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SYNERGISTIC THREATS: CLIMATE CHANGE AND ANTHROPOGENIC PRESSURE ON WESTERN GHATS BIODIVERSITY

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Abstract:
The Western Ghats of India, a UNESCO World Heritage Site and one of the world's eight 'hottest hotspots' of biological diversity, faces a severe conservation crisis due to the synergistic effects of climate change and escalating anthropogenic pressures. The paper is an attempt to explore the emerging synergistic threats to the Western Ghats World Heritage Site due to climate change and anthropogenic pressure. This unique mountain chain, older than the Himalayas, is recognized for its immense global importance in conserving biological diversity, influencing the Indian monsoon weather pattern and harbouring an exceptionally high level of endemism. However, the climate-driven challenges are profoundly compounded by intense human activities across the Ghats. Widespread threats include agricultural expansion, livestock grazing, illegal hunting and the extraction of forest products such as fuelwood and fodder, which lead to habitat degradation and local species extinction. Incessant infrastructure development is severely disrupting connectivity for wide-ranging species like the Asian Elephant and Tiger. The proliferation of plantations for has displaced vast patches of natural forests, while urbanization and pollution, particularly from agricultural and domestic sources, severely impact both terrestrial and critically important freshwater ecosystems. The interaction between these climatic and anthropogenic factors creates a vicious cycle which in turn increases the vulnerability of ecosystems to human disturbances. Thus, urgent and coordinated conservation responses that integrate climate resilience with strategies to mitigate anthropogenic threats to safeguard this invaluable global heritage are the need of the hour.

Keywords: Western Ghats, Climate Change, Anthropogenic Pressure, Biodiversity Hotspot, Synergistic Threats.

Introduction

The Western Ghats, spanning along India's western coast from Gujarat to Kerala, represents one of Earth's most exceptional biodiversity hotspots and a critical ecological asset for the Indian subcontinent (MoEF, 2009). Recognized as a UNESCO World Heritage Site in 2012 and designated among the world's eight "hottest hotspots" of biological diversity, this ancient mountain chain harbours extraordinary levels of endemism and species richness (CEPF, 2007). However, this irreplaceable natural heritage faces unprecedented threats from the convergent forces of climate change and intensifying anthropogenic pressures, creating a synergistic cascade of impacts that imperils the region's ecological integrity and the millions of people dependent upon its ecosystem services. Thus, the paper is an attempt to explore the emerging synergistic threats to the Western Ghats World Heritage Site due to climate change and anthropogenic pressure.

Geological heritage and biodiversity

The Western Ghats trace their origins to the breakup of the supercontinent Gondwanaland during the Cretaceous period, approximately 150 million years ago (IUCN, 2012). This ancient lineage, coupled with prolonged geological stability and geographic isolation, has facilitated extraordinary evolutionary processes that produced remarkable biological diversity. The region encompasses diverse ecosystems ranging from tropical wet evergreen forests receiving heavy rainfall to dry deciduous formations on the eastern rain-shadow slopes. The biodiversity richness of the Western Ghats is staggering. The region harbours at least 5000 species of flowering plants, with approximately 352 trees are endemic to this mountain range. The fauna includes over 139 mammal species (17 endemic), 508 bird species (16 endemic), 179 amphibian species, 157 reptile species and 219 freshwater fish species (WGEEP, 2011; IUCN, 2014).

Beyond its biodiversity value, the Western Ghats functions as the "water tower of peninsular India," sustaining the livelihoods and water security of the region. The mountain range gives rise to numerous major river systems toward the Bay of Bengal and into the Arabian Sea. The complex topography, high rainfall gradient and diverse forest ecosystems create exceptional watershed functions, regulating water flow, maintaining groundwater recharge and moderating regional climate patterns (Gunawardene *et al.*, 2007). The forests of the Western Ghats also provide critical carbon sequestration services. These carbon storage and sequestration functions contribute significantly to regional and global climate regulation, making the conservation of Western Ghats forests essential for climate change mitigation (Kale *et al.*, 2009).

