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ECOLOGICAL RESTORATION OF THE ARAVALI HILLS: CURRENT STATUS, CHALLENGES AND FUTURE PROSPECTS

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Abstract: *The Aravali Hills, among the oldest fold mountain systems in the world, extend over approximately 692 km across northwestern India and perform vital ecological functions, including regional climate regulation, groundwater recharge, biodiversity conservation, and mitigation of desertification. The hills formed over 2.5 billion years ago, making them older than the Himalayas. The Guru Shikhar (1,722 meters) located in the Sirohi district near Mount Abu. It serves as a natural "Green Wall" preventing the eastward expansion of the Thar Desert into the fertile Indo-Gangetic plains. Despite their strategic environmental significance, the Aravali ecosystem has experienced severe degradation over recent decades due to unregulated mining, deforestation, rapid urban and industrial expansion, and increasing climate variability. This study critically assesses the current ecological status of the Aravali Hills and evaluates the effectiveness of restoration initiatives undertaken in the region. The findings indicate that while localized interventions, such as afforestation programmes, mine reclamation, watershed development, and the establishment of biodiversity parks, have resulted in partial improvements in vegetation cover and ecosystem functions. The paper identifies key drivers of environmental degradation and highlights gaps in policy implementation, governance, and long-term ecological monitoring. It proposes a sustainable restoration framework that integrates strict regulatory enforcement, community participation, scientific monitoring using geospatial tools, and climate-resilient ecological practices to ensure long-term restoration and sustainable management of the Aravali ecosystem.*

Key words: Aravali Hills, Ecological Restoration, Biodiversity, Environmental Degradation

Introduction

Mountain ecosystems play a crucial role in maintaining environmental stability by regulating climate, conserving biodiversity, and sustaining hydrological cycles. These ecosystems act as natural water towers, carbon sinks, and biodiversity reservoirs, particularly in arid and semi-arid regions where ecological resilience is limited (UNEP, 2019). In India, mountain systems such as the Himalayas, Western Ghats, and Aravali Hills are vital for ecological balance and human well-being. The Aravali Hills, among the oldest fold mountain ranges in the world, originated more than 2.5 billion years ago during the Proterozoic era. Stretching approximately 692 km from Gujarat through Rajasthan to Haryana and Delhi, the range forms a significant ecological barrier against the eastward expansion of the Thar Desert and plays a critical role in influencing rainfall patterns, groundwater recharge, and regional climate moderation in northwestern India (MoEFCC, 2018). Historically, the Aravali landscape supported dense dry deciduous forests, perennial and seasonal streams, fertile soils, and diverse flora and fauna adapted to semi-arid conditions. However, over the past few decades, the ecological integrity of the Aravali Hills has been severely compromised. Rapid population growth, expanding urbanization, infrastructure development, and unregulated mining of minerals such as limestone, marble, and granite have resulted in widespread deforestation, soil erosion, habitat fragmentation, and groundwater depletion.

The pressure has been particularly intense in the National Capital Region (NCR), where urban expansion has led to large-scale land-use change and encroachment into forest and hill areas (FSI, 2021). The degradation of the Aravali ecosystem has raised serious environmental concerns, including declining groundwater tables, increased frequency of dust storms, loss of biodiversity, and heightened vulnerability to climate variability. According to the Forest Survey of India, several districts within the Aravali range have experienced a significant decline in forest cover and forest quality over recent decades, directly affecting ecosystem services and local livelihoods (FSI, 2021). The weakening of this ancient mountain system has also contributed to rising temperatures and altered micro-climatic conditions in adjacent urban and rural areas. Recognizing the ecological importance of the Aravali Hills, the Government of India and various state governments have initiated conservation and restoration measures, including afforestation programs, mine reclamation, and watershed development projects. In addition, the Supreme Court of India has played a pivotal role in environmental protection by imposing restrictions on mining activities and directing authorities to safeguard the Aravali ecosystem through landmark judgments, notably in the *M.C. Mehta vs Union of India* case (Supreme Court of India, 2009). Despite these interventions, ecological degradation continues due to weak enforcement, fragmented planning, and limited community participation. In this context, ecological restoration of the Aravali Hills has emerged as a critical environmental priority.

