

Comprehensive Evaluation on Climate Change Trends in Nepal: A Review

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Abstract: Climate change is a defining global challenge, profoundly affecting ecosystems, economies, and societies. Within the framework of sustainable development, it is imperative to address these impacts through effective mitigation and adaptation strategies. Nepal, a nation highly vulnerable to climate change due to its unique geography and socio-economic conditions, provides a critical case for understanding localized climate impacts. This literature review explores Nepal's climate dynamics, emphasizing rising temperatures, altered precipitation patterns, glacier retreat, and the increased frequency of extreme weather events. These changes significantly impact agriculture, water resources, and livelihoods, exacerbating poverty and socio-economic vulnerabilities in this predominantly agrarian society. Mitigation strategies in Nepal focus on renewable energy, sustainable land-use practices, and energy efficiency, while adaptation measures include climate-resilient infrastructure, early warning systems, and climate-smart agriculture.

Keywords: Climate change, global warming, temperature, livelihood.

INTRODUCTION

Climate change stands as one of the defining challenges of our era, exerting profound impacts across ecosystems, economies, and societies worldwide. Within the paradigm of sustainable development, the imperative to comprehend and address these impacts becomes paramount. This necessitates the development and implementation of effective mitigation and adaptation strategies aimed at not only reducing greenhouse gas emissions but also bolstering resilience to the dynamic climate. In the specific context of Nepal, a nation acutely vulnerable to the repercussions of climate change, it becomes imperative to scrutinize local climate change trends while considering global perspectives to devise interventions that are contextually relevant and impactful.

Climate change represents a multifaceted phenomenon with far-reaching implications for the environment, economies, and societies worldwide. Its manifestations, including rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events, pose formidable challenges to human well-being and ecological integrity (Betsill & Bulkeley, 2021). The consequences of climate change are particularly pronounced in vulnerable regions like Nepal, where the impacts extend beyond environmental degradation to encompass social and economic upheaval. As such, addressing climate change emerges as a critical imperative within the framework of sustainable development.

Sustainable development, as articulated in the Brundtland Report of 1987, entails meeting the needs of the present without compromising the ability of future generations to meet their own needs. Central to this concept is the recognition of

the interconnectedness between environmental protection, economic development, and social equity. However, the accelerating pace of climate change threatens to undermine progress toward sustainable development goals, exacerbating poverty, inequality, and environmental degradation.

Where, mitigation and adaptation stand as two complementary approaches to addressing climate change. Mitigation efforts aim to reduce greenhouse gas emissions, thereby curbing the drivers of climate change (Cramer, *et al.*, 2018). These efforts encompass a range of actions, from transitioning to renewable energy sources to improving energy efficiency and promoting sustainable land use practices. On the other hand, adaptation strategies focus on enhancing resilience to the impacts of climate change, recognizing that some degree of change is inevitable. Adaptation measures may include building climate-resilient infrastructure, implementing early warning systems for natural disasters, and diversifying livelihoods to reduce vulnerability to environmental shocks.

Moreover, the global climate scenario describes the overall state of Earth's climate, which is influenced by various factors such as temperature, precipitation, sea level, and atmospheric composition. Currently, the global climate is experiencing significant changes primarily due to human activities, particularly the emission of greenhouse gases like carbon dioxide (CO₂) from burning fossil fuels and deforestation (Engle, *et al.*, 2020). These emissions trap heat in the atmosphere, leading to a phenomenon known as global warming. As a result, temperatures around

the world are rising, causing shifts in weather patterns, melting polar ice caps and glaciers, and increasing the frequency and intensity of extreme weather events like hurricanes, heat waves, and droughts.

While the global community has recognized the urgency of addressing climate change through initiatives such as the Paris Agreement, the implementation of effective mitigation and adaptation measures remains a formidable challenge. This is particularly true for developing countries like Nepal, which face numerous socio-economic constraints in addition to the physical impacts of climate change. Therefore, it is imperative to undertake localized assessments of climate change trends and vulnerabilities to inform contextually relevant interventions.

This research embarks on a comprehensive examination of climate change trends in Nepal, juxtaposed with global perspectives, to formulate nuanced mitigation and adaptation strategies conducive to sustainable development. By elucidating the interplay between local realities and global trends, this study seeks to provide insights into navigating the challenges posed by climate change while advancing Nepal's sustainable development goals.

Climate Change Scenario in Nepal

The climate change provides a wealth of insights into its causes, impacts, and potential responses. Numerous studies have documented the observed and projected impacts of climate change on various regions, highlighting the disproportionate burden borne by vulnerable populations (Hickman, *et al.*, 2021; Jansson & Hofmockel, 2020). In Nepal, a landlocked country nestled in the Himalayas, the impacts of climate change are particularly acute due to its unique geography and socio-economic context.

Temperature rise is among the most widely documented manifestations of climate change in Nepal. Studies indicate a consistent upward trend in temperatures across the country, leading to changes in precipitation patterns, melting glaciers, and alterations in ecosystems (Fawzy, *et al.*, 2020; Ghosh, 2018). The consequences of rising temperatures are manifold, affecting agriculture, water resources, and human health. For instance, changes in precipitation patterns have implications for rain-fed agriculture, with implications for food security and livelihoods (Charoenratana & Kharel, 2024).

