CLIMATE CHANGE AND PLANT DIVERSITY IN INDIA: A REGIONAL VULNERABILITY ASSESSMENT OF THE EASTERN GHATS, NORTHERN ANDHRA PRADESH

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Abstract: The accelerating global climate crisis poses a profound and uneven threat to plant diversity, the foundation of terrestrial ecosystems and planetary stability. This review develops a framework to evaluate climate-driven biodiversity vulnerabilities in India, with a focused assessment of the Northern Andhra Pradesh (NAP) region within the Eastern Ghats. India, a megadiverse nation, faces mounting ecological pressures from climate variability and human disturbance. The review identifies knowledge gaps and assesses the regional vulnerability of flora under changing climatic regimes, revealing that while research predominantly targets themes such as "management," "impact," and "land use," endemic and region-specific studies remain significantly underrepresented. Findings indicate alarming species distribution shifts (11.0 m/decade upward; 16.9 km/decade poleward) and projected extinction risks of 38–52% for narrowly adapted taxa. The NAP region, already burdened by cyclones, heat stress, erratic monsoons, and anthropogenic pollution, exhibits heightened susceptibility among endemic plant species critical to ecosystem stability and tribal livelihoods. The review argues that conservation strategies must transition from broad national frameworks to region-specific, climate-smart planning that integrates Traditional Ecological Knowledge (TEK) with modern GIS and Earth Observation technologies, an approach vital for safeguarding biodiversity resilience and advancing India's commitments to UN Sustainable Development Goals (SDGs) 13 and 15.

Keywords: Plant Diversity; Climate Resilience; Endemic Species; Eastern Ghats; Conservation Planning; India.

1. Introduction

The intrinsic link between climate stability and biological diversity dictates that as the Earth's climate fluctuates, biological systems are compelled toward reorganization, fundamentally threatening the stability of human civilization. India, recognized as one of the world's 17 megadiverse countries, holds an unparalleled repository of plant diversity, including a vast array of endemic species vital for global genetic resources. This floral wealth, however, has come under profound and multifaceted threat from accelerated climate change, exacerbated by pervasive anthropogenic activities, including industrial pollution and unsustainable resource consumption.

This vulnerability is particularly acute given the dual ecological role of plant communities. On one hand, they are passive victims of climate change, subject to physiological stress from altered temperature and water regimes. On the other, they function as essential agents of climate regulation through atmospheric carbon sequestration, water-cycle management, and ecosystem stabilization. The integrity of these plant systems therefore directly affects the planet's capacity to regulate its own temperature, and the global response to the climate crisis must move beyond a singular focus on industrial greenhouse-gas reduction to systematically incorporate the protection and restoration of natural habitats as a core, cost-effective mitigation strategy.

This review synthesizes current scientific literature to critically assess this crisis. It first establishes the global and national context of climate-driven floral decline using quantifiable data. It then examines the specific, localized threats facing the plant communities of Northern Andhra Pradesh (NAP), a region encapsulating the vulnerable Eastern Ghats. Finally, it explores the adaptive measures, policy transitions, and research imperatives required to secure India's plant diversity, providing a template for integrated regional conservation planning in a rapidly warming world.

2. Core Review: Climate Impact on Flora, Regional Vulnerability, and Knowledge Gaps

The worldwide biodiversity crisis, driven by climatic shifts, sets the stage for the specific threats facing Indian flora. Global studies confirm that climate change alters natural ecosystems by increasing atmospheric CO_2 levels, driving accelerated glacial melt, and creating conditions for prolonged severe drought. The primary biological responses observed are complex adaptations, migratory shifts, or extinction. Observed species distributions are shifting to higher elevations at a median rate of 11.0 m per decade and 16.9 km per decade toward higher latitudes as species track optimal climatic envelopes.

The consequence for narrowly adapted and endemic species, particularly those confined by geographical barriers such as mountain ranges or coastlines, is severe: extinction rates are projected to reach 38% to 52% under modeling scenarios that assume limited or no migratory capacity. These declines stem not only from temperature stress but from ecological mechanisms including shifts in phenology — the timing of flowering and fruiting — which disrupt plant-pollinator and plant-herbivore relationships, leading to reproductive failure and population collapse.

2.1 General Threats to Indian Plant Diversity and Socio-Economic Impact

In India, this widespread environmental challenge undermines the nation's determination for sustainable development and resource security. Climate change escalates pressure on plant genetic resources through shifts in activity timing and microhabitat utilization, while a fast-changing climate adversely affects soil properties and depletes water resources essential for growth and agricultural productivity. The threat is geographically and socio-economically non-uniform: rain-fed agricultural regions, which cover the majority of India, are disproportionately affected, contributing to projections that crop yields in vulnerable regions could decline by more than 30% by 2050. The need to conserve plant biodiversity therefore transcends pure ecological mandates — it is a matter of public health, since medicinal flora provides primary healthcare for a significant share of the global population, and a matter of economic survival.

2.2 The Specific Vulnerability of Northern Andhra Pradesh (NAP)

Northern Andhra Pradesh is ecologically positioned to face some of the nation's most acute and compounded threats, largely owing to its location along the Bay of Bengal, which makes it susceptible to extreme weather events, particularly increased cyclone frequency and erratic monsoonal patterns. The region's flora, strongly associated with the ancient and ecologically diverse Eastern Ghats, hosts numerous endemic and narrowly adapted species, making them especially vulnerable to observed rates of climate-induced range shift. Dry deciduous forests, evergreen patches, and coastal mangroves each face distinct vulnerabilities: increased salinity intrusion and coastal erosion driven by rising sea levels and intensified cyclones threaten endemic halophytes and coastal plant nurseries.