Objectives of the Study

The specific objectives of this study are:

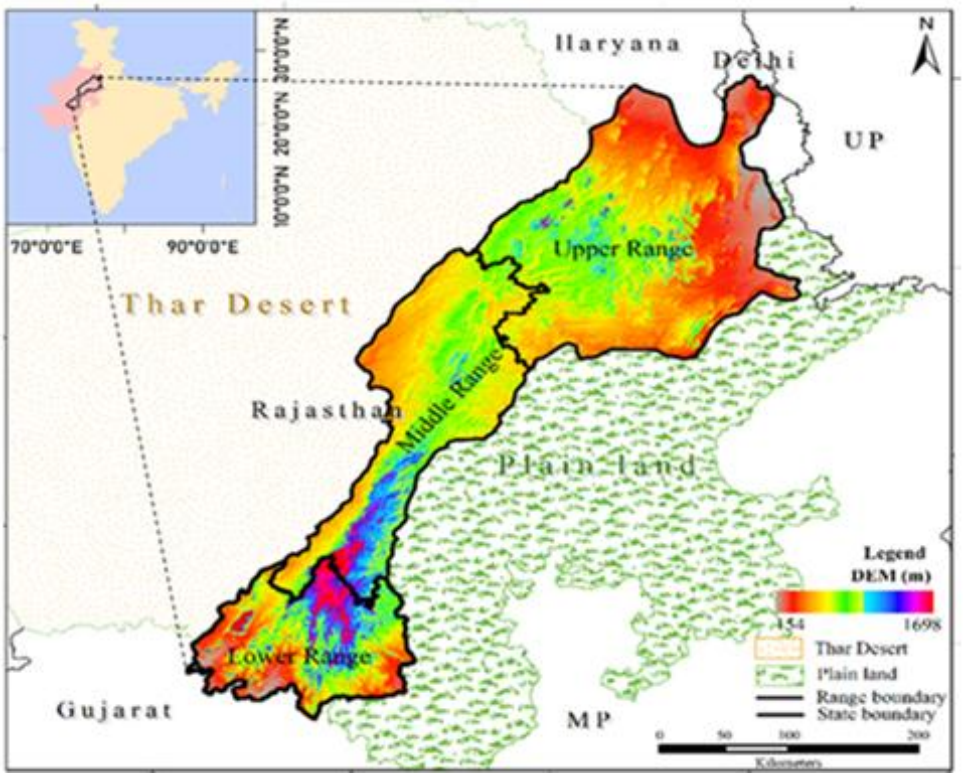
1. To examine the physical and ecological characteristics of the Aravali Hills.
2. To assess the extent and causes of environmental degradation.
3. To evaluate existing ecological restoration initiatives.
4. To identify challenges in the restoration process.

Study Area

The Aravalli's, is the oldest fold mountains on Earth. It spans over 800 km. from Gujarat to Delhi (through Rajasthan and Haryana) in a southwest-northeast direction across northwestern India. Geographically, the range lies between 23°00′ N to 28°00′ N latitudes and 72°30′ E to

77°30′ E longitudes, covering parts of Gujarat, Rajasthan, Haryana, and the National Capital Territory of Delhi. The Aravali system begins near Palanpur in Gujarat, reaches its highest elevation at Mount Abu (1,722 m above mean sea level) in southern Rajasthan, and terminates at the Delhi Ridge, an extension of the range within the Indo-Gangetic Plain. The Aravali Hills are characterized by low to moderate elevations, with average heights ranging from 300 to 900 meters. The range is composed predominantly of ancient metamorphic and igneous rocks, including gneiss, schist, quartzite, and marble, making the terrain geologically fragile and highly susceptible to weathering and erosion. Over geological time, extensive denudation has resulted in discontinuous hillocks rather than a continuous mountain chain. The Aravali region falls largely within the semi-arid to arid climatic zone, with marked spatial variability in rainfall. The average annual rainfall ranges from 300 mm in the western arid margins to about 650 mm in the southeastern parts of the range. Summers are extremely hot, with temperatures frequently exceeding 45°C, while winters remain mild to cool. The range exerts a significant influence on regional climate by partially obstructing the southwest monsoon and acting as a climatic divide between the Thar Desert and the eastern plains. Ecologically, the Aravali Hills support dry deciduous and tropical thorn forest types, though forest cover is highly fragmented and discontinuous. According to the Forest Survey of India, forest cover in many Aravali districts has declined substantially due to mining, agricultural expansion, and urbanization. The region also plays a crucial hydrological role, forming the watershed for several rivers such as the Banas, Luni, Sahibi, and seasonal tributaries of the Sabarmati, and contributing to groundwater recharge in an otherwise water-stressed region.

