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The Ecology-Commerce Nexus of Biodiversity Loss: Implications for Human Health and Economic Productivity in the Aravalli Range, India

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Abstract

Biodiversity loss has emerged as a critical challenge with far-reaching ecological, public health, and economic consequences. This study investigates the relationship between biodiversity degradation, human health outcomes, and economic productivity in the Aravalli Range, India-one of the country's most environmentally stressed ecological regions. Drawing upon secondary data from government reports, international databases, and peer-reviewed literature, the study employs a descriptive and trend-based analytical framework to examine changes in forest cover, water availability, health-related vulnerabilities, public health expenditure, and selected indicators of human development. The findings suggest that biodiversity degradation in the Aravalli region contributes to ecosystem instability and water stress, which in turn increase health risks and economic burdens through higher healthcare expenditure, reduced labour productivity, and constraints on sustainable development. The study further demonstrates that the economic costs associated with ecosystem degradation remain largely underrepresented in conventional measures of economic performance and development planning. By integrating ecological, health, and economic dimensions within a commerce-oriented natural capital framework, the paper highlights biodiversity as a productive economic asset essential for long-term human well-being and economic resilience. The findings underscore the need for biodiversity-sensitive governance, ecosystem valuation, and the integration of natural capital considerations into economic policy and development strategies.

Keywords

Biodiversity loss, Economic productivity, Ecosystem degradation, Human Development Index, Human health, Water Scarcity.

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1. Introduction

Biodiversity constitutes a fundamental component of natural capital and underpins the ecosystem services that sustain human well-being, economic activity, and environmental stability. Healthy ecosystems provide essential services such as water purification, climate regulation, pollination, disease regulation, and nutrient cycling, all of which contribute directly and indirectly to human health and economic productivity (WHO, 2015; Costanza *et al.*, 2014; Dasgupta, 2021). As recognized within the natural capital framework, biodiversity is not merely an environmental asset but a productive resource that supports livelihoods, public health, and long-term economic development. Consequently, biodiversity conser= vation has emerged as an important consideration within sustainable development and economic governance discourse.

Despite its importance, biodiversity loss has become one of the most significant global challenges of the twenty-first century. Recent assessments indicate that the accelerating decline of species, habitats, and ecosystem functions is undermining ecosystem resilience and reducing the capacity of natural systems to support human societies (IPBES, 2019; Díaz *et al.*, 2019). The degradation of ecosystem services contributes to increasing water scarcity, environmental stress, and heightened exposure to health risks, thereby generating substantial social and economic costs. These impacts often manifest through reduced labour productivity, increased healthcare expenditure, and weakened developmental outcomes, particularly in regions where communities remain highly dependent on ecosystem resources (World Bank, 2021; Dasgupta, 2021). From an economic perspective, such consequences represent negative externalities and the depreciation of natural capital that remain inadequately reflected in conventional measures of economic performance and development planning.

The growing recognition of the interdependence between ecological systems and economic outcomes has strengthened interest in understanding biodiversity through an integrated ecological-economic perspective. Within this framework, biodiversity conservation generates economic value through the maintenance of ecosystem services, while biodiversity degradation creates hidden costs that affect households,

businesses, and governments alike (Costanza *et al.*, 1997; TEEB, 2010). Ecosystem degradation can reduce water availability, increase public health burdens, disrupt livelihood opportunities, and impose additional expenditure on environmental restoration and healthcare systems. As a result, biodiversity loss is increasingly viewed not only as an environmental concern but also as a development and economic challenge with implications for long-term sustainability.

India occupies a particularly important position within this discourse. As one of the world's mega-diverse countries, India hosts a rich variety of ecosystems, species, and genetic resources while simultaneously supporting a large population that depends directly and indirectly on ecosystem services for water security, health, agriculture, and livelihood generation (Convention on Biological Diversity, 2022). However, rapid urbanization, industrialization, land-use change, and resource extraction have intensified pressures on biodiversity and ecosystem integrity. The degradation of natural capital therefore has implications extending beyond ecological sustainability to encompass economic productivity, public health, and human development (UNDP, 2020).

Within the Indian context, the Aravalli Range represents an ecologically and economically significant landscape. Stretching across north-western India, the Aravalli ecosystem serves as a critical ecological corridor and supports diverse flora and fauna while providing essential ecosystem services such as groundwater recharge, soil stabilization, biodiversity conservation, carbon sequestration, and micro-climatic regulation. These services contribute substantially to regional water security, environmental quality, agricultural productivity, and economic activity. However, increasing pressures from mining, deforestation, land-use transformation, and urban expansion have accelerated ecological degradation across the region. Such changes have been associated with declining groundwater levels, habitat fragmentation, environmental stress, and growing public health concerns, thereby creating challenges for sustainable regional development.