Glacier retreat is another prominent consequence of climate change in Nepal, with significant implications for downstream water availability and hydroelectric power generation (Devkota, *et al.*, 2018). Glaciers in the Himalayas act as natural reservoirs, storing water during the wet season and releasing it gradually during the dry season. However, the accelerated pace of glacier melt due to rising temperatures jeopardizes this natural water supply, posing challenges for communities reliant on glacier-fed rivers for irrigation, drinking water, and hydropower.

The increased frequency and intensity of extreme weather events constitute another dimension of climate change impacts in Nepal (Flint, *et al.*, 2024). Floods, landslides, and droughts have become more frequent and severe, exacerbating vulnerabilities in mountainous regions prone to natural hazards. These events not only result in loss of life and property but also disrupt livelihoods and exacerbate poverty, particularly among marginalized communities (Joshi, *et al.*, 2017).

In response to these challenges, scholars and policymakers have emphasized the importance of integrating mitigation and adaptation strategies to build resilience to climate change (Masson-Delmotte, *et al.*, 2021; Monroe, *et al.*, 2019; Parmesan, *et al.*, 2022). Mitigation efforts in Nepal have focused on promoting renewable energy sources such as hydropower and solar energy, as well as improving energy efficiency and promoting sustainable land use practices (Karki, 2024). However, progress in these areas has been hindered by socio-economic constraints, inadequate infrastructure, and limited technical capacity.

Adaptation strategies in Nepal encompass a range of measures aimed at enhancing resilience to the impacts of climate change. These include the construction of climate-resilient infrastructure, such as flood defenses and landslide mitigation measures, as well as the development of early warning systems for natural disasters (Raza, *et al.*, 2019; Rolnick, *et al.*, 2022). Additionally, efforts to diversify livelihoods and promote climate-smart agriculture aim to reduce vulnerability to environmental shocks and enhance adaptive capacity at the community level.

Nepal Geography

Nepal's unique geographical features, including its diverse topography and climatic zones, contribute

to a rich tapestry of ecosystems and vegetation types (Khan, *et al.*, 2022). The country's climate exhibits considerable variability, ranging from subtropical in the lowlands to alpine in the high Himalayas (Khanal & Kattel, 2017). Understanding the complex interplay between Nepal's climate conditions and vegetation dynamics is crucial for assessing the economic responses of these ecosystems and informing sustainable development strategies. Nepal's climate is influenced by a variety of factors, including its latitudinal and altitudinal variations, the Indian monsoon, and regional weather patterns (Lebel, *et al.*, 2015; Nijhawan, *et al.*, 2022). The country can be broadly divided into three climatic regions: the Tropical, Temperate, and Alpine zones.

The Tropical region, encompassing the southern Terai plains, experiences a hot and humid climate characterized by high temperatures and abundant rainfall during the monsoon season (June to September). Temperatures can soar above 40°C in summer, while winters are milder with temperatures ranging from 15°C to 25°C. The Temperate region, covering the mid-hills of Nepal, experiences a moderate climate with distinct seasons. Summers are warm and rainy, with temperatures ranging from 20°C to 30°C, while winters are cool and dry, with temperatures dropping below freezing in higher elevations (Seddon, *et al.*, 2020; Seidl, *et al.*, 2017; Tol, 2018). The Alpine region, comprising the high Himalayas in the northern part of the country, experiences cold temperatures and heavy snowfall. High-altitude areas remain snow-covered throughout the year, with temperatures often plummeting below zero (Ojha, *et al.*, 2021). Precipitation in the form of snow contributes significantly to the region's hydrology, feeding rivers that sustain downstream ecosystems and communities.

Nepal's climate is strongly influenced by the Indian monsoon, which brings the majority of the country's annual rainfall. The monsoon typically begins in June and lasts until September, providing crucial moisture for agriculture and sustaining ecosystems across the country (Perkins, 2013). However, erratic rainfall patterns and the increasing frequency of extreme weather events, such as floods and landslides, pose significant challenges for water resource management and disaster risk reduction efforts.

Nepal's diverse climatic zones support a rich array of vegetation types, ranging from tropical forests

in the lowlands to alpine meadows and glaciers in the high Himalayas. These ecosystems provide a wide range of goods and services essential for human well-being and economic development, including timber, non-timber forest products, water resources, and biodiversity (Rankoana, 2020; Regmi, 2020).

The Terai region, characterized by dense subtropical forests and grasslands, supports a thriving forestry sector and agricultural activities such as rice cultivation and commercial farming of crops like sugarcane and wheat. The region's fertile soils and abundant water resources make it a breadbasket for Nepal, contributing significantly to the country's agricultural output and economy.