Figure 01: Key Map



Data Sources and Methodology

This study relies on secondary data from various sources, including government reports from the Ministry of Environment, Forest and Climate Change (MoEFCC) and the Forest Survey of India. It also incorporates environmental case laws, research articles, policy documents, and environmental assessments. Qualitative analysis was employed to synthesize ecological trends, restoration outcomes, and policy effectiveness.

Geology and Relief

The Aravali range is geologically one of the oldest mountain systems in the world, with its origin dating back to the Proterozoic era. The hills are composed predominantly of metamorphic and igneous rocks, including gneiss, schist, quartzite, marble, and granite, belonging to the Aravali Supergroup. These rocks have undergone intense folding, faulting, and metamorphism over geological time, followed by prolonged weathering and erosion. Relief in the Aravali region is generally low to moderate, reflecting advanced stages of denudation. The average elevation of the hills ranges between 300 and 900 meters above mean sea level, with occasional higher peaks and ridges. Mount Abu (1,722 m), located in southern Rajasthan, represents the highest point of the range and forms a prominent geomorphological and ecological unit with relatively higher rainfall and dense forest cover. Elsewhere, the range is characterized by discontinuous hillocks, residual ridges, and isolated rocky outcrops, particularly in northern Rajasthan and Haryana. The highly weathered and fractured nature of Aravali rocks has resulted in shallow and stony soils with low fertility and limited water-holding capacity. These conditions make the region extremely vulnerable to soil erosion, land degradation, and desertification, especially where vegetation cover has been removed due to mining, deforestation, and grazing. The fragile geological structure also increases susceptibility to ecological damage from unscientific mining and construction activities.

Climate and Drainage

The Aravali Hills lie predominantly within the semi-arid to arid zone, though local variations exist due to altitude and slope orientation. The region experiences extreme seasonal contrasts, with hot summers, mild winters, and a short monsoon period. The average annual rainfall ranges from about 300 mm in the western parts to nearly 650 mm in the southeastern sections of the range. Rainfall is highly variable and erratic, often occurring in short, high-intensity spells that enhance surface runoff and soil erosion. Temperatures during summer frequently exceed 45°C, while winter temperatures may fall below 5°C in certain areas. In recent decades, climate change has intensified temperature extremes and increased the frequency of droughts, further stressing the fragile Aravali ecosystem. The Aravali Hills play a significant role in shaping regional drainage patterns and hydrology. The range acts as a watershed divide between rivers draining toward the Arabian Sea and the Bay of Bengal. Important rivers influenced or originating in the Aravali system include the Banas, Luni, and Sahibi, along with numerous seasonal streams and rivulets. These streams are largely rain-fed and exhibit seasonal flow, with many becoming dry during the summer months. Despite limited surface water availability, the fractured rock structure of the Aravali Hills facilitates groundwater recharge, making the range a crucial source of subsurface water for surrounding plains. However, extensive mining, deforestation, and urban development have disrupted natural recharge processes, leading to a decline in groundwater levels in many parts of the region.

Biodiversity and Ecological Significance

The Aravali Hills support a unique and ecologically significant assemblage of flora and fauna adapted to semi-arid and arid environmental conditions. The natural vegetation of the region primarily consists of tropical dry deciduous and tropical thorn forests, which play a vital role in soil conservation, carbon sequestration, and micro-climate regulation. The dominant tree species of the Aravali ecosystem is *Anogeissus pendula* (Dhok), which is well adapted to shallow soils and low rainfall conditions and forms the climax vegetation across large parts of Rajasthan's Aravali belt. According to the Forest Survey of India (FSI), the Aravali landscape supports over 300 species of vascular plants, including trees, shrubs, grasses, and medicinal plants. Other important floral species include *Boswellia serrata*, *Butea monosperma*, *Acacia nilotica*, *Ziziphus mauritiana*, and *Prosopis cineraria*, many of which are ecologically and socio-

economically significant. These forests provide essential ecosystem services such as fodder, fuelwood, non-timber forest products, and livelihood support for local communities.