Although a substantial body of literature has examined biodiversity conservation, ecosystem services, environmental sustainability, and public health outcomes, these themes have largely been studied in isolation. Limited research has adopted an integrated natural capital perspective that simultaneously evaluates the ecological, health, and economic consequences of biodiversity loss within a specific regional context. In particular, empirical studies linking biodiversity degradation to water stress, health-related expenditure, labour productivity, and broader development outcomes remain scarce for the Aravalli Range. This fragmentation restricts a comprehensive understanding of the economic implications of ecosystem

decline and limits the incorporation of biodiversity considerations into development planning and governance frameworks.

Against this backdrop, the present study examines the relationship between biodiversity loss, human health, and economic productivity in the Aravalli Range, India. Using a descriptive and trend-based analytical approach, the study integrates ecological, water, health, and development indicators to evaluate the broader consequences of ecosystem degradation. The paper seeks to demonstrate that biodiversity conservation and ecosystem restoration are not merely environmental imperatives but strategic economic investments that contribute to human well-being, productivity, and sustainable development. In doing so, the study contributes to the growing literature on biodiversity, natural capital, and sustainable development while highlighting the importance of incorporating ecosystem values into economic planning, governance, and policy formulation.

2. Conceptual Framework: The Ecology-Commerce Nexus of Biodiversity, Health and Economic Productivity

The conceptual framework of this study is based on the Ecology-Commerce Nexus, an integrated analytical perspective that views biodiversity as a productive component of natural capital supporting both human well-being and economic development. Within this framework, ecological systems are recognized not merely as environmental assets but as economic resources that generate valuable ecosystem services essential for sustaining livelihoods, public health, and long-term productivity. Biodiversity supports a wide range of ecological functions, including water regulation, climate moderation, soil conservation, pollination, nutrient cycling, and disease control. These ecosystem services contribute directly to environmental sustainability and indirectly to economic performance by maintaining the ecological conditions necessary for human and economic activity (Costanza *et al.*, 2014; Dasgupta, 2021; World Bank, 2021).

The framework assumes that biodiversity loss initiates a chain of interconnected ecological, social, and economic consequences. As biodiversity declines, ecosystems become less resilient and less capable of providing critical regulatory and provisioning services. This process represents the depreciation of natural capital, reducing the capacity of ecological systems to support human societies and economic activities. The resulting environmental stress often manifests through ecosystem degradation, declining resource availability, and increased vulnerability to ecological disturbances. Since many of these costs are not reflected in market prices or national accounting systems, the economic consequences of biodiversity loss frequently remain hidden despite their substantial long-term implications.

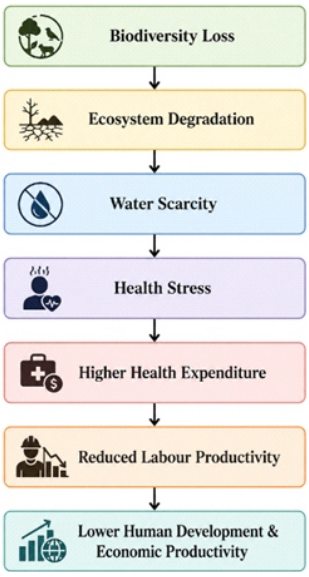
A central pathway within the framework links biodiversity loss to human health outcomes. Ecosystem degradation can adversely affect environmental quality, disrupt natural disease regulation mechanisms, increase climate-related stress, and reduce access to ecosystem-derived resources that contribute to public health. Such changes heighten health vulnerabilities and place additional pressure on healthcare systems (IPBES, 2019; Díaz *et al.*, 2019). Deteriorating health conditions weaken human capital by reducing labour efficiency, increasing absenteeism, and raising public and private healthcare expenditure. Consequently, adverse health outcomes represent an important channel through which biodiversity loss influences economic productivity and development.

Water scarcity is conceptualized as a critical mediating variable connecting ecological degradation with health and economic outcomes. Biodiverse ecosystems contribute significantly to groundwater recharge, watershed protection, and hydrological stability. The degradation of these ecosystems reduces their capacity to regulate water resources, leading to declining groundwater availability and increasing water stress. Reduced water security negatively affects agricultural production, industrial activity, and household welfare while simultaneously increasing the risk of water-related health problems. Water scarcity therefore functions as a key transmission mechanism through which biodiversity loss affects both human well-being and economic performance.