For the Indigenous Peoples of this region, whose livelihoods, traditional medicine, and food security are directly linked to these plant communities, the consequences are immediate. They are the first to experience the effects of environmental degradation, which can lead to forced, non-adaptive migration, displacement, and compromises in social capital and mental health. Addressing these threats requires granular, place-based conservation efforts, particularly in areas showing a research deficit, such as the forest and wetland ecosystems of the NAP coastal belt, to prevent irreversible loss of this regional floral heritage.

2.3 Global Research Deficit and the Need for Targeted Scientometrics

A key impediment to effective regional action is the global research imbalance revealed by scientometric analysis. While literature on the climate-biodiversity nexus is increasing overall, effort remains heavily concentrated, both geographically and institutionally, with developed nations particularly the USA and a small set of high-profile institutions dominating the publication record, largely due to disparities in research funding, technological infrastructure, and institutional capacity.

The practical consequence is a profound knowledge gap in regions of high biodiversity but low research output, including vast tracts of India. Current research hotspots — “management,” “impact,” and “land use” — are insufficient to guide conservation decisions in endemism-rich zones like the Eastern Ghats, where local climate-plant interaction models remain scarce. This deficit means national and international policies often lack the fine-scale data

needed to predict how NAP's endemic species will respond to localized threats such as specific heat waves or changing fog frequency, underscoring the need for collaborative, region-specific, interdisciplinary research.

3. Discussion: Adaptive Strategies and Policy Integration

3.1 Conservation Strategies, Carbon Sequestration, and Ecosystem Resilience

Given the magnitude of the threat, biodiversity conservation must be recognized not merely as a desirable environmental objective but as a necessary climate-mitigation strategy. Strategic conservation strengthens ecosystem resilience the capacity of an ecosystem to recover from or absorb external pressures thereby sustaining vital services. This role is most evident in carbon sequestration: forest types across India, from the tropical moist deciduous forests of the Eastern Ghats to coastal mangrove systems, contribute significantly to global carbon budgets by storing atmospheric carbon in biomass and soils.

For NAP, comprehensive Nature-Based Solutions (NbS) including degraded-land restoration, reforestation with native endemic species, and sustainable forest management are paramount and align with international policy goals; a review of the draft post-2020 global biodiversity framework (CBD) identified direct climate-mitigation co-benefits in 14 of its 21 action targets. Preserving the genetic diversity of plant populations further provides essential genetic insurance, ensuring that stress-tolerant traits needed for future adaptation are not irrevocably lost.

3.2 Bridging Knowledge and Policy Gaps with Technology and Tradition

Addressing NAP's challenges requires overcoming the research and policy deficiencies identified globally through collaborative, interdisciplinary research focused on vulnerable ecosystems. Policy implementation must be strengthened through integration of Traditional Ecological Knowledge (TEK) from local Indigenous Peoples, who possess time-tested understanding of endemic flora, local climate patterns, and sustainable harvesting practices — knowledge that is crucial for in-situ conservation and restoration, particularly in the tribal populations of the Eastern Ghats, and that can inform the cultivation and propagation of rapidly declining species.

Advanced conservation tools must also be adopted at the regional scale: GIS and Earth Observation systems can map and monitor fine-scale shifts in NAP's plant distributions, track deforestation, and provide early warning of plant stress such as drought indicators. Plant Tissue Culture (PTC) technology, as advocated by strategies such as the Kew conservation model, offers a powerful tool for ex-situ conservation, enabling rapid propagation of endangered endemic species for safe conservation and reintroduction, and supporting ambitious targets such as the post-2020 framework's 30-by-30 protected-area goal.

3.3 Policy and Funding Imperatives for Regional Conservation

Translating these strategies into results requires stronger policy and financial frameworks. National Biodiversity Strategic Action Plans (NBSAPs) must move beyond generic guidelines to integrate region-specific mandates reflecting NAP's unique vulnerabilities, backed by dedicated budget allocation and targeted Climate Financing mechanisms designed for biodiversity projects in developing regions. These financial streams must prioritize local governance, empowering regional authorities and indigenous communities to lead conservation efforts. Integrating biodiversity conservation into national economic planning, rather than treating it as a peripheral environmental issue, is essential for long-term sustainability; without this institutional and financial commitment, the Eastern Ghats' plant diversity will face an ever-increasing risk of irreversible loss.

4. Conclusion

Climate change and biodiversity loss constitute the most urgent, interlinked global challenges of the modern era. The fate of plant diversity in India, exemplified by the compounded vulnerabilities of Northern Andhra Pradesh, serves as a critical test case for global adaptive capacity. The evidence confirms that without regionally focused policy and integrated action, the loss of narrowly adapted flora will continue to accelerate, with severe ecological, social, and economic consequences. By moving beyond generalized conservation, recognizing biodiversity conservation as a necessary climate-mitigation strategy, and prioritizing regional, climate-smart models that integrate TEK with advanced science and targeted funding, India can strategically secure its floral wealth. Strong governmental involvement, accountability of resources, collaborative regional research, and unequivocal prioritization of these integrated efforts are essential to securing environmental sustenance and achieving SDGs 13 and 15 for both the nation and the vulnerable communities of the NAP region.

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