Eco. Env. & Cons. 31 (July Suppl. Issue) : 2025; pp. (S1-S6)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2025.v31i04s.001
Website: www.envirobiotechjournals.com

Climate change and its impact on ecosystem services

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(Received 22 December, 2024; Accepted 24 February, 2025)

ABSTRACT

Climate change is one of the most significant global challenges of the 21st century, with profound impacts on ecosystem services that sustain human life and well-being. Ecosystem services are the benefits derived from natural systems encompass provisioning, regulating, supporting and cultural services, all of which are crucial for food security, water supply, air quality, disease regulation and cultural identity. However, climate change is altering the dynamics of these services through rising temperatures, changing precipitation patterns, ocean acidification and more frequent extreme weather events. These changes affect biodiversity, ecosystem functioning and the ability of ecosystems to provide essential services. Over time, climate change may have a direct or indirect impact on the range and extents of ecosystem services in terms of both quality and quantity. The ecosystem's supporting services (soil formation, biomass production, nutrient cycling, atmospheric oxygen production, and the water cycle), provisioning services (Food, drinking water, fabrics, plants, animal species, timber, wood fuel, fodder), regulating services (such as seed dispersal, decomposition, flood control, water management, carbon sequestration, climate regulation, and cross-pollination)all are affected due to climate change. In addition, cultural services such as tourism and leisure, aesthetics, cultural heritage, spiritual and religious values, education, social interactions, and ecotourism all will become less prevalent due to climate change. This write up examines the relationship between climate change and ecosystem services and to discuss the potential adaptation and mitigation strategies for the impacts of climate change on ecosystem services. It also highlights the urgent need for integrated approaches in conservation and policy development to protect both natural ecosystems and human well-being.

Key words: *Climate change, Ecosystem services, Cultural services, Temperature, Human beings, Biodiversity*

Introduction

Climate change is significantly altering ecosystems worldwide and these changes have profound implications for the ecosystem services that humans rely on. Climate change refers to long-term shifts in temperature, precipitation and other atmospheric conditions that impact the Earth's ecosystems and its services. Ecosystem services are the benefits that humans obtain from the natural environment such as food, clean water, pollination of crops, regulation of climate and cultural values. Climate change is threatening these services in various ways, primarily by disrupting the stability and functioning of ecosystems. It is true that climate change is occurring. Over the ensuing decades, it is anticipated to be the primary danger to biodiversity and one of the key elements influencing human health and well-being (Thomas *et al.,* 2004). According to multilateral environmental agreements (MEA) ecosystem services are the advantages that ecosystems provide to society. And these services were divided into four categories: sustaining, regulatory, cultural and providing services. Ecosystem services are being impacted by climate change and global warming, which is making many species vulnerable to extinction. This is due to the fact that a stable community depends on the balance between biotic and abiotic compo-

nents, which is being affected by climate change. Human beings are the part of biosphere as they are fully dependent on it. Therefore, the effect of climate change on "ecosystem services" is of tremendous concern.

Numerous studies conclusively show that global warming is changing the distribution of animal and plant species, altering the make-up of both natural and agricultural ecosystems and changing the range and effects of pathogenic organisms. According to IPCC (2014), the global mean temperature is predicted to increase by more than 2 °C by 2050 compared to preindustrial levels, which will have a detrimental effect on ecosystems and result in a significant loss of ecosystem services and functions. Petchey *et al.* (2010) give an interesting example of how connectance, a key component of the food web, may alter as temperature rises. Connectance is the percentage of actual trophic interactions among all possible interactions if all species were connected. Climate change and ecosystem services are intricately linked. While ecosystems provide essential services that help buffer the impacts of climate change, the degradation of these ecosystems due to climate change can reduce their ability to perform these services. Addressing climate change and protecting ecosystem services go hand in hand, with nature-based solutions offering significant potential for building resilience and mitigating climate impacts (Locatelli, 2016).