Climate change impacts

Climate change poses multifaceted threats to the Western Ghats, manifesting through altered temperature regimes, shifting precipitation patterns and increased frequency of extreme weather events. Higher temperatures on montane ecosystems and specialized endemic species are devastating, particularly given the limited dispersal capabilities and narrow thermal tolerances of many Western Ghats species.

- **Altered precipitation patterns**: The monsoon rainfall patterns that define the Western Ghats climate are exhibiting significant temporal and spatial variability. Divergent regional trends, with the northern Western Ghats experiencing rainfall increase, while the southern regions show concerning decrease was recorded (Mahen Konwar *et al.*, 2014; Kumar *et al.*, 2014). The contrasting patterns reflect complex interactions between large-scale climatic drivers, including sea surface temperature variations in the Arabian Sea and Indian Ocean. The changing rainfall regime has direct implications for forest ecosystems and hydrological functions. In addition, rainfall intensity during monsoon months is increasing, leading to more extreme precipitation events separated by longer dry periods. This shift toward more variable and intense rainfall patterns increases all kinds of risks (SANDRP, 2013).
- **Impacts on endemic species**: Climate change threatens to disrupt the delicate ecological balances that have sustained Western Ghats biodiversity through millennia. Drastic reductions in medicinal plants endemic to the Western Ghats due to loss of suitable habitat due to changing climatic conditions. Endemic bird species face particularly acute climate threats (IUCN, 2014). Amphibians, which represent the most threatened vertebrate class globally, face compound climate threats in the Western Ghats. The endemic Malabar tree toad (*Pedostibes tuberculosus*) exemplifies these vulnerabilities, with distribution models projecting potential population declines of 68.7% due to climate change. Habitat fragmentation, pollution, disease, and morphological deformities associated with climate change have contributed to amphibian population declines over the past four decades.

- **Shola-grassland vulnerability:** The unique shola-grassland ecosystems of the higher Western Ghats face existential threats from climate change. These forests, characterized by stunted evergreen trees growing in valley bottoms and surrounded by rolling grasslands, occur above 1,800 meters elevation in the Nilgiris, Anamalais and Palani hills. Shola ecosystems harbour exceptional biodiversity and provide critical watershed functions, acting as natural water storage structures that feed perennial streams supplying major rivers (Lockwood, 2006). Climate change threatens to disrupt the delicate equilibrium between shola forests and grasslands through altered fire regimes, changing precipitation patterns and temperature increases that favour the expansion of woody vegetation into grasslands. These changes interact synergistically with anthropogenic disturbances, including the spread of invasive species and past conversion to plantations, creating cascading impacts on ecosystem structure and function

Anthropogenic pressures

While climate change presents a growing threat, anthropogenic pressures have been transforming Western Ghats landscapes creating a legacy of habitat loss, fragmentation and degradation that compounds climate impacts. The Western Ghats has experienced extensive forest loss over the past century. Historical analysis indicates that between 1920 and 1990, approximately 40% of the original natural vegetation was lost or converted to open lands, plantations, and reservoirs (Menon and Bawa, 1997). The annual deforestation rate during this period averaged 0.57%, driven primarily by agricultural expansion, establishment of tea and coffee plantations and infrastructure development.

- **Agricultural expansion and plantation agriculture**: The conversion of natural forests to agricultural lands and commercial plantations represents one of the most significant drivers of biodiversity loss in the Western Ghats. Tea plantations in South Indian states increased by 17.7% between 1987 and 1998, expanding from 74,765 ha to 87,993 ha. Coffee cultivation, while traditionally practiced under shade canopy systems that maintain some biodiversity value, has expanded extensively throughout the region, particularly in Karnataka's Kodagu district (SACON, 2015). Land use change analysis reflects the compounded pressures of population growth, urbanization and agricultural intensification that have characterized development trajectories across the Western Ghats states. The introduction and expansion of exotic plantation species has created additional ecological impacts.
- **Mining and quarrying**: Mining and quarrying activities represent another major source of ecological degradation in the Western Ghats. The region's mineral wealth, including iron ore, manganese, bauxite and various building stones, has attracted intensive extraction activities, often conducted with insufficient environmental safeguards. Mining operations cause direct habitat destruction through removal of vegetation and topsoil, while associated activities including road construction, waste dumping and sedimentation of water bodies extend impacts across broader landscapes.
- **Hydroelectric projects**: The construction of dams and hydroelectric projects has submerged extensive forest areas across the Western Ghats while fragmenting river systems and disrupting aquatic ecosystems. Major hydropower projects have inundated large tracts of prime forest habitat, displacing wildlife populations and eliminating critical corridors. Beyond direct habitat loss, dams alter downstream hydrological regimes, affecting floodplain forests, wetlands, and the aquatic species dependent on natural flow patterns (Raju and Raju, 2014). The environmental impacts of hydroelectric development extend beyond the immediate reservoir areas.
- **Infrastructure development**: Infrastructure development, including expansion of road and rail networks, has created additional pressures on Western Ghats ecosystems. Linear infrastructure fragments habitats, impedes wildlife movement, facilitates access for resource extraction and encroachment, and increases collision mortality for wildlife. Moreover, the likelihood of landslides is higher in areas disturbed by linear infrastructure compared to undisturbed steep forests. The construction process

involves removal of vegetation, destabilization of slopes through excavation and dumping of debris that makes landscapes more vulnerable to mass wasting during intense rainfall events (Tikke *et al.*, 2014).

- **Invasive species**: The introduction and spread of invasive alien species represents a pervasive threat to Western Ghats biodiversity. According to Aravindhan and Rajendran (2014a) a total number of 90 invasive alien species under 74 genera belonging to 37 families have been recorded from Boluvampatti forest range in Southern Western Ghats of Tamil Nadu, India alone. The pathways for alien species introduction include aquarium trade, aquaculture, ornamental plant cultivation, forestry plantations and agricultural practices. The proliferation of invasive species in the Western Ghats threatens native biodiversity through competition, predation, habitat modification and alteration of ecosystem processes. The rapid spread and establishment of invasives reflects the compounded effects of habitat disturbance, which creates opportunities for colonization and climate change, which favour non-native species adapted to variable conditions over specialized endemic species. Aravindhan and Rajendran (2014b) reported that the invasion of *Lantana camara* led to the degradation of typical structure of valuable flora in the Velliangiri Hills in terms of richness, diversity and composition of native species.
- **Human-wildlife conflict**: The intensification of human-wildlife conflict represents a symptom of habitat degradation and fragmentation throughout the Western Ghats. Competition for space and resources between expanding human populations and wildlife has escalated conflicts involving elephants, leopards, tigers and other large mammals (Karanth *et al.*, 2012; Karanth, 2013). Human-elephant conflict has intensified as habitat fragmentation forces elephants into new areas and agricultural lands. The conflict patterns reveals that high human population density, habitat loss and agricultural practices serve as primary drivers of conflict events. Jayson and Christopher (2008) reported the human-elephant conflict in the Peppara Wildlife Sanctuary, Kerala, India and crop damage is linked to the cropping pattern and location of settlements.

Synergistic interactions and cumulative impacts

The threats to Western Ghats biodiversity operate not in isolation but through complex synergistic interactions that amplify overall impacts. Climate change interacts with habitat fragmentation to constrain species' abilities to track shifting climatic conditions. As temperature and precipitation patterns change, species must either adapt in place, migrate to more suitable areas or face population decline and potential extinction. However, fragmented landscapes impede migration, trapping species in degraded habitats as conditions deteriorate. The interaction between fire and aridity demonstrates another critical synergism. Climate change-induced increases in drought frequency and intensity create conditions conducive to more extensive and severe fires. Simultaneously, anthropogenic activities including grazing, selective logging and collection of forest products alter forest structure in ways that increase fire susceptibility. The combined effects of enhanced aridity and anthropogenic disturbance produce fire regimes that exceed the adaptive capacity of many native species, particularly those adapted to wet evergreen forests with historically minimal fire exposure.