In the mid-hills and valleys, diverse vegetation types, including broadleaf forests, coniferous forests, and mixed deciduous forests, provide valuable ecosystem services such as soil conservation, water regulation, and carbon sequestration (Sharma, *et al.*, 2024). These ecosystems support traditional livelihoods based on agriculture, horticulture, and livestock rearing, as well as emerging industries such as ecotourism and herbal medicine production.

The high Himalayas, characterized by rugged terrain and harsh climatic conditions, are home to unique alpine vegetation adapted to extreme environments (Shrestha, *et al.*, 2024; Thapa R & Dhakal, 2024). These ecosystems provide critical habitat for iconic species such as the snow leopard, Himalayan musk deer, and blue sheep, which contribute to Nepal's burgeoning nature tourism industry. Additionally, alpine meadows and wetlands serve as important grazing grounds for livestock, supporting the livelihoods of mountain communities (Thapa S, *et al.*, 2024). However, Nepal's vegetation and ecosystems are increasingly under pressure from human activities, including deforestation, land degradation, and climate change. Deforestation, driven by factors such as agricultural expansion, logging, and infrastructure development, has led to the loss of critical habitat and biodiversity, as well as increased vulnerability to natural disasters such as floods and landslides.

Climate change poses additional challenges for Nepal's vegetation and ecosystems, altering precipitation patterns, increasing the frequency of extreme weather events, and disrupting ecological processes (Wågsæther & Ziervogel, 2011). Glacier melt and changes in snowfall patterns threaten water availability downstream, impacting

agriculture, hydropower generation, and freshwater ecosystems. Shifts in temperature and precipitation regimes also affect the distribution and composition of vegetation, leading to changes in species abundance and distribution. In response to these challenges, Nepal has implemented various policies and initiatives aimed at conserving its natural resources and promoting sustainable development. The government has established protected areas, national parks, and wildlife reserves to safeguard biodiversity and ecosystems, while also promoting community-based natural resource management approaches that empower local communities to participate in conservation efforts and benefit from sustainable resource use.

Furthermore, Nepal has prioritized climate change adaptation and mitigation efforts, including reforestation and afforestation programs, sustainable land management practices, and renewable energy development initiatives. These efforts aim to enhance resilience to climate change impacts, reduce greenhouse gas emissions, and promote sustainable development pathways that balance economic growth with environmental conservation and social equity.

Despite these efforts, significant gaps remain in both the understanding of climate change impacts and the implementation of effective adaptation measures in Nepal. Challenges such as limited access to finance, inadequate institutional capacity, and competing development priorities hinder progress in building climate resilience. Furthermore, the complex interplay between climate change and socio-economic factors underscores the need for interdisciplinary approaches that address underlying vulnerabilities and inequalities.

In the global context, initiatives such as the Paris Agreement represent important milestones in the collective effort to address climate change. The agreement aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels, with efforts to pursue a more ambitious target of 1.5 degrees Celsius. However, achieving these targets requires coordinated action at the national, regional, and international levels, as well as a commitment to equitable and inclusive development.

In summary, climate change poses significant challenges to sustainable development in Nepal, exacerbating existing vulnerabilities and undermining progress in poverty alleviation and

environmental conservation. Addressing these challenges requires integrated approaches that combine mitigation and adaptation strategies tailored to local contexts. By building resilience to climate change, Nepal can mitigate the impacts of environmental shocks and pursue a path of sustainable development that is equitable, inclusive, and environmentally sustainable.

CONCLUSION AND RECOMMENDATION

Climate change is an undeniable reality with profound consequences for the environment, societies, and economies worldwide. Nepal, due to its unique geographical and socio-economic conditions, faces disproportionate challenges stemming from climate-induced impacts. The observed trends of rising temperatures, changing precipitation patterns, glacial retreat, and an increase in extreme weather events underscore the urgent need for comprehensive and targeted interventions. These changes threaten Nepal's water security, agriculture, biodiversity, and overall sustainable development prospects.

The intertwined nature of climate change and sustainable development necessitates an integrated approach that balances mitigation and adaptation strategies. While mitigation efforts focus on reducing greenhouse gas emissions through renewable energy adoption, sustainable land use, and energy efficiency improvements, adaptation measures are crucial for building resilience in vulnerable communities. Nepal's adaptation strategies, including climate-resilient infrastructure, early warning systems, and diversified livelihoods, must be strengthened through increased investments, policy support, and international collaboration.

Moreover, Nepal's geographic diversity and dependence on climate-sensitive sectors emphasize the need for region-specific policies and localized assessments. Strengthening scientific research, fostering community participation, and leveraging indigenous knowledge are essential components of a robust climate response strategy. Additionally, addressing socio-economic constraints, including limited financial resources and institutional capacities, is critical for ensuring the successful implementation of climate policies.

The global climate crisis requires collective action, and Nepal's efforts must be aligned with international frameworks such as the Paris Agreement. By integrating climate resilience into

its development agenda, Nepal can enhance its adaptive capacity while contributing to global sustainability goals. Moving forward, a holistic and proactive approach that combines policy innovation, stakeholder engagement, and scientific advancements will be crucial in mitigating climate change impacts and securing a sustainable future for Nepal and its people.

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