Today, more than ever, ecosystem services are being impacted by climate change. Little attention has been given to the ecosystem services that are being lost as a result of climate change, which has completely altered most freshwater ecosystems, profoundly altered oceans, and put coral reefs in grave risk (Locatelli, 2018; Scholes, 2016). The difficulties that species have due to behavioral shifts and mutualism disruptions are another way that climate change has an impact on ecosystem services. Species extinction has been noted in certain settings where migrations are essential for life yet there are no routes for effective mobility in the fragmented area. These suggest that the species' services are disappearing due to climate change (Carpenter *et al.*, 2009). One of the main causes of environmental changes and their effects on human well-being is believed to be climate change. Therefore, it is essential to comprehend the connections between ecosystem services (ES) and climate change in order to create mitigation and adaptation strategies that work (Uta and Tasser, 2024).

This review investigates the connections between climate change and ecological services. In addition to the threat posed by climate change to ecosystem services, it outlines the ecosystem services that aid in adaptation and mitigation.

Climate change and challenges to ecosystem

Climate change is significantly impacting ecosystem services including provisioning (food, water, raw materials), regulating (climate regulation, flood control), cultural (recreation, spiritual benefits), and supporting (nutrient cycling, soil formation) services. As the climate warms, ecosystems are undergoing profound changes, with shifting weather patterns, rising sea levels and extreme events such as storms and droughts. These changes threaten the stability and capacity of ecosystems to provide essential services. For example, altered precipitation and temperature patterns affect agricultural yields, water availability, and the health of forests and wetlands. Coral reefs, vital for coastal protection and biodiversity, are particularly vulnerable to rising ocean temperatures and acidification. Similarly, altered habitats put many species at risk, disrupting the intricate web of life that underpins ecosystem services.

Climate change is anticipated to have an impact on animal populations and cause a large-scale extinction of species in the future but there is already evidence of its consequences for a number of taxa. There have been detrimental effects on the population, range size, survival and reproduction rates of both mammal and avian species due to climate change. Due to the dependence of its vast population on agriculture, the excessive demand for its natural resources and its comparably small size, India is particularly vulnerable to climate change in comparison to inadequate coping techniques. Worldwide, study on mammals is conducted for both theoretical and practical purposes, at all levels of biological organization and in all types of habitats (Berteaux and Stenseth, 2006). According to Turner *et al.,* (2020) the possibility of abrupt and irreversible changes in ecosystems is linked to climate variability and extremes. Since extreme events are inherently unpredictable and stochastic, it is challenging to monitor abrupt changes in ecological systems (ACES) objectively.

Because of climate change and other factors contributing to global warming, ecosystems are chang-

ing quickly. These factors include variations in precipitation, atmospheric carbon dioxide concentration, water balance, ocean chemistry, the frequency and severity of extreme weather events. Different ecosystems react differently to changes in the climate due to intricate relationships between various creatures, disturbances and other stresses. Global biodiversity is at risk due to changes in natural ecosystems, which also have an impact on the world's food production. The studies in this section contribute to our understanding of how ecosystem attributes are affected by climate change (nutrient flow, trophic webs or energy flux, biotic diversity cycling or material flow) among many ecological groups (terrestrial vegetation, marine sediment invertebrates, terrestrial microorganisms in the soil) (Molotoks *et al.*,2020).

Effect of climate change on Ecosystem services

Effect on supporting services

Climate change can significantly affect supporting services of the ecosystem, which are the foundational processes that sustain life on Earth and enable the provision of other ecosystem services. These services include biomass production, nutrient cycling, water purification, and pollination, all of which are vital for human survival and well-being.

Iglesias and Whitlock, (2020) examine how fire affects the species composition of forest trees by using palaeo environmental records of pollen and charcoal from temperate forests in the Northern and Southern Hemispheres. Climate change can lead to species extinctions or migrations, reducing biodiversity. The loss of species can undermine ecosystem resilience, means ecosystems may become less able to recover from environmental stresses (e.g., storms, floods or droughts) (Locatelli, 2018). This decreases the availability and quality of services such as food, clean water and climate regulation. Many species may not be able to adapt or move fast enough to cope with rising temperatures, leading to shifts in the distribution of ecosystems, such as forests, wetlands and coral reefs. This can disrupt food chains, affecting services like pollination, pest control and nutrient cycling (Locatelli *et al.*, 2015)

The fundamental ecosystem service that is impacted by climate change is biomass production (Reyers *et al.*, 2016; Malhi *et al.*,2020). All higher trophic levels, including herbivores and carnivores, rely on photosynthesis or primary production. One of the primary functions of both terrestrial and aquatic ecosystems is photosynthesis, which transforms light energy into chemical energy and biomass. Climate change has an impact on photosynthetic rates and, consequently, biomass output. As a result, ecosystem services such as the availability of food, water and clean air for society are lost (Jabbour, 2016; Colvin *et al.*, 2019). Primary production and nutrient cycling are crucial to the ecosystem's resistance, resilience, and functioning. We also need to learn more about the ecological processes that support the preservation and adaptation of ecosystem services in times of change (Lavorel *et al.*, 2015).

Climate change has changed the fundamental mechanisms that maintain ecosystems and had observable effects on the environmental services that urban areas depend on. Increased temperatures and changed precipitation patterns have an impact on the composition and health of soil, which in turn affects soil fertility and nutrient cycling (Scholes, 2016; Weiskopf *et al.*, 2020; Bakure *et al.*, 2022). Increased decomposition of soil organic matter due to rising temperatures may increase soil carbon losses and alter C:N balances (Davidson and Janssens, 2006).

Effect on provisioning services

In rural communities, especially in developing nations, provisioning services is essential to their coping and adaptation strategies (Innes and Hickey, 2006). Many rural populations rely on forest products as safety nets to help them deal with difficult situations, such as when agriculture production fails due to drought conditions. Both timber and non-timber forest resources, such as firewood, wild fruits, mushrooms and fodder are essential to livelihood diversification, an anticipatory and adaptable tactic that lessens the susceptibility of communities and households to changes in the climate. Several studies in Bolivia (Robledo *et al.*, 2004) and Cameroon (Bele *et al.*, 2011) have shown the significance of ecosystem provisioning services for livelihood diversification and resilience.

Changes in temperature, precipitation and the frequency of extreme weather events (e.g., droughts, floods, heat waves) affect crop yields and livestock health. Climate change can lead to the spread of pests and diseases that threaten food crops, and can disrupt the growing seasons. Rising ocean temperatures, acidification, and changes in ocean currents are affecting fish populations, disrupting marine

food webs and impacting fisheries-an important source of protein and livelihood for many communities (Pattanayak and Sills, 2001). Sun *et al*., (2025) demonstrated that some studied discussed about drought implications with one or more ecosystem services, instead focusing primarily on biodiversity. Drought effects on biodiversity varied among species and taxonomic groups. Provisioning services for stress management might be a sign of poverty rather than a means of adaptation since it frequently stems from a lack of other coping mechanisms. When resources are scarce, there are many people in need, and there are no other options, ecosystem services as a safety net may become a poverty trap (Levang *et al.,* 2005).

Effect on regulating services

Ecosystem regulating services are generally thought to be groups that rely primarily on the interaction between ecosystems and biodiversity. As a result, climate change makes it susceptible to ecological deterioration and biodiversity loss (Mooney, 2005). Ecosystem functioning and many activities, including the control of human habitat, soil, water quality and atmosphere, result in regulating services (Zhang *et al.,* 2007; West *et al.,* 2011).

Climate change is causing more intense rainfall events in some regions and longer dry spells in others, which disrupts the availability and quality of freshwater. Wetlands, which play a critical role in purifying water, may dry up or become degraded. Melting glaciers and snow packs, particularly in mountain regions, are altering the timing and availability of water for agriculture, drinking, and energy production. For instance, downstream communities that depend on snowmelt for water may experience water shortages.

Effect on Cultural and Aesthetic Services

The non-material benefits that humans derive from nature, such as spiritual, artistic, educational, and recreational benefits, are referred to as cultural ecosystem services (Ament *et al.,* 2017). The general quality of life in cities is improved by parks, green areas, and lively urban landscapes, which provide areas for social contact, recreation, and relaxation (Cox *et al.,* 2017; Verma *et al.,* 2020).

Many cultures derive important spiritual, recreational and aesthetic value from natural landscapes, such as forests, mountains and coastal areas. Climate change is threatening these landscapes through phenomena like desertification, coral bleaching and the destruction of iconic ecosystems, which can have cultural and emotional consequences for communities that depend on these landscapes for their identity and well-being. The most challenging services to describe, according to Bennett *et al.,* 2009 were cultural ecosystem services. According to some authors they can be complicated yet crucial for human welfare because of their relationships to human emotion and motivation (Khan *et al.,* 2013).

Solutions for mitigating the effects of climate

The effects of climate change are becoming more and more apparent to policymakers and land managers. Effective adaptation and mitigation strategies to preserve ecosystem services require both spatially precise information on possible changes in ecosystem services across various scales and knowledge of general consequences (Uta and Tasser, 2024). The mitigation and adaptation methods for climate change both depend extensively on ecosystem services (Folke, 2007). Reducing sources of emissions or improving sinks of greenhouse gases is the goal of mitigation, while modifying human or natural systems to lessen damage or take advantage of possibilities brought about by climate change is the goal of adaptation. Climate change is a global issue that requires collaboration across nations and sectors. It is important to strengthen the international climate agreements like the Paris Agreement, which aims to limit global warming to well below 2°C and pursue efforts to limit it to 1.5 °C. Encourage countries to adopt and meet ambitious emissions reduction targets, with developed countries leading by example. It is necessary to facilitate the transfer of clean technologies to developing countries to help them mitigate climate change and adapt to its impacts (Dawson *et al.,* 2011).

Thus, managing ecosystems can help mitigate the effects of climate change. For instance, reforestation (turning recently non-forested land into forest) and a forestation (turning long-time non-forested land into forest) raise the amount of carbon in the vegetation, while forest protection helps lower carbon emissions from deforestation. By conserving soil and introducing trees into agroforestry systems, agricultural management can help improve carbon sequestration (Uprety *et al.,* 2012).

Even in low- and medium-range scenarios of global warming, the majority of ecosystems are suscep-

tible to climate change (Scholes and Settele, 2014). Along with other risks like pollution, overexploitation of resources and changes in land use, they are likely to be impacted by climate-related disturbances like floods, drought, and wildfire, as well as gradual changes in temperature or precipitation. The ecological interactions between species and their geographic ranges, as well as the structure and function of ecosystems, will all be impacted by these alterations and disturbances, leading to modifications in biodiversity and ecosystem services (Locatelli *et al.,* 2008).

Green and blue infrastructures are examples of nature-based solutions that communities can use to lessen the consequences of climate change, lower vulnerabilities, and encourage adaptation. Finding a balance between maintaining environmental services and urban growth is crucial. In order to preserve the long-term viability and operation of urban ecosystems, synergies and trade-offs must be carefully evaluated. For efficient climate change adaptation and sustainable urban growth, environmental services must be incorporated into planning and policy frameworks (Pandey and Ghosh, 2023). Different animals like mammals, migratory birds are more prone to climate change (rising temperatures, altered precipitations and chages in wind patterns) which disrupt their habitat, food availability, timing of migration and different ecological services (Kumar *et al*., 2024).

Conclusion

The impact of climate change on ecosystem services is broad and multifaceted, with consequences for biodiversity, food security, water resources, human health and cultural values. Many ecosystem services are interconnected, so a disruption in one service (e.g., pollination) can have cascading effects on others (e.g., food production, water regulation). Given the importance of these services for human well-being, it is critical to address climate change through mitigation (reducing greenhouse gas emissions) and adaptation (enhancing ecosystem resilience) strategies. Preserving and restoring ecosystems, along with implementing sustainable practices in agriculture, forestry, and urban planning, can help ensure that ecosystem services continue to support both human societies and the natural environment in the face of climate change.

Addressing climate change requires integrated approaches to both mitigate its impacts and adapt to its consequences. Sustainable management of natural resources, enhanced conservation efforts, and restoring ecosystems are critical steps to ensure the continued availability of ecosystem services. In parallel, reducing greenhouse gas emissions and shifting to renewable energy sources can help stabilize the climate and protect these vital services for future generations.

Conflict of Interest – None

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