The framework further incorporates the economic concepts of natural capital depreciation, negative externalities, and market failure. When the environmental costs associated with biodiversity loss are excluded from production and consumption decisions, economic agents are incentivized to overexploit ecological resources. This results in socially inefficient outcomes where short-term economic gains are achieved at the expense of long-term ecological sustainability and economic resilience. The failure to internalize environmental costs contributes to the systematic undervaluation of ecosystem services and may create an inaccurate perception of economic progress (TEEB, 2010; Dasgupta, 2021).

Based on these relationships, the study conceptualizes biodiversity loss as an indirect driver of economic stress operating through ecosystem degradation, water insecurity, and adverse health outcomes. The proposed framework suggests that biodiversity conservation and ecosystem restoration generate economic benefits by strengthening ecosystem services, improving public health conditions, enhancing resource security, and reducing productivity losses. In ecologically sensitive regions such as the Aravalli Range, where communities remain closely dependent on ecosystem resources, these interconnections become particularly significant. Accordingly, biodiversity conservation is viewed not merely as

an environmental objective but as a strategic investment in natural capital, human capital, economic productivity, and sustainable development.



3. Review of Literature

3·1 Global Perspectives on Biodiversity, Human Health and Economic Development

The relationship between biodiversity, human health, and economic development has attracted increasing attention within environmental and ecological economics literature. Early work by Costanza *et al.* (1997) demonstrated the substantial economic value of ecosystem services, arguing that ecological systems generate critical benefits that are often excluded from conventional market valuation. Subsequent studies expanded this perspective by emphasizing biodiversity as a key component of natural capital that supports economic productivity and human well-being (Costanza *et al.*, 2014).

The World Health Organization has consistently highlighted the importance of biodiversity and ecosystem services for public health, particularly through their role in water purification, air quality regulation, food security, and disease control (WHO, 2015; WHO, 2020). Similarly, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services reported that approximately one million species face extinction risks due to human activities, with significant implications for ecosystem resilience, food systems, and public health outcomes (IPBES, 2019). Díaz *et al.* (2019) further argued that biodiversity decline reduces nature's capacity to provide essential services necessary for sustaining human societies.

From an economic perspective, the Dasgupta Review (2021) conceptualizes biodiversity as a productive asset and argues that economic

systems have historically treated natural capital as a free and inexhaustible resource. The review contends that the failure to account for biodiversity loss results in market failures, inefficient resource allocation, and long-term economic vulnerabilities. Collectively, these studies establish a strong theoretical and empirical foundation linking biodiversity conservation with health security, economic resilience, and sustainable development.

3·2 Biodiversity Governance: SDGs, CBD and the Global Biodiversity Framework

International governance frameworks increasingly recognize biodiversity as a prerequisite for sustainable development. The United Nations Sustainable Development Goals integrate biodiversity considerations across multiple goals, including health and well-being (SDG 3), clean water and sanitation (SDG 6), climate action (SDG 13), and life on land (SDG 15), highlighting the interconnected nature of ecological and socio-economic development (United Nations, 2015).

The Convention on Biological Diversity has played a central role in promoting biodiversity conservation through international cooperation and policy coordination. The Kunming-Montreal Global Biodiversity Framework emphasizes ecosystem restoration, sustainable resource management, and the integration of biodiversity values into national accounting and development planning processes (CBD, 2022). These initiatives reflect a growing recognition that biodiversity conservation is not solely an environmental objective but also an economic and developmental necessity.

Despite significant progress in global biodiversity governance, implementation challenges remain substantial. Several assessments indicate persistent gaps between conservation commitments and on-ground outcomes, particularly in developing economies facing competing development priorities. Consequently, researchers increasingly advocate the incorporation of ecosystem valuation and natural capital accounting into policy frameworks to better align economic decision-making with ecological sustainability.

3·3 Biodiversity, Ecosystem Degradation and Development in India

India represents one of the world's megadiverse countries and supports a large population dependent on ecosystem services for livelihoods, agriculture, water security, and public health. National assessments conducted by the Ministry of Environment, Forest and Climate Change and the Forest Survey of India indicate that while forest conservation efforts have achieved some success, several ecosystems continue to face pressures from urbanization, infrastructure expansion, mining activities, and land-use change (MoEFCC; FSI).

Water security has emerged as a critical concern within the Indian environmental context. Reports of the Central Ground Water Board highlight increasing groundwater depletion across several regions of the country, particularly in semi-arid and ecologically fragile landscapes (CGWB). Environmental degradation and declining ecosystem quality have also been linked to public health vulnerabilities. Studies conducted by the Indian Council of Medical Research emphasize the growing influence of environmental stressors on disease burden and population health outcomes, particularly among vulnerable communities (ICMR).

These findings suggest that biodiversity conservation in India is closely linked with broader development objectives, including water security, public health, and sustainable economic growth. However, much of the existing literature continues to examine these dimensions independently rather than through an integrated ecological-economic framework.

