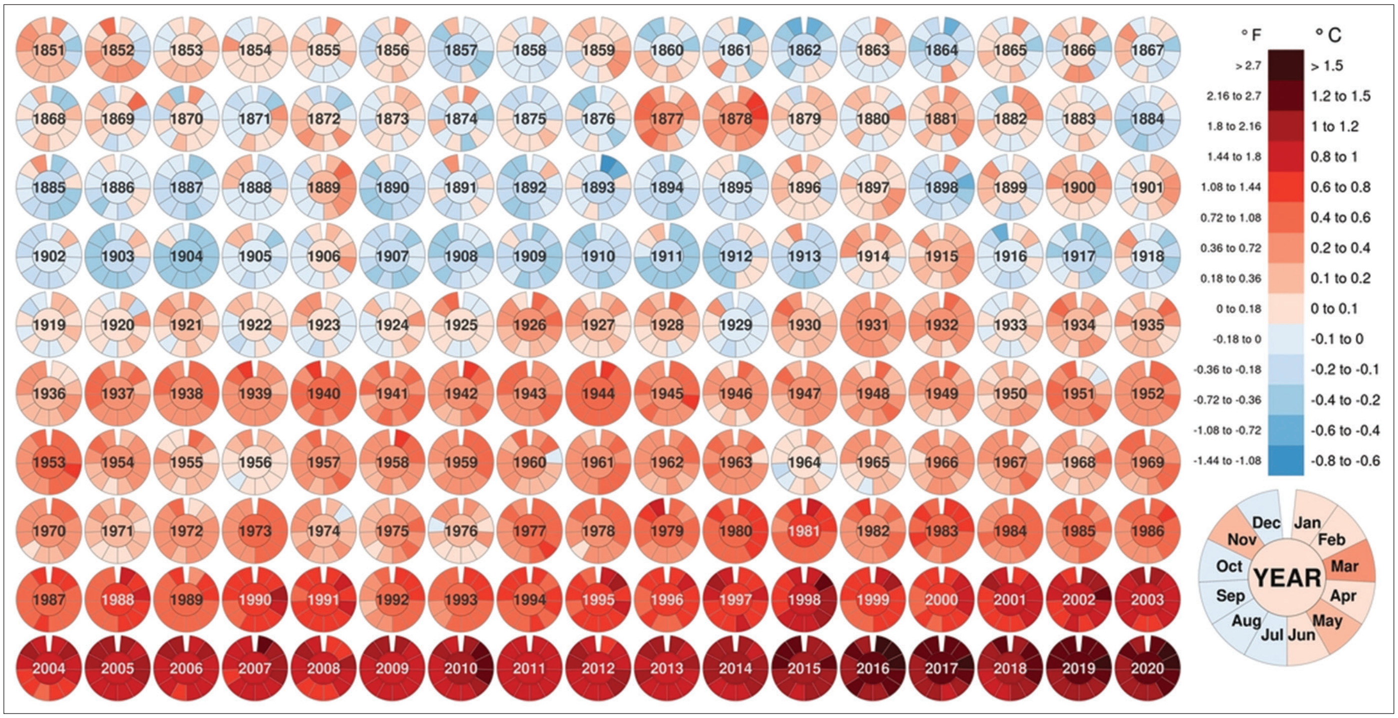

Figure 2: The changes in monthly mean global temperature from 1851 to 2020 (Data HadCRUT5 created by: @neilrkaye).