Faunal diversity in the Aravali region is equally significant, particularly given its location within a human-dominated and climatically stressed landscape. The hills support several medium and large mammals, including the leopard (*Panthera pardus*), striped hyena (*Hyaena hyaena*), nilgai (*Boselaphus tragocamelus*), Indian fox, jungle cat, and wild boar. The presence of apex predators such as the leopard highlights the ecological importance of the Aravali Hills as a functional wildlife habitat, especially in fragmented forest landscapes (MoEFCC, 2018). The Aravali ecosystem is also rich in avian biodiversity, supporting more than 120 species of birds, including resident and migratory species such as peafowl, partridges, raptors, and wetland birds in seasonal water bodies. Biodiversity parks developed in parts of the Aravali range, such as the Aravali Biodiversity Park, Gurugram, have recorded a high diversity of birds, reptiles, butterflies, and native plant species, underscoring the region's restoration potential. Ecologically, the Aravali Hills serve as a crucial wildlife corridor connecting forest patches across Rajasthan, Haryana, and the Delhi Ridge, facilitating animal movement and genetic exchange. However, rapid urbanization, mining, road construction, and land-use change have resulted in severe habitat fragmentation, disrupting these corridors and increasing human–wildlife conflict. Studies indicate that fragmentation between the Rajasthan–Haryana Aravali belt has significantly reduced habitat connectivity, threatening long-term species survival (FSI, 2021). Beyond biodiversity conservation, the Aravali ecosystem plays a critical role in preventing desertification, moderating local climate, supporting groundwater recharge, and enhancing ecological resilience in northwestern India. Degradation of this ecosystem, therefore, has far-reaching implications not only for wildlife but also for human populations dependent on its ecosystem services.

Causes and Extent of Environmental Degradation

The Aravali Hills have experienced extensive environmental degradation over the past several decades due to a combination of anthropogenic pressures and weak regulatory enforcement. The fragile geological structure and semi-arid climate of the region further amplify the impacts of human-induced disturbances. The major drivers and extent of degradation are discussed below.

Mining

Mining has been one of the most significant contributors to environmental degradation in the Aravali region. The hills are rich in marble, limestone, granite, and base metal ores, leading to widespread legal and illegal mining activities, particularly in Rajasthan and Haryana. Unscientific mining practices involving blasting, removal of overburden, and lack of reclamation have resulted in hill slope destabilization, loss of vegetation cover, and severe soil erosion. According to the Supreme Court of India, illegal mining in the Aravali range has caused irreversible damage to the natural landscape, prompting judicial intervention. In the landmark *M.C. Mehta vs Union of India* case, the Court imposed restrictions and bans on mining in ecologically sensitive areas of the Aravali Hills, especially in Haryana (Supreme Court of India, 2009). Despite these measures, illegal mining continues in several pockets, leading to groundwater depletion and air pollution.

Deforestation and Fuelwood Extraction

Deforestation in the Aravali region has been driven by agricultural expansion, grazing pressure, and dependence of local communities on forests for fuelwood and fodder. According to the Forest Survey of India (FSI), several Aravali districts have witnessed a decline in forest

cover and forest quality over recent decades. Fragmentation of forests has reduced canopy density, resulting in increased surface runoff, soil erosion, and loss of habitat for wildlife (FSI, 2021). Fuelwood extraction remains a major livelihood activity in rural parts of Rajasthan and Haryana, further stressing already degraded forest ecosystems. The removal of native tree species has also facilitated the spread of invasive plant species.

Urban and Industrial Expansion

Rapid urbanization and industrial growth, particularly in and around the National Capital Region (NCR), have exerted intense pressure on the Aravali ecosystem. Cities such as Gurugram, Faridabad, Alwar, and Jaipur have expanded into forest and hill areas, leading to large-scale land-use change. Infrastructure development, road construction, and real estate projects have fragmented habitats and disrupted natural drainage systems. Studies indicate that urban expansion has significantly altered land cover patterns in the northern Aravali range, reducing green cover and increasing heat island effects. Industrial activities have also contributed to air and water pollution, further degrading the ecological quality of the region (MoEFCC, 2018).