3·4 Studies on the Aravalli Range

The Aravalli Range constitutes one of India's oldest mountain systems and performs critical ecological functions, including groundwater recharge, soil conservation, biodiversity conservation, and micro-climatic regulation. Existing studies identify mining, deforestation, urban expansion, and land-use transformation as major drivers of ecological degradation within the region.

Research undertaken by environmental organizations and academic institutions documents declining vegetation cover, habitat fragmentation, groundwater stress, and increasing environmental vulnerability across the Aravalli landscape. Several studies emphasize the importance of the Aravallis in maintaining regional hydrological balance and mitigating desertification processes in north-western India. Other investigations have highlighted the depletion of medicinal plants, biodiversity decline, and the weakening of ecosystem services resulting from anthropogenic pressures.

Although these studies provide valuable insights into ecological degradation within the Aravalli ecosystem, they remain predominantly environmental in orientation. Limited attention has been devoted to examining how biodiversity loss influences public health outcomes, healthcare expenditure, labour productivity, and broader economic development indicators. As a result, the economic implications of ecosystem degradation remain insufficiently explored within the regional literature.

3·5 Synthesis and Research Gap

The literature reviewed demonstrates a growing global consensus that biodiversity constitutes a critical form of natural capital supporting ecosystem stability, human health, and economic productivity. Existing studies establish important linkages between biodiversity conservation,

ecosystem services, public health, and sustainable development. International governance frameworks further reinforce the need to integrate biodiversity considerations into policy and economic planning.

However, three important gaps remain evident. First, much of the existing literature examines biodiversity, health, and economic development separately rather than through an integrated analytical framework. Second, limited research explicitly investigates the economic consequences of biodiversity degradation through pathways such as healthcare expenditure, labour productivity, and human development outcomes. Third, the mediating role of water scarcity linking biodiversity loss to health and economic performance remains underexplored in region-specific studies, particularly within ecologically sensitive landscapes such as the Aravalli Range.

The present study seeks to address these gaps by examining biodiversity loss, water scarcity, human health, and economic productivity within a unified natural capital framework. By focusing on the Aravalli Range, the study contributes to the emerging literature that links ecological sustainability with economic development and human well-being.

4. Study Area: The Aravalli Range

The Aravalli Range is one of the oldest fold mountain systems in the world and constitutes a major ecological landscape in north-western India. Extending approximately 700 kilometres from Gujarat through Rajasthan and Haryana to Delhi, the Aravallis serve as a critical ecological barrier that influences regional climate, supports biodiversity, and contributes significantly to groundwater recharge in an otherwise semi-arid environment. The mountain range plays an important role in maintaining ecological balance and providing ecosystem services essential for human well-being and economic activities across the region.

Ecologically, the Aravalli ecosystem supports diverse flora and fauna adapted to arid and semi-arid conditions. The range functions as an important habitat corridor and contributes to soil conservation, carbon sequestration, watershed protection, and micro-climatic regulation. These ecosystem services support agricultural productivity, water security, and environmental sustainability in surrounding regions. However, increasing anthropogenic pressures, including mining, deforestation, urban expansion, infrastructure development, and land-use transformation, have significantly altered the structure and functioning of the ecosystem. Various environmental assessments have reported habitat fragmentation, vegetation degradation, and declining ecological integrity across several sections of the Aravalli belt (MoEFCC; Forest Survey of India).

Among the ecosystem services provided by the Aravallis, water regulation is of particular economic significance. The range facilitates

groundwater recharge and supports regional hydrological stability through its forest cover and watershed functions. Reports of the Central Ground Water Board indicate increasing groundwater stress in many districts influenced by the Aravalli system, with ecological degradation contributing to declining recharge capacity and reduced water availability. Water scarcity has important implications for agriculture, industry, and household welfare while simultaneously increasing health risks associated with inadequate access to safe water resources.

The ecological degradation of the Aravalli Range has broader implications for economic productivity and human development. The weakening of ecosystem services can increase healthcare expenditure, reduce labour productivity, heighten vulnerability to climate-related risks, and impose additional costs on governments and communities. These impacts illustrate how biodiversity loss generates economic consequences that are often overlooked in conventional development assessments. Consequently, the Aravalli Range provides a highly relevant case for examining the interrelationships between biodiversity loss, water security, human health, and economic productivity.

Given its ecological significance, growing environmental pressures, and direct relevance to regional development challenges, the Aravalli ecosystem serves as an appropriate study area for analysing the broader implications of biodiversity degradation. The region offers a valuable context for understanding how the loss of natural capital affects human well-being and economic resilience, thereby contributing to the emerging discourse on biodiversity, sustainable development, and ecological economics.

5. Research Gap and Objectives

5·1 Research Gap

Existing global studies have firmly established the linkages between biodiversity loss, ecosystem degradation, environmental stress, and human well-being (IPBES, 2019; WHO, 2020). Research has increasingly recognized biodiversity as a critical component of natural capital that supports ecosystem services essential for health, livelihoods, and economic development. Within the Indian context, numerous studies and government assessments document region-specific challenges, including declining forest quality, groundwater depletion, land degradation, and increasing environmental health vulnerabilities (MoEFCC; Forest Survey of India; Central Ground Water Board; Indian Council of Medical Research).

Despite this growing body of literature, several important gaps remain. First, much of the existing research adopts ecological or public health perspectives, with limited attention to commerce-oriented outcomes such as labour productivity, public health expenditure, and broader development

indicators. Second, the role of water scarcity as a key transmission mechanism linking biodiversity degradation to health and economic outcomes remains insufficiently explored within integrated ecological-economic frameworks. Third, region-specific studies of ecologically sensitive landscapes, particularly the Aravalli Range, rarely examine biodiversity loss, human health, and economic productivity within a unified analytical structure.

As a result, biodiversity degradation continues to be under-recognized as an economic concern despite generating significant negative externalities, imposing hidden costs on society, and creating long-term risks for sustainable development. Addressing these gaps requires an integrated approach that considers the ecological, health, and economic dimensions of biodiversity loss simultaneously.

5·2 Objectives of the Study

In response to the identified research gaps, the present study seeks to achieve the following objectives:

1 To analyze recent trends in biodiversity degradation in the Aravalli Range using ecosystem-based proxy indicators.
2. To examine the linkages between biodiversity loss and human health outcomes, with particular reference to environmental and water-related stress.
3. To assess the role of water scarcity as a potential mediating pathway connecting biodiversity degradation and health-related vulnerabilities.
4. To evaluate the economic implications of biodiversity loss with reference to public health expenditure and labour productivity.
5. To examine the influence of biodiversity degradation on broader human development outcomes, with particular reference to the Human Development Index (HDI).
6. To interpret biodiversity loss within a commerce-oriented natural capital framework and highlight its implications for sustainable development and economic resilience.

6. Research Methodology

6·1 Research Design

The study adopts a descriptive and analytical research design to examine the interrelationships between biodiversity loss, human health, and economic productivity in the Aravalli Range. A descriptive approach is employed to identify trends and patterns in ecological, health, and economic indicators, while analytical interpretation is used to examine the potential linkages among these variables within a natural capital framework. This design is appropriate because the study seeks to understand broad ecological-economic relationships rather than establish direct causal effects.

The analysis is guided by a commerce-oriented perspective that interprets biodiversity loss as a form of natural capital depreciation and a source of negative economic externalities. Accordingly, the study evaluates how ecosystem degradation may influence human well-being and economic outcomes through pathways such as water scarcity, health stress, and productivity constraints.

6·2 Data Sources and Period of Study

The study is based exclusively on secondary data obtained from authoritative national and international sources to ensure reliability, transparency, and comparability. Secondary data are particularly suitable for the present study because biodiversity, health, and economic indicators are generated by specialized institutions through standardized data collection procedures and are widely used in environmental and development research.

The period of analysis spans 2019-2024, covering pre-pandemic, pandemic, and post-pandemic phases. This period enables the examination of recent trends while capturing structural changes affecting environmental conditions, public health, and economic performance.

Major sources of data include the following:

- Ministry of Environment, Forest and Climate Change (MoEFCC) - India State of Forest Reports (ISFR).
- Forest Survey of India (FSI) - Forest cover and vegetation assessments.
- Central Ground Water Board (CGWB) - Groundwater assessment reports.
- Indian Council of Medical Research (ICMR) - Disease burden and environmental health studies.
- National Health Accounts (NHA) - Public health expenditure statistics.
- Ministry of Statistics and Programme Implementation (MoSPI) - Economic and productivity indicators.
- United Nations Development Programme (UNDP) - Human Development Index (HDI).
- Food and Agriculture Organization (FAO) and World Bank - International environmental and development datasets.

The analysis focuses on the Aravalli Range and associated regions where ecological conditions, water availability, and human development indicators are directly influenced by the functioning of the Aravalli ecosystem.

6·3 Variables and Proxy Indicators

Direct measurement of biodiversity, ecosystem services, and health outcomes at the regional level is often constrained by data limitations. Therefore, the study employs following proxy indicators, a widely accepted approach in environmental economics and sustainability research:

- Biodiversity Indicators.
- Forest cover trends.
- Land degradation status.
- Vegetation stress and ecosystem condition.
- Water and Health Indicators.
- Groundwater stress levels.
- Water availability trends.
- Disease burden and environmental health vulnerabilities.
- Public health expenditure.
- Economic and Development Indicators.
- Labour productivity trends.
- Health-related economic burden.
- Human Development Index (HDI).

Water scarcity is treated as a mediating variable that potentially connects biodiversity degradation with health and economic outcomes. The conceptual framework assumes that ecosystem degradation may reduce water security, thereby influencing both public health conditions and economic productivity.

6·4 Analytical Approach

The study employs a trend-based and comparative analytical approach. Data are organized into thematic tables and examined across the study period to identify observable patterns and associations among biodiversity, water, health, and economic indicators. Descriptive statistics, percentage changes, and comparative trend analysis are used wherever appropriate.

The interpretation of findings is guided by the concepts of natural capital depreciation, market failure, and negative externalities. Biodiversity loss is viewed as an environmental cost that may generate indirect economic consequences through reduced ecosystem services, increased health burdens, and productivity constraints. Given the descriptive nature of the study and the reliance on secondary data, the analysis focuses on identifying plausible associations rather than establishing causal relationships.

6·5 Limitations of the Study

The study is subject to certain limitations. First, the analysis relies exclusively on secondary data, which may vary in coverage, methodology, and reporting standards across institutions. Second, biodiversity and ecosystem services are represented through proxy indicators rather than direct ecological measurements. Third, the study adopts a descriptive analytical approach and therefore does not employ econometric techniques to establish causal relationships among variables. Consequently, the findings should be interpreted as indicative of broader ecological-economic patterns rather than definitive causal effects.

Despite these limitations, the study provides valuable insights into the interconnected nature of biodiversity, human health, and economic productivity and contributes to the growing literature on natural capital and sustainable development.

7. Results and Interpretation

7·1 Forest Cover Status of Selected Aravalli Districts in Gujarat

Table-1A: Forest Cover Status of Selected Aravalli Districts in Gujarat (2023)

District	Total Forest Cover (km^2)	% of Geographical Area	Change from 2021 (km^2)
Aravalli	279.54	8.87	+17.13
Banaskantha	812.51	7.54	-4.67
Sabarkantha	559.67	13.16	+18.41
Mahisagar	293.83	11.70	-10.13
Chhota Udepur	453.81	13.14	-13.02

Source: Compiled by the author from Forest Survey of India (FSI), India State of Forest Report (ISFR) 2023.

The above table presents forest cover patterns in selected districts forming part of the Gujarat segment of the Aravalli landscape based on the India State of Forest Report (2023). The findings reveal mixed trends in forest cover between 2021 and 2023, indicating that ecological conditions vary across districts. Aravalli and Sabarkantha districts recorded positive changes of 17.13 km^2 and 18.41 km^2 respectively, suggesting localized improvements in forest cover. In contrast, Banaskantha, Mahisagar, and Chhota Udepur experienced declines ranging from 4.67 km^2 to 13.02 km^2, reflecting continuing ecological pressures.

Despite some gains, the overall pattern does not indicate uniform ecosystem recovery across the region. Forest cover as a proportion of geographical area remains relatively modest in several districts, while the observed declines in others point to ongoing challenges associated with

land-use change, habitat fragmentation, resource extraction, and environmental stress. These findings suggest that biodiversity conservation outcomes within the Aravalli landscape remain uneven and that localized improvements have not fully offset broader ecological vulnerabilities.

From the perspective of the study's conceptual framework, the mixed forest cover trends indicate continued pressure on the natural capital base that supports critical ecosystem services such as groundwater recharge, climate regulation, soil conservation, and biodiversity maintenance. The persistence of ecological stress may therefore have implications for water security, human well-being, and long-term economic sustainability within the Aravalli region.

7·2 Forest Cover Status of Selected Aravalli Districts in Haryana

Table-1B: Forest Cover Status of Selected Aravalli Districts in Haryana (2023)

District	Total Forest Cover (km²)	% of Geographical Area	Change from 2021 (km²)
Faridabad	78.43	10.58	-1.08
Gurugram	113.11	8.99	+0.15
Mahendragarh	111.31	5.86	-1.72
Mewat (Nuh)	108.96	7.23	-4.05
Rewari	61.45	3.86	-0.52

Source: Compiled by the author from Forest Survey of India (FSI), India State of Forest Report (ISFR) 2023.

The above table presents forest cover patterns in selected Haryana districts that form part of the Aravalli landscape. The findings indicate that forest cover remains relatively limited across most districts, reflecting the ecological fragility of the region. Gurugram recorded a marginal increase of 0.15 km² in forest cover between 2021 and 2023, whereas Faridabad, Mahendragarh, Mewat (Nuh), and Rewari experienced declines ranging from 0.52 km² to 4.05 km². Among the districts considered, Faridabad exhibits the highest proportion of forest cover relative to geographical area (10.58%), followed by Gurugram (8.99%) and Mewat (7.23%).

The predominance of negative forest-cover changes suggests that ecological pressures continue to affect significant portions of the Haryana segment of the Aravalli Range. Urban expansion, infrastructure development, land-use transformation, and resource extraction are likely contributors to these trends. The decline is particularly notable in Mewat (Nuh), which recorded the largest reduction in forest cover during the assessment period.

From the perspective of the study's conceptual framework, the observed forest-cover losses indicate continuing pressure on the natural

capital base that supports groundwater recharge, climate regulation, soil conservation, and biodiversity maintenance. These ecosystem services are critical for regional water security and human well-being. Consequently, the findings suggest that ecological degradation remains an important concern within the Haryana portion of the Aravalli landscape and may have broader implications for environmental sustainability and long-term economic resilience.

7·3 Forest Cover in the Delhi Segment of the Aravalli Landscape

Table-1C: Forest Cover Status of Selected Aravalli Districts in Rajasthan (2023)

District	Total Forest Cover (km^2)	% of Geographical Area	Change from 2021 (km^2)
Alwar	455.01	5.61	-13.72
Jaipur	428.80	3.76	-11.65
Sikar	119.19	1.54	-8.65
Jhunjhunu	59.44	1.00	-6.44
Udaipur	774.54	6.47	-5.73

Source: Compiled by the author from Forest Survey of India (FSI), India State of Forest Report (ISFR) 2023.

The above Table presents forest cover patterns in selected districts forming part of the Rajasthan segment of the Aravalli Range. The findings reveal a consistent decline in forest cover across all selected districts between 2021 and 2023, indicating continuing ecological pressures within the region. Alwar recorded the largest decline (-13.72 km^2), followed by Jaipur (-11.65 km^2), Sikar (-8.65 km^2), Jhunjhunu (-6.44 km^2), and Udaipur (-5.73 km^2).

Although Udaipur possesses the highest forest cover among the selected districts (774.54 km^2), followed by Alwar (455.01 km^2) and Jaipur (428.80 km^2), the negative changes observed across all districts suggest that biodiversity conservation gains remain fragile. Forest cover as a proportion of geographical area remains relatively low in several districts, particularly Sikar (1.54%) and Jhunjhunu (1.00%), reflecting the ecological vulnerability of the semi-arid Aravalli landscape.

The uniform decline in forest cover across these districts points towards persistent environmental pressures arising from land-use change, urban expansion, mining activities, infrastructure development, and increasing resource demands. Such trends are significant because the Aravalli ecosystem performs critical functions including groundwater recharge, soil conservation, biodiversity maintenance, and climate regulation.

From the perspective of the study's conceptual framework, the observed decline in forest cover represents a gradual depreciation of natural capital within the Aravalli region. The weakening of ecosystem

services may adversely affect water security, environmental quality, and long-term economic resilience. These findings therefore support the broader argument that biodiversity degradation in the Aravalli Range generates ecological costs with potential implications for human well-being, productivity, and sustainable development.

7·4 Cover Status of Selected Aravalli-Influenced Districts and Forest Fire Trends in the Delhi Segment of the Aravalli Landscape (2023)

Table-1D: Forest Cover Status of Selected Aravalli-Influenced Districts in Delhi (2023)

District	Total Forest Cover (km²)	% of Geographical Area	Change from 2021 (km²)
South Delhi	70.89	44.58	+0.90
New Delhi	48.64	31.18	-0.91
South-East Delhi	19.54	19.35	-0.44
South-West Delhi	12.65	4.47	+0.50

Source: Compiled by the author from Forest Survey of India (FSI), India State of Forest Report (ISFR) 2023.

Table-1E: Forest Fire Incidents in Selected Aravalli-Influenced Districts of Delhi

District	Forest Fires (2022-23)	Forest Fires (2023-24)
South Delhi	–	9
New Delhi	1	3
South-East Delhi	–	1
South-West Delhi	1	1

Source: Compiled by the author from Forest Survey of India (FSI), India State of Forest Report (ISFR) 2023.

The Delhi Ridge, often regarded as the northernmost extension of the Aravalli Range, represents an ecologically significant urban forest system that contributes to biodiversity conservation, air quality regulation, groundwater recharge, and climate moderation within the National Capital Territory. The forest cover data reveal considerable variation across Aravalli-influenced districts. South Delhi possesses the largest forest cover (70.89 km²), accounting for 44.58% of its geographical area, followed by New Delhi (48.64 km²). South-East Delhi and South-West Delhi contain comparatively smaller forested areas but remain important components of the Ridge ecosystem.

Changes between 2021 and 2023 indicate mixed trends. South Delhi and South-West Delhi recorded marginal increases in forest cover, whereas New Delhi and South-East Delhi experienced slight declines. Although these

changes are relatively small, they suggest that ecological conditions within the Delhi Ridge remain dynamic and sensitive to urban development pressures.

The forest fire data provide additional evidence of environmental stress. Total fire detections in Delhi increased from 7 incidents during 2022-23 to 16 incidents during 2023-24. South Delhi accounted for the largest increase, recording nine fire incidents in 2023-24. The rising incidence of forest fires may reflect increasing climatic stress, prolonged dry conditions, anthropogenic disturbances, and growing pressure on urban forest ecosystems.

From the perspective of the study's conceptual framework, the Delhi segment of the Aravalli landscape continues to provide valuable ecosystem services despite its highly urbanized setting. However, the combination of fluctuating forest cover and increasing forest-fire occurrences indicates emerging ecological vulnerabilities. These trends highlight the importance of conserving the Delhi Ridge as a component of the wider Aravalli ecosystem and as a form of natural capital that contributes to environmental quality, public health, and long-term urban sustainability.

8. Discussion

The findings of this study indicate that biodiversity degradation in the Aravalli Range has implications extending beyond environmental sustainability to encompass human health and economic productivity. Evidence from Gujarat, Haryana, Rajasthan, and Delhi reveals uneven but generally fragile forest-cover trends, accompanied by groundwater stress and increasing ecological pressures. These patterns suggest a gradual weakening of the natural capital base that supports critical ecosystem services, particularly water regulation and environmental stability.

The results are consistent with the study's conceptual framework, which proposes that biodiversity loss affects economic outcomes through ecological and health-related pathways. As ecosystem quality declines, the capacity of the Aravallis to support groundwater recharge and watershed functions is reduced, contributing to chronic water stress. This, in turn, heightens health vulnerabilities and increases public expenditure requirements, reinforcing the link between ecological degradation and human well-being.

From a commerce perspective, the findings reflect the consequences of negative environmental externalities. While economic activities such as urban expansion, mining, and land-use change may generate short-term gains, the associated ecological costs are largely borne by society. Rising health expenditure, water insecurity, and pressures on productivity represent hidden costs that are not adequately captured in conventional economic accounting systems.

Water scarcity emerges as a key transmission mechanism connecting biodiversity degradation with broader economic outcomes. The weakening of ecosystem services can increase resource-management costs, reduce productive efficiency, and place additional fiscal burdens on governments. Consequently, biodiversity loss should be viewed not only as an environmental concern but also as a development challenge with implications for long-term economic resilience.

Overall, the study supports the argument that biodiversity conservation and ecosystem restoration constitute investments in natural capital. Strengthening the ecological resilience of the Aravalli Range can contribute to improved water security, better health outcomes, enhanced productivity, and more sustainable economic development. The findings therefore reinforce the importance of integrating biodiversity considerations into economic planning and governance frameworks.

9. Conclusion

This study examined the interrelationships between biodiversity loss, human health, and economic productivity in the Aravalli Range through the lens of the Ecology-Commerce Nexus. Drawing upon secondary evidence relating to forest cover trends, groundwater stress, public health indicators, labour productivity, and human development outcomes, the study demonstrates that biodiversity degradation extends far beyond ecological concerns and generates important economic and social consequences.

The findings indicate that the Aravalli ecosystem continues to experience significant environmental stress, reflected in declining forest cover across several districts, persistent groundwater pressure, and growing ecological vulnerability. These changes weaken ecosystem services that support water security, environmental regulation, and public well-being. The evidence further suggests that ecological degradation contributes indirectly to rising health-related costs, increased fiscal burdens, and constraints on productivity and development outcomes. Although the study does not establish direct causal relationships, the observed patterns consistently support the proposition that biodiversity loss generates economic costs through interconnected ecological and human pathways.

These findings support the study's central argument that biodiversity conservation and ecosystem restoration should be viewed as strategic economic investments rather than solely environmental objectives. Strengthening the ecological resilience of the Aravalli landscape is likely to generate benefits in the form of improved water security, better public health outcomes, enhanced productivity, and greater long-term economic sustainability.

From a commerce perspective, the study highlights biodiversity as a productive form of natural capital rather than merely an environmental resource. The degradation of biodiversity represents a form of capital depreciation that reduces the economy's capacity to generate sustainable returns over time. As ecosystem services deteriorate, hidden costs emerge in the form of water scