

Original Article

ANALYZING THE ROLE OF ECOSYSTEM SERVICES IN CLIMATE CHANGE ADAPTATION: A LITERATURE REVIEW

Shaila Naaz ^{1*} , Dr. Nirmita Mehrotra ²

¹ Research Scholar, Gautam Buddha University, Gautam Buddh Nagar, Uttar Pradesh, India

² Head, Department of Urban and Regional Planning, Gautam Buddha University, Gautam Buddh Nagar, Uttar Pradesh, India



ABSTRACT

Understanding the role of ecosystem services in climate change is fundamental for several reasons. Ecosystems offer services that benefit human well-being, such as food provision, water purification, climate regulation, and natural hazard mitigation. These services are crucial for supporting adaptation strategies by offering essential resources and buffering against the impacts of climate change. This paper investigates the multi-dimensional contributions of ecosystem services to climate change adaptation, emphasizing their economic, social, and environmental dimensions. Ecosystems themselves possess adaptive capacities that can be crucial for human adaptation. Natural habitats like wetlands, forests, and mangroves have shown resilience and the ability to mitigate climate-related risks by, for instance, buffering against floods, sequestering carbon, and providing habitats for diverse species. However, climate change poses significant threats to these services. Therefore, studying ecosystem services in the context of climate change adaptation becomes critical for understanding vulnerabilities and developing strategies to protect, restore and manage these services. Integrating this understanding into adaptation planning and policymaking can foster more effective strategies to cope with the challenges posed by climate change.

Keywords: Ecosystem Services, Resilience, Climate Change, Adaptation and Mitigation

INTRODUCTION

Climate change represents one of the most pressing challenges of our time, with far-reaching consequences for ecosystems, societies, and economies worldwide. The manifestations of climate change, such as rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events, necessitate innovative and adaptive approaches to mitigate its impacts. In this context, the role of ecosystem services emerges as a critical factor in enhancing the resilience of both natural and human systems. Ecosystem services, encompassing a diverse array of benefits that ecosystems provide to humanity, play an important role in climate change adaptation. This research seeks to delve into the multidimensional contributions of ecosystem services in the face of a changing climate. By categorizing these services into provisioning, regulating, supporting, and cultural dimensions, we aim to comprehensively explore their significance in building adaptive capacity. Provisioning Services involve the tangible goods and resources provided by ecosystems, such as food, water, and raw materials. Understanding how agriculture, fisheries, and other provisioning services can adapt to changing climate conditions is paramount for ensuring food security and livelihood sustainability.

*Corresponding Author:

Email address: Shaila Naaz (khanshailanaaz@gmail.com), Dr. Nirmita Mehrotra (nirmita2006@gmail.com)

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Regulating Services encompass the ecological processes that mitigate environmental risks and maintain balance. For instance, wetlands act as natural buffers against floods, and forests regulate climate by sequestering carbon. Examining the resilience of these services is crucial for adapting to the heightened frequency and intensity of extreme weather events. Supporting Services involve the underlying processes that enable ecosystems to function, such as nutrient cycling, soil fertility, and biodiversity. Investigating how these supporting services respond to climate change contributes to our understanding of the overall adaptive capacity of ecosystems. Cultural Services reflect the non-material benefits that ecosystems provide, including recreational opportunities, aesthetic values, and cultural significance. Recognizing the role of cultural services in climate change adaptation is essential for fostering community engagement and building a sense of responsibility towards the environment. Adaptation is the process of adjustment to actual or expected climate change and its effects. Climate change adaptation entails implementing measures to cope with evolving climatic conditions, including seizing potential benefits if they exist [IPCC \(2022\)](#), [IPCC \(2014a\)](#). Recent [IPCC \(2022\)](#) research issues a warning to the global community, emphasizing the need to prepare for more severe impacts unless greenhouse gas emissions are halved within this decade, coupled with a swift escalation of adaptation measures. Various studies underscore the urgency of adapting to climate change alongside mitigation efforts ([Abbass et al. \(2022\)](#), [Dellmuth et al. \(2021\)](#)). The challenge of adapting to climate change arises not because the concept is novel, but due to the unprecedented scale and speed of the adjustments required and the inherent uncertainty regarding the exact nature of anticipated changes [F. Bosello et al. \(2009\)](#).

Table 1

Table 1 Ecosystem Services According to the Classification of the Millennium Ecosystem Assessment

	Provisioning Services
	Food
	Food from nature (game, fish, berries, mushrooms)
	Food from agricultural production (cereals, meat, fruit, vegetables)
	Raw material
	Fiber
	Bioenergy
	Wood
	Genetic resources
	Resistance of Crops against pathogens
	Biochemicals
Supporting Services	REGULATING SERVICES
Soil Formation	Air quality regulation
Nutrient Cycling	Clean air
Carbon Sequestration	Climate regulation
Primary production	Suitable climate for humans
	Water regulation (including purification and storage)
	Irrigation, Industrial and household use
	Purification of nutrients and Waste
	Pollination of Plants
	Biological Control
	Pest and Disease Control
	Cultural Services
	Aesthetic values
	Spiritual, religious and historical Values and Information
	Culture and art
	Science and education
	Recreation and ecotourism

Source Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC. 160 pp

REVIEW OF LITERATURE

According to [Pal et.al \(2023\)](#), Green areas have a positive impact on the environment by promoting biodiversity, reducing air pollution, attenuating the effects of heat islands, and reducing noise pollution. They are particularly essential in urban areas because they have positive social effects, the abundance of recreational activities, encourage social interaction and integration, and help to promote both physical and mental health. The concept of urban ecosystems has been defined as “those in which people live at high densities, and where built structures and infrastructure cover much of the land surface [Russo and Cirella \(2021\)](#). According to [Lombard et al. \(2024\)](#), including human dimensions in conservation practice is increasingly recognized as being essential for creating sustainable and equitable solutions to the current biodiversity crisis. However, including ecosystem services in conservation planning is challenging because services can be intangible and difficult to map, and incorporating equitable access. Most ecosystems are vulnerable to climate change, even under scenarios of low to medium global warming [Scholes and Settele \(2014\)](#). They are expected to be affected by gradual shifts in temperature and precipitation, as well as climate-related disturbances like flooding, droughts, and wildfires, compounded by other threats such as land-use changes, pollution, and overexploitation of resources. These changes and disturbances will impact ecosystem structure and function, alter ecological interactions among species, and shift species' geographic ranges, ultimately leading to changes in biodiversity and ecosystem services [Locatelli et al., \(2008\)](#). The vulnerability of ecosystems has global climate implications: disturbances that release carbon into the atmosphere can create vegetation-climate feed backs that exacerbate global warming [Canadell et al. \(2004\)](#). Additionally, climate change may impact local and regional ecosystem services, such as water regulation and timber production, with direct consequences for human societies [Shaw et al. \(2011\)](#). Ecosystem resilience in the face of climate change depends on various factors, including non-climatic pressures, landscape configuration, and species diversity and richness [Locatelli et al. \(2008\)](#). Key components like nutrient cycling and primary production play a critical role in maintaining ecosystem function, resistance, and resilience. It is essential to deepen our understanding of the ecological mechanisms that support the continuity and adaptation of ecosystem services during periods of change [Lavorel et al. \(2015\)](#). Minimizing short-term or non-climatic threats to ecosystems allows for the integration of targeted climate change adaptation measures into management practices. Effective management can mitigate climate change risks and enhance the adaptive capacity of ecosystems and species [Scholes and Settele \(2014\)](#). Strategies may include buffering ecosystems from disturbances through fire or pest management or facilitating ecological adjustments, such as reducing landscape fragmentation to support species migration [Guariguata et al. \(2008\)](#). Adaptation efforts must be ongoing, aiming not to maintain current conditions or establish a new equilibrium but to continually respond to changing climates [Stein et al, \(2013\)](#).

AIM

- To Establish the role of ecosystem services in climate change adaptation.

OBJECTIVES

- To define the role of ecosystem services in climate change adaptation.
- To establish the relationship between ecosystem services and factors of climate change.
- To assess the impact of climate change on different ecosystem services.
- To provide recommendations and a framework for climate change adaptation plans.

MATERIALS AND METHODS

The methodology for writing this paper is to find a problem statement and build a hypothesis. After that go through the literature study of the relevant topics to give out the research gap. The process of literature study is done through books, research papers, publications, articles, journals, chapters, thesis, dissertations, and review papers. Ecosystem services are prevalent in the context of the site and how the whole network is working. After site study and analysis, the inference has been noted down. The hypothesis has been cross-checked that if it is correct or not. After that, the proceed framework is provided and the limitations of it is discussed. The paper is finally concluded by providing the guidelines to be followed to establish ecosystem services for the regeneration of urban ecosystems.

RESULTS AND DISCUSSIONS

CLIMATE CHANGE FACTORS

The primary climate change factors are as follows:

- **Greenhouse Gas Emissions:** The burning of fossil fuels (coal, oil, and natural gas), deforestation, industrial processes, and agricultural practices release significant amounts of greenhouse gases (GHGs) into the atmosphere. The major GHGs include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases.
- **Deforestation and Land Use Changes:** Deforestation, often for agriculture or urban development, reduces the number of trees that absorb CO₂ from the atmosphere. This contributes to increased greenhouse gas concentrations and disrupts the natural carbon cycle.
- **Industrial Processes:** Certain industrial activities release greenhouse gases and other pollutants directly into the atmosphere. For example, the production of cement and other industrial processes can result in CO₂ emissions.
- **Agricultural Practices:** Enteric fermentation from ruminant animals (such as cows and sheep) releases methane, a potent greenhouse gas. Additionally, the use of synthetic fertilizers in agriculture contributes to nitrous oxide emissions.
- **Waste Management:** Decomposition of organic waste in landfills produces methane. Poor waste management practices contribute to the release of greenhouse gases into the atmosphere.
- **Transportation:** The combustion of fossil fuels in vehicles, airplanes, and ships releases CO₂ and other pollutants into the atmosphere, contributing to global warming.
- **Changes in Land Cover:** Conversion of natural landscapes into urban areas alters land cover and can contribute to changes in local climate patterns.
- **Industrial Agriculture:** Large-scale agriculture, including monoculture and the use of chemical inputs, can lead to soil degradation and contribute to greenhouse gas emissions.
- **Feedback Mechanisms:** Certain climate change impacts can trigger additional changes that amplify warming effects. For example, melting Arctic ice reduces the Earth's albedo, leading to more heat absorption and further warming. Some processes can counteract warming effects. For instance, increased CO₂ levels can stimulate plant growth, aiding in carbon sequestration.

CLIMATE CHANGE PARAMETERS CONCERNING FOUR ECOSYSTEM SERVICES

Provisioning Services: Changes in temperature and precipitation directly affect the availability and productivity of crops, influencing food production. Altered climate conditions may impact crop yields, potentially leading to food shortages and affecting provisioning services related to agriculture. Rising sea levels can result in saltwater intrusion, affecting coastal agriculture and fisheries. This impacts the provisioning of seafood and other marine resources, essential for the livelihoods of communities dependent on these services.

Regulating Services: Changes in ocean temperature and acidity affect marine ecosystems, impacting regulating services such as fisheries. Coral reefs, crucial for maintaining fish populations, are particularly vulnerable to these changes. Changes in the frequency and intensity of extreme weather events, like hurricanes and floods, can disrupt ecosystem functions. These events may alter the regulation of water flow, soil stability, and overall resilience of ecosystems.

Supporting Services: Alterations in vegetation health and distribution impact supporting services such as nutrient cycling, pollination, and habitat provision. These changes can affect the overall health and resilience of ecosystems. Changes in snow cover and glacial retreat influence water availability, impacting supporting services related to freshwater resources. These alterations can affect downstream ecosystems and human communities.

Cultural Services: Climate-induced changes in biodiversity can impact cultural services associated with the aesthetic, spiritual, and recreational values of ecosystems. Shifts in the distribution of species may affect traditional practices and cultural significance. The cultural services including recreational activities and spiritual connections, can be affected by extreme weather events. Changes in weather patterns may impact cultural practices linked to specific seasons.

Table 1

Table 2 Climate Change Parameters Concerning Four Ecosystem Services	
Eco System Services	Climate Change Parameter
Provisioning Services	1) Temperature and Precipitation Patterns 2) Sea Level Rise

Regulating Services	1) Ocean Temperature and Acidification 2) Extreme Weather Events
Supporting Services	1) Vegetation and Ecosystem Changes 2) Snow Cover and Glacial Retreat
Cultural Services	1) Changes in Biodiversity 2) Cultural Impacts of Extreme Events
Source Authors	

THE RELATIONSHIP BETWEEN VARIOUS CLIMATE CHANGE FACTORS AND DIFFERENT ECOSYSTEM SERVICES

Greenhouse gas emissions, primarily carbon dioxide from burning fossil fuels and deforestation, contribute to climate change. This can impact provisioning services related to agriculture by influencing temperature and precipitation patterns. This affects crop yields, posing challenges to food security. Deforestation, a major factor in climate change, can disrupt regulating services such as water regulation and climate stability. Forests play a crucial role in maintaining local and global climate patterns, influencing rainfall and temperature. Deforestation can lead to changes in these patterns, affecting ecosystems and human societies. Industrial processes contribute to greenhouse gas emissions and air pollutants, influencing climate change. This can impact supporting services such as soil fertility and biodiversity. Climate change impacts related to agriculture can affect cultural services tied to traditional farming practices, seasonal events, and cultural landscapes. Inadequate waste management leading to methane emissions from landfills contributes to climate change. This can influence regulating services like flood control and water quality. Changes in precipitation patterns and extreme weather events may exacerbate the impacts of poor waste management on local ecosystems. Changes in sea surface temperatures and precipitation patterns may affect fish stocks and crop yields, impacting food availability. Changes in land cover, such as urbanization or conversion of natural landscapes, can impact supporting services like soil fertility and biodiversity. Climate change-induced alterations in land cover can affect the overall health and resilience of ecosystems. Changes in vegetation patterns affect supporting services like nutrient cycling, pollination, and habitat provision. Altered vegetation may impact the overall structure and functioning of ecosystems.

Table 3

Table 3 Factors of Climate Change and Eco System Services	
Greenhouse Gas Emissions Transportation	Provisioning Services
Deforestation Waste Management Ocean Temperature	Regulating Services
Industrial Processes Changes in Land Cover Vegetation Changes	Supporting Services
Agricultural Practices Extreme Weather Events	Cultural Services
Source Authors	

CONCLUSION

As climate change continues to manifest its impacts, from altered precipitation patterns to the increasing frequency of extreme weather events, the importance of ecosystem services becomes ever more apparent. As climate change poses challenges to these urban eco system services, recognizing their importance becomes paramount for fostering adaptability and long-term ecological stability. In synthesizing our findings, it is evident that a holistic approach is imperative for effective climate change adaptation. By acknowledging the interconnectivity of ecosystem services and understanding their vulnerabilities, policymakers, conservation practitioners, and communities can craft informed strategies. Such strategies should not only address the immediate impacts of climate change but also foster a sustainable coexistence between human societies and the ecosystems upon which they depend . Through collaborative efforts and an unwavering commitment to sustainable practices, we can pave the way for a harmonious coexistence with the natural world, ensuring the adaptive capacity of both ecosystems and human societies in the face of an ever-evolving climate.

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