Invasive species proliferation reflects synergistic interactions between multiple stressors. Habitat disturbance through logging, agriculture, or infrastructure development creates establishment opportunities for invasive species. Climate change favour invasives over natives by creating conditions outside the historical range of variation to which natives are adapted. Meanwhile, invasive species themselves alter ecosystem properties including nutrient cycling, hydrology, and fire regimes in ways that further disadvantage native species and prevent ecosystem recovery. The cumulative impacts of these synergistic threats manifest in landscape-level changes that fundamentally transform Western Ghats ecosystems. Between 2000 and 2014, the Western Ghats lost vast stretches of forest, with deforestation occurring primarily outside protected areas. Forest protection through wildlife sanctuaries

and national parks successfully reduced forest loss but effectiveness varied spatially, with protected areas closer to towns and roads experiencing proportionally greater losses.

Conservation challenges and policy responses

Recognizing the mounting threats to Western Ghats ecosystems, the Government of India established the Western Ghats Ecology Expert Panel (WGEEP) in 2010 under the chairmanship of ecologist Madhav Gadgil. The WGEEP report, submitted in 2011, proposed designating the entire Western Ghats region as an Ecologically Sensitive Area (ESA) with three levels of ecological sensitivity. The report recommended strict regulations on mining, quarrying, construction and polluting industries in designated areas while advocating for a bottom-up governance approach involving local communities in conservation and resource management (Gadgil *et al.*, 2011). The WGEEP recommendations faced substantial opposition from state governments and development interests concerned about restrictions on economic activities. In response, the Ministry of Environment and Forests established a High-Level Working Group under space scientist K. Kasturirangan in 2012 to re-examine the WGEEP report. The Kasturirangan Committee submitted its findings in 2013, proposing a more limited approach designating only 37% of the Western Ghats as ESA. The report distinguished between "cultural landscapes" with human settlements, agriculture and plantations and "natural landscapes" requiring conservation with 90% of natural landscapes to be designated as ESA (Kasturirangan *et al.*, 2013).

The Kasturirangan Committee recommended complete bans on mining, quarrying, and sand mining in ESAs, restrictions on thermal power projects and allowance of hydropower projects only after detailed study. The report emphasized incentivizing "green growth" strategies that balance conservation with development, citing coffee plantations in Kodagu and cardamom plantations in Idukki as examples of environmentally compatible land uses. Implementation of Western Ghats conservation recommendations has proven contentious and incomplete. States have resisted ESA designations that would restrict development activities and resource extraction. Local communities express concerns about livelihood impacts and restrictions on traditional resource use. The failure to achieve consensus on conservation approaches reflects fundamental tensions between conservation priorities and livelihood and development pressures in a region supporting dense human populations with legitimate development aspirations.

Conclusion

The Western Ghats faces a convergence of threats unprecedented in scope and intensity. Climate change manifests through altered temperature and precipitation regimes, increased frequency of extreme events and disruption of ecological relationships that have sustained extraordinary biodiversity through millennia. Anthropogenic pressures including deforestation, agricultural expansion, mining, infrastructure development, spread of invasive species and altered fire regimes compound climate impacts through synergistic interactions that amplify threats and constrain adaptive responses. The scientific evidence documenting biodiversity declines, ecosystem degradation and mounting risks is unequivocal. Hundreds of endemic species face extinction risks as they already limited habitats contract and fragment. The hydrological functions that support water security erode as forests disappear and rainfall patterns shift. Carbon sequestration services critical for climate regulation decline as forest cover diminishes. Effective conservation of the Western Ghats requires integrated approaches addressing both climate change and anthropogenic pressures through complementary strategies. Climate change adaptation requires maintaining ecological connectivity, protecting climate refugia, restoring degraded ecosystems and assisting species movements as conditions shift. Addressing anthropogenic pressures demands strengthened protected area management, enforcement of environmental regulations, land-use planning that balances conservation with development, restoration of degraded forests and grasslands,

control of invasive species and engagement of local communities as conservation partners. The Western Ghats represents both an irreplaceable natural heritage and a critical resource supporting human wellbeing and its conservation serves not only biodiversity protection but also water security, climate regulation, livelihood support and cultural preservation for the millions of people whose lives intertwine with these ancient mountain range. However, strong political will and societal commitment are the need of the hour to conserve the mountain range. The synergistic threats facing Western Ghats biodiversity demand synergistic solutions integrating conservation science, traditional knowledge, policy reform and community engagement to secure this global treasure for future generations.

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