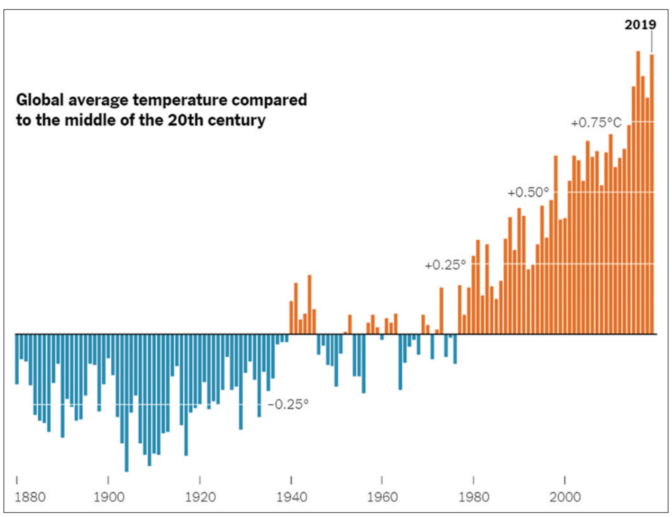

Figure 3: The changes in global average temperature from 1880 to 2019.

increased rates of soil erosion lead to nutrient loss, which affects agricultural productivity [118,119] and cause eutrophication of water bodies' [120]. Advanced stages of soil erosion, such as rill and gully erosion, can devastate entire areas, rendering them unfit for agricultural use [121,122]. Soil erosion is expected to increase with climate change and is the major problem that reduces the useful storage capacity of river dam reservoirs [123]. A study has been conducted to investigate the impact of climate change on soil erosion, runoff, and wheat productivity in central Oklahoma. The study concluded that no-till and conservation tillage systems will be effective in combating soil erosion under projected climates in central Oklahoma [124].

Soil fertility and productivity declines are common in tropical and subtropical areas of Asia, South America, and Africa, where soil loss due to erosion is estimated to be 30–40 t/ha/year [125,126]. Microorganisms present in the soil play important role in nutrient cycling and thus the decrease in MCCs in soil due to climate change affect the soil health and fertility.

Increasing challenges and concerns on global warming and changing climate have led to special attention to soil and its capability in carbon sequestration. In a study, the effect of climate change on soil organic carbon storage using the Rothamsted C model in the agricultural lands of Golestan province has been studied. The results suggested that with increasing temperature, the rate of decomposition of soil organic carbon will increase [127]. Soil organic carbon is an important carbon pool which can alleviate the increasing concentration of atmospheric carbon dioxide as part of the carbon cycling process. A study on the basis of Rothamsted C model concluded soil organic carbon will in general decline during the next decades. Further the rate of decrease of soil organic carbon will be higher over time if there is no addition of organic matter is adopted in China [128].

Another study focused on impact of global climate change on terrestrial soil CH_4 emissions. The meta-analysis in the study suggested that future climate change will decline the natural buffering capability of terrestrial ecosystems on CH_4 fluxes [129].

6.2. Water Resources

Climate change is expected to pose negative impact on water resources and freshwater ecosystems in almost every part of the world. However, the intensity and characteristics of the impact can vary widely from region to region. There may be water shortages in some regions. A study concluded that climate change will lead to water scarcity to meet the rising demand for food. It is estimated to be 60% higher in Africa by 2030, which will spike food prices and worsen food scarcity [130]. The shorter rainy periods and seasonality shifts might affect water resources by reducing water availability with wide ranging consequences for local societies and ecosystems [131].

With the increasing demand, large population will be at risk of water scarcity. The rise in sea level in coastal regions possibly will threaten the livelihood and lives of millions of people. The occurrence of droughts and floods is likely to increase in many parts of the world. All these factors will contribute to high economic cost and decline in the yield ultimately leading to higher risk of hunger and poverty [132].

A study has been conducted to analyze the impact of climate change on stream flow in the Godavari basin simulated using a conceptual model including CMIP6 dataset. The findings highlighted the importance of taking into consideration the potential impacts of future scenarios on water resources so that effective and sustainable water management practices could be developed [133]. Another study investigated the impact of the climate and land-use changes on water balance in 2037, the end of the National Strategy, for the Mun River Basin, NE Thailand. The study recommended soil-water conservation measures to alleviate the adverse effects of bioenergy [134]. The changing climate will also impact the water quality of lakes. A study has been conducted to investigate the effects of climate change on the water quality of Baiyangdian Lake in the past 30 years using correlation analysis, regression analysis, and the generalized additive model. The major conclusions of the study were the increment in the oxygen demand of organic matter in the lake due to rising temperature, increased total phosphorus in the lake due to increased precipitation and altered nitrogen and dissolved oxygen concentration in lake [135].

It is very important for water resources managers to be aware of the impact the climate change will have on hydrological cycle and flow regime and be prepared to find the strategies to cope with it. The better understanding on the link between the change in climate, water resources and the anthropogenic activities will help the water resource managers to make more rational decisions on the allocation and management of the water resources [136]. Social and environmental aspects including agriculture, biodiversity conservation, and tourism are connected to quality and availability of water resources, and consequently adaptation measures will be strongly bound with policies in a wide spectrum of disciplines [137].

7. CONSERVATION OF SOIL HEALTH, FERTILITY, AND WATER RESOURCES IN CHANGING CLIMATE

Soil and water are fundamental and basic necessities. The negative impact of changing climate on these basic resources is major global issue and developing strategies for their conservation is of utmost importance. The major research priorities of current studies are growing more food, conservation of the environment and reduction of global warming. Despite of changes in hydrology, climate, and increasing demand of agricultural commodities, there is a greater need to look further than the traditional approaches of the last century and embracing an expanded view of water and soil conservation to maintain an environmentally sound and sustainable landscape. Most importantly the new strategies must be based on far more effective policies and programs [138]. Agroforestry is one of the emerging technologies for water and soil conservation. It consists of a broad range of the practices including managing and establishing trees purposely around or within croplands, farm animal grounds, and pasture lands with the rationale of managing soil erosion, improving wildlife habitat, developing sustainable agricultural practices, ameliorating the effects of environmental pollution, and also adding to farm economy by harvesting tree based specialty products [139]. Conservation agriculture, another important approach for conservation of soil and water takes into account the conservation of biodiversity, labor and natural resources. It decreases drought stress, raises available soil water and maintains the soil health for a longer term. The strategy is practiced in Argentina, Australia, Brazil, Canada, New Zealand, Paraguay, and USA [140]. Further, it is also becoming popular in China, Kazakhstan, Russia and Ukraine and past decades it is spreading in Africa, Asia, and Europe [141].

Another important approach for maintaining soil health and fertility is the use of beneficial soil microbiomes. Microbes perform countless functions with key role in biogeochemical cycling and sustainability [142]. The utilization of the beneficial microbiomes is an important practice for agro-environmental sustainability. These microbiomes are treasure troves for innovative and potential developments in diverse sectors of agriculture, chemicals, environmental protection, food, and pharmaceuticals. The use of beneficial microbes is the vital practices for the sustainable energy and food production. The current research around the globe is majorly focused on exploring these beneficial microbes for maximizing their application under the limitation of the natural and anthropogenic activities, climate change, use of agro chemicals as these activities are continuously menacing stable agricultural production [143]. In order to fulfill water demand in the near future, it is necessary to rationalize the various means of collecting and storing water. In India, harvesting of rainwater is supposed to contribute in partially meeting the future water requirements. The climate change is expected to make monsoon less reliable as an assured source of water. Thus, efforts are required for more efficient groundwater recharge and rainwater harvesting through adoption and adaptation of technological options. Harnessing excessive monsoon runoff for additional groundwater storage will not only increase the water availability to meet growing demand, but also help to control the damage caused by flooding [144]. Other innovative approaches which may be adopted for water availability include desalination of seawater by evaporation using solar or wind energy which is cost effective and less expensive the cost of tapping groundwater, generation of rainfall using precipitation enhancement such as cloud seeding, and water in surface reservoirs or underground through artificial recharge. Furthermore, increasing irrigation efficiency using another new technology such as sprinkler design with low energy precision application might also be useful [145].

Many NGOs and government organizations are already working on the mitigation strategies for rising climate change. The Indian Council of Agricultural Research under ministry of agriculture and farmers welfare has launched a flagship network project which aims to study the impact of climate change on agricultural sector. The project also takes into account the development and promotion of climate resilient technologies in agriculture which will address vulnerable areas of the country and the output of the projects will help the districts and regions prone to climatic hazards. Rainfed area development scheme is being implemented for promotion of sustainable integrated farming systems. With the help of technological interventions, GOI is preparing efficiently to boost the crop produce and reduce the crop loss. Action against hunger is another important step to cope up with the hunger in scenario of climate crisis. Sankalp Taru Foundation is focusing on protection and conservation of the environment. Mukti is working for the social and economic development and environmental protection of the Sunderbans of West Bengal. Ashoka Trust for Research in Ecology and the Environment is working on issues including biodiversity and conservation, climate change mitigation and development, land and water resources, ecosystem services, and human well-being. Mobius Foundation is working for the environment in Delhi. The Gram Chetna Kendra aims to offer solutions to water problems keeping in mind the frequent damages droughts have induced in

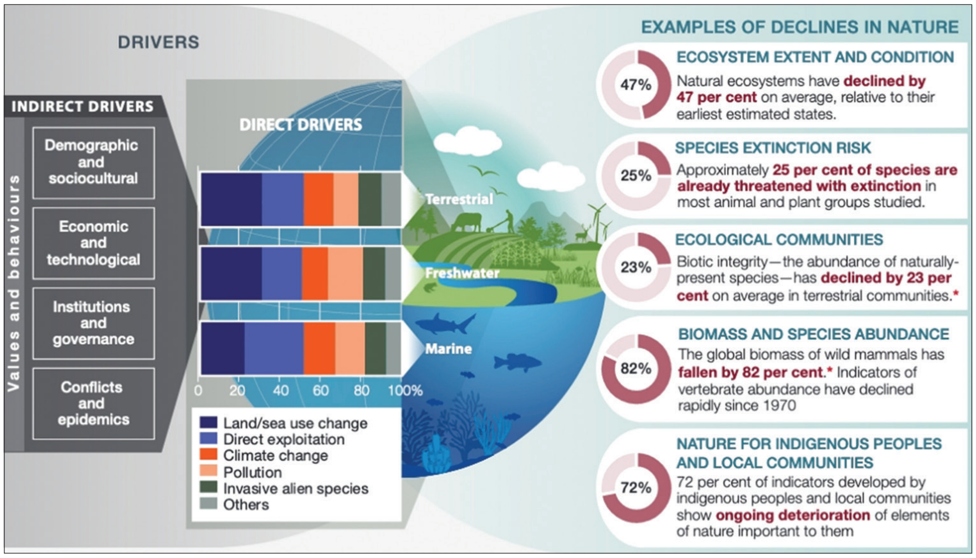

Figure 4: IPBES, global assessment report for policy makers.

Rajasthan. Greenpeace India is working on environment preservation. It has its presence in over 56 countries worldwide across various continents such as Asia, Europe, America, and few others. Greenpeace India promotes four different movements: preserving the oceans, preventing climate change, sustainable agriculture, and preventing another nuclear catastrophe [Figure 4].

8. EFFECTS OF CLIMATE CHANGE ON ECONOMICS

It has long been understood that economic consequences are climate-related. This relationship between climate and economics determines the extent and scale of the market impact of climate change in the next 100 years and beyond. Therefore, recent literature uses panel econometric methods to assess the response of economic results to weather, which is usually defined as implementation based on distribution of climate variables such as precipitation, temperature, and wind [146-148]. This estimation on economically and statistically important effects of weather on an assortment of economic outcomes, including crop yields, industrial output, and labor productivity [149]. The cumulative impact of global climate change is determined by how the world reacts to changes. According to the reports, climate change has already resulted in extreme weather events and a rise in sea level, posing new threats to agricultural production in several parts of the world. Current economic modeling may significantly understate the impact of potentially catastrophic climate change, emphasizing the need for a new generation of models capable of defining a more accurate picture of damages [150-152].

The main dynamic effect is through capital accumulation. Assuming a constant savings rate, if climate change negatively impacts production, the amount of economic investment will be reduced. In the long run, this will lead to lower capital stocks, lower GDP and, in most cases, lower consumption per capita. This effect of capital accumulation can be exacerbated in the context of endogenous growth if low investment slows technological advances while improving labor productivity or human capital accumulation. The second dynamic effect concerns savings. We can expect our forward-thinking agents to predict future climate change and change saving behavior in a perfect world. This, too, will have an impact on capital accumulation, and thus growth and future GDP [153].

Since then, practitioners and academics in development have grappled with the interplay of economic growth and environmental protection. Understanding and acting on these interactions has become critical to development in all countries, particularly in developing ones. The management of the environment has become an essential component of any viable path to poverty reduction and prosperity. Environmental degradation, poor health, and lost economic output result from poor environmental management practices. Poor people are the most vulnerable to these trends, though we must acknowledge that poverty also contributes to them [154,155]. Poor countries and poor people will suffer the most as they rely more on climate sensitive economic activities such as agriculture and possess weaker capability to adapt efficiently. In addition, poor people are also more likely to live in hazard zones and will be more vulnerable to the pests and diseases that follow drought, floods, and heat waves. Climate change can hinder development and growth, increase vulnerability, threaten health and return people to poverty [156]. Given the earth's finite resources, the application of economic principles and empirical findings should be a central component in the quest to meet humanity's aspirations for a good life.

A study investigated that increment in temperature considerably reduces the economic performance in Sub-Saharan Africa. In addition, the relationship between real gross domestic product per capita on one hand, and the climate factors on the other, is intrinsically non-linear has been shown in the study [157]. An integrated assessment model (ENVISAGE), including a CGE-based economic module and a climate module has been used to assess the impact of climate change on economic aspects. Results revealed that the influence of climate change is substantial, particularly for developing countries and in the long run, amelioration and adaptation policies are required to bring about sustainability in economic growth [158]. Another study focused on the impact of the climate change shocks on economic growth. The non-linear autoregressive distributional lag technique has been used for estimation of the asymmetric effect of climate change on the economic growth of Pakistan. The report indicated that at national level, tree planting projects, and safeguard greenery at all costs while at international level, adoption of policies and mitigation strategies to control climate change are of major importance [159]. There is a strong case to be made for greater efforts to increase understanding of the environmental, social, and economic dimensions of sustainable development, which necessitates a greater integration of economics, social sciences, and natural sciences [160].

9. CONCLUSION AND FUTURE PROSPECT

The world is already experiencing the negative effects of climate change from higher temperature to changing precipitation patterns, and severity of natural disasters. Climate change directly or indirectly affects the biodiversity through multitude of pathways. It is extremely challenging to predict the patterns and probabilities of biodiversity loss. Efforts are needed to prevent and manage the negative impacts of changing climate. The uncertainties in global climate changes require integrated multidisciplinary studies to form exact scientific basis for the adapting or lessening the adverse effects of climate change. In fact, the coming decade will be really crucial in determining to what extent humanity can improve the potential devastating effects of climate change. The transition to sustainability will be very difficult, but it is key factor to securing a future for biodiversity. It is important to minimize the ecological and societal consequences of changing biological diversity. The strong initiatives are required for biodiversity conservation, to enhance ecological understanding and ameliorate the consequences.

10. AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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13. ETHICAL APPROVAL

This study does not involve experiments on animals or human subjects.

14. DATA AVAILABILITY

All the data is available with the authors and shall be provided upon request.

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