Invasive Species Proliferation

The degradation of native forests has facilitated the spread of invasive alien species, particularly *Prosopis juliflora*, introduced during the colonial period for fuelwood and afforestation. Although the species is drought-resistant, its aggressive growth has displaced native vegetation, reduced biodiversity, and altered soil properties. The dominance of *Prosopis juliflora* has resulted in simplified ecosystems with lower ecological resilience. Its proliferation is widely observed in degraded mining areas and abandoned lands across the Aravali range, posing a major challenge for ecological restoration efforts.

Extent of Environmental Degradation

The cumulative impact of mining, deforestation, urbanization, and invasive species has led to:

- Significant loss of forest cover and quality
- Decline in groundwater levels (up to 1–2 meters per year in some mining-affected areas, as reported by CGWB)
- Increased soil erosion and desertification risks
- Disruption of wildlife corridors and increased human–wildlife conflict

The Forest Survey of India has consistently highlighted the decline and fragmentation of forest cover in Aravali districts, emphasizing the urgent need for comprehensive restoration and conservation measures (FSI, 2021).

Ecological Restoration Initiatives

Recognizing the ecological degradation of the Aravali Hills, various restoration initiatives have been undertaken by central and state governments, judicial bodies, non-governmental organizations, and urban local bodies. These efforts aim to restore forest cover, stabilize degraded landscapes, improve hydrological functions, and conserve biodiversity. However, their effectiveness varies spatially and institutionally.

Afforestation and Reforestation Programmes

Afforestation and reforestation constitute the most widespread restoration measures in the Aravali region. National schemes such as the National Afforestation Programme (NAP), Compensatory Afforestation Fund Management and Planning Authority (CAMPA), and Green India Mission (GIM) have supported plantation activities across degraded forest lands and

mining-affected areas. According to the Ministry of Environment, Forest and Climate Change (MoEFCC), thousands of hectares in Rajasthan and Haryana have been brought under plantation through these schemes since the early 2000s. However, the ecological effectiveness of these efforts has been mixed. In many cases, plantations relied on fast-growing or non-native species, which improved green cover numerically but contributed little to biodiversity or ecosystem resilience. Studies and field observations indicate that plantations dominated by monocultures lack structural diversity and are less effective in soil and water conservation compared to native dry deciduous species (MoEFCC, 2018).

Mine Reclamation and Backfilling

Mine reclamation has been an essential component of restoration efforts in the Aravali Hills, particularly following judicial interventions. The Supreme Court of India, through various orders, mandated the closure of illegal mines and the ecological rehabilitation of abandoned mining sites in Haryana and Rajasthan (*M.C. Mehta vs Union of India*). Reclamation measures include backfilling of pits, stabilization of mine spoils, soil treatment, and plantation of native species. While some reclaimed sites show early signs of vegetation recovery, large areas remain ecologically unstable due to poor soil quality, lack of long-term monitoring, and continued illegal mining activities. Reports suggest that mine reclamation remains largely cosmetic rather than ecosystem-based, limiting its long-term success (MoEFCC, 2018).

Watershed Development Projects

Given the water-scarce nature of the Aravali region, watershed development has been a key restoration strategy. Programs under the Integrated Watershed Management Programme (IWMP) and state-level initiatives have focused on check dams, contour bunding, percolation tanks, and rainwater harvesting structures. According to the Central Ground Water Board (CGWB), watershed interventions in parts of the Aravali belt have contributed to localized improvements in groundwater recharge and reduced soil erosion. Traditional water conservation structures such as johads, revived through community participation in districts like Alwar, have demonstrated significant ecological and social benefits, including increased water availability and improved agricultural productivity.

Establishment of Biodiversity Parks

One of the most successful ecological restoration examples in the Aravali region is the establishment of biodiversity parks, particularly in urban and peri-urban landscapes. The Aravali Biodiversity Park (ABP), Gurugram, developed on a degraded mining site, serves as a model of science-based ecological restoration. The park has restored over 150 hectares using native plant species and ecological succession principles. Studies report the presence of over 300 plant species, more than 200 bird species, and numerous reptiles, butterflies, and small mammals, highlighting the potential of ecological restoration even in severely degraded landscapes. Similar initiatives in Delhi's Ridge area have also contributed to habitat restoration and environmental awareness.

Assessment of Restoration Outcomes

While restoration initiatives have led to localized improvements in vegetation cover, soil stability, and biodiversity, overall ecological recovery across the Aravali Hills remains fragmented and inconsistent. The lack of landscape-level planning, inadequate coordination among agencies, limited community involvement, and absence of long-term ecological monitoring continue to constrain restoration success. Consequently, restoration efforts often fail to restore natural ecosystem functions and connectivity across the broader Aravali landscape.

Challenges in Ecological Restoration

Despite increasing recognition of the ecological importance of the Aravali Hills, restoration efforts face multiple structural, institutional, and environmental challenges. These challenges limit the effectiveness and long-term sustainability of restoration initiatives across the region.

Weak Enforcement of Environmental Regulations

Although several environmental laws and judicial directives exist to protect the Aravali ecosystem, enforcement remains inconsistent. The Supreme Court of India, through landmark judgments such as *M.C. Mehta vs Union of India*, imposed restrictions on mining and construction activities in ecologically sensitive zones of the Aravali Hills. However, reports by the Comptroller and Auditor General (CAG) and MoEFCC indicate gaps between policy formulation and ground-level implementation, resulting in continued environmental violations. Weak institutional capacity, lack of inter-agency coordination, and inadequate monitoring mechanisms have undermined effective enforcement.

Continued Encroachment

Illegal mining and land encroachment persist as major challenges, particularly in Rajasthan and Haryana. Despite official bans, satellite imagery and field studies reveal ongoing extraction of minerals such as limestone and marble from protected and forest lands. These activities cause irreversible landscape alteration, groundwater depletion, and air pollution. According to government and court-appointed committee reports, several abandoned mines remain unrestored, further exacerbating land degradation and safety risks.

Community Participation

Ecological restoration efforts in the Aravali region have largely followed a top-down approach, with limited involvement of local communities in planning, implementation, and monitoring. While forest-dependent communities possess valuable traditional knowledge related to water conservation and vegetation management, this knowledge remains underutilized. Successful examples such as community-led watershed restoration in Alwar district, including the revival of traditional johads, demonstrate that participatory approaches yield better ecological and social outcomes. The absence of widespread community engagement has constrained the scalability and sustainability of restoration initiatives.

Climate-Induced Stress on Vegetation

Climate change has emerged as a significant challenge to ecological restoration in the Aravali Hills. Increasing temperatures, erratic rainfall patterns, prolonged droughts, and extreme weather events have reduced seedling survival rates and slowed natural regeneration. According to climate assessments by MoEFCC and UNEP, semi-arid regions such as the Aravali belt are particularly vulnerable to climate variability. Restoration projects that do not incorporate climate-resilient species and adaptive management practices often fail to achieve long-term success.

Lack of Long-Term Ecological Monitoring

A major limitation of restoration initiatives in the Aravali Hills is the absence of systematic, long-term ecological monitoring. Many projects focus on short-term targets such as plantation numbers rather than ecosystem functionality and resilience. The lack of scientific monitoring using GIS, remote sensing, and biodiversity indicators makes it difficult to assess restoration outcomes, identify failures, and adapt management strategies. The Forest Survey of India has repeatedly emphasized the need for continuous monitoring to evaluate forest health and ecological recovery.

Future Prospects and Sustainable Restoration Framework

The long-term ecological restoration of the Aravali Hills requires a holistic, science-based, and participatory framework that moves beyond isolated plantation activities and addresses the landscape as an integrated socio-ecological system. Given the increasing pressures of climate change, urbanization, and resource extraction, future restoration strategies must be both ecologically resilient and socially inclusive.

Strict Implementation of Environmental Laws and Court Orders

Effective restoration of the Aravali ecosystem is contingent upon robust enforcement of existing environmental laws, including the Forest Conservation Act (1980), Environment Protection Act (1986), and judicial directives issued by the Supreme Court of India. The landmark *M.C. Mehta vs Union of India* case led to the closure of several illegal mines in Haryana and Rajasthan, demonstrating that judicial intervention can yield tangible ecological benefits when properly implemented. Strengthening institutional capacity, improving inter-state coordination, and leveraging technology for surveillance can enhance compliance and prevent further degradation.

Landscape-Level Restoration Planning

Future restoration efforts must adopt a landscape-level approach, integrating forests, watersheds, grasslands, and human settlements rather than focusing on isolated sites. Studies suggest that fragmented restoration fails to restore ecological connectivity and wildlife corridors, particularly between Rajasthan–Haryana–Delhi Aravali belts. Landscape planning can help restore hydrological flows, reduce soil erosion, and facilitate species movement. Successful models from watershed-based restoration projects in semi-arid India demonstrate that such integrated planning enhances ecosystem resilience and service delivery.

Use of Native Species and Ecological Principles

The use of native, site-specific plant species is essential for sustainable restoration in the semi-arid Aravali region. Species such as *Anogeissus pendula*, *Boswellia serrata*, *Butea monosperma*, and *Prosopis cineraria* are better adapted to low rainfall, shallow soils, and high temperatures. Ecological restoration projects like the Aravali Biodiversity Park, Gurugram, which replaced invasive *Prosopis juliflora* with native species, have demonstrated improved biodiversity, soil stability, and ecosystem functionality. This example highlights the importance of ecological succession, soil restoration, and long-term maintenance.

Community-Based Conservation Models

Integrating local communities into restoration planning and implementation is critical for long-term success. Community-led initiatives, such as the revival of traditional water harvesting systems (johads) in Alwar district, have significantly improved groundwater levels and vegetation cover while enhancing local livelihoods. According to studies and government reports, participatory watershed management has resulted in measurable increases in water availability and agricultural productivity. Scaling up such community-based conservation models can ensure social acceptance, reduce resource conflicts, and strengthen stewardship of restored landscapes.

Scientific Monitoring Using GIS and Remote Sensing

Scientific monitoring is essential to assess restoration outcomes and guide adaptive management. The application of GIS, remote sensing, and biodiversity indicators enables continuous monitoring of forest cover, land-use change, vegetation health, and habitat connectivity. The Forest Survey of India has demonstrated the utility of satellite-based

assessments in tracking forest cover changes across Aravali districts. Integrating such tools with field-based ecological monitoring can improve transparency, accountability, and evidence-based decision-making in restoration projects.

Integrating Ecological Restoration with Sustainable Livelihoods

For restoration to be sustainable, it must be aligned with livelihood opportunities for local communities. Promotion of non-timber forest products, eco-tourism, agroforestry, and nature-based enterprises can generate income while conserving ecosystems. National initiatives such as the Green India Mission emphasize the linkage between ecological restoration and livelihood security. Integrating restoration with sustainable livelihoods not only reduces dependency on extractive activities but also ensures long-term maintenance of restored ecosystems.

Conclusion

The Aravali Hills constitute one of India's most ancient and ecologically significant mountain systems, performing critical functions in climate regulation, biodiversity conservation, groundwater recharge, and prevention of desertification in northwestern India. Despite their immense environmental value, the Aravali ecosystem has undergone severe degradation over the past several decades due to unregulated mining, deforestation, rapid urbanization, and climate-induced stresses. The cumulative impact of these pressures has resulted in fragmented habitats, declining forest quality, falling groundwater levels, and increased ecological vulnerability across the region. This study highlights that although ecological restoration initiatives including afforestation programmes, mine reclamation, watershed development, and biodiversity parks have generated localized improvements in vegetation cover and ecosystem functions, their overall impact remains limited due to fragmented implementation, weak enforcement, and inadequate long-term monitoring. Restoration efforts have often focused on short-term targets rather than restoring natural ecological processes, landscape connectivity, and ecosystem resilience. The findings underscore the urgent need for a comprehensive, science-based, and participatory restoration approach that integrates ecological principles with social and economic considerations. Strengthening governance through strict enforcement of environmental laws and judicial directives, particularly in mining and urban expansion zones, is essential to prevent further degradation. Equally important is the active involvement of local communities, whose traditional knowledge and stewardship can significantly enhance restoration outcomes, as demonstrated by successful watershed and community-led conservation initiatives in the Aravali region. The increasing impacts of climate change necessitate the adoption of climate-resilient restoration strategies, including the use of native species, adaptive management practices, and continuous scientific monitoring using GIS and remote sensing technologies. Integrating ecological restoration with sustainable livelihood opportunities, such as agroforestry, non-timber forest products, and eco-tourism, can ensure long-term maintenance of restored ecosystems while improving socio-economic well-being. In conclusion, the ecological restoration of the Aravali Hills is not merely an environmental imperative but a critical component of sustainable regional development and climate adaptation. A coordinated, multi-stakeholder approach that aligns conservation goals with development planning is essential to safeguard this fragile ecosystem for future generations and to realize broader national objectives related to environmental sustainability and resilience.

References

1. Central Ground Water Board (CGWB). (2020) Groundwater Year Book Rajasthan and Haryana. Government of India.

2. Champion, H.G., & Seth, S.K. (1968) A Revised Survey of the Forest Types of India. Government of India Press, New Delhi.
3. Comptroller and Auditor General of India (CAG). (2017) Performance Audit on Environmental Management. Government of India.
4. Forest Survey of India (2021) India State of Forest Report 2021. Ministry of Environment, Forest and Climate Change, Government of India, Dehradun.
5. Forest Survey of India (FSI). (2021) India State of Forest Report. Dehradun: Ministry of Environment, Forest and Climate Change, Government of India.
6. Forest Survey of India (FSI). (2021) India State of Forest Report. Dehradun: Government of India.
7. Geological Survey of India (2019). Mineral Resources of Rajasthan. GSI Publications, Kolkata.
8. Government of Haryana. (2019) Action Plan for Conservation of Aravali Region. Chandigarh.
9. Gupta, A., & Nair, S.S. (2020) Ecological restoration in degraded landscapes of India: A review of challenges and opportunities. Tropical Ecology, 61(4), 445-462.
10. Indian Meteorological Department (2020) Climate Data for Northwestern India (1980-2020). IMD, New Delhi.
11. Khare, N., Srivastava, P.K., & Mall, L.P. (2018) Vegetation dynamics and carbon sequestration in the Aravalli Hill Range. Journal of Mountain Science, 15(7), 1534-1548.
12. Ministry of Environment, Forest and Climate Change (2019) Report of the Expert Committee on Aravalli Conservation. Government of India, New Delhi.
13. Ministry of Environment, Forest and Climate Change (MoEFCC). (2018) National Afforestation Programme Guidelines. New Delhi: Government of India.
14. Murthy, I.K., Gupta, M., Tomar, S., Munsi, M., Tiwari, R., Hegde, G.T., & Ravindranath, N.H. (2013. Carbon sequestration potential of agroforestry systems in India. Journal of Earth Science & Climatic Change, 4(1), 1-7.
15. Prusty, B.A.K., Mishra, P.C., & Azeez, P.A. (2009) Dust accumulation and leaf pigment content in vegetation near the national highway at Sambalpur, Orissa, India. Ecotoxicology and Environmental Safety, 72(3), 865-871.
16. Rai, S.C., & Sharma, E. (1998) Comparative assessment of runoff characteristics under different land use patterns within a Himalayan watershed. Hydrological Processes, 12(13-14), 2235-2248.
17. Ramakrishnan, P.S. (2007) Sustainable Mountain Development: From Rio to Rio+20 and beyond. Bishen Singh Mahendra Pal Singh, Dehradun.
18. Rodgers, W.A., Panwar, H.S., & Mathur, V.B. (2002) Wildlife Protected Area Network in India: A Review (Executive Summary). Wildlife Institute of India, Dehradun.
19. Sharma, E., Chettri, N., & Oli, K.P. (2010) Mountain biodiversity conservation and management: A paradigm shift in policies and practices in the Hindu Kush-Himalayas. Ecological Research, 25(5), 909-923.
20. Singh, S., & Kumar, A. (2017) Environmental degradation of the Aravali range: Causes and consequences. Indian Journal of Environmental Studies, 24(2), 45–58.
21. Supreme Court of India. (2009) M.C. Mehta vs Union of India (Aravali mining case), Writ Petition (Civil) No. 4677/1985.
22. Supreme Court of India. (2018) Order on protection of Aravali Hills, Environmental Matters.
23. Tewari, V.P., & Verma, A. (2019) Carbon sequestration potential of Aravalli Hills ecosystem. Indian Forester, 145(3), 201-208.
24. UNEP (2019) Ecosystem Restoration for Sustainable Development. United Nations Environment Programme.
25. Wildlife Institute of India (2018) Status of Wildlife in Aravalli Landscape. WII Technical Report, Dehradun.
26. Wildlife Institute of India (2016) Biodiversity Assessment of Semi-Arid Ecosystems in India. Dehradun.
27. World Wildlife Fund-India (2020) Conserving the Aravallis: Challenges and Opportunities. WWF-India, New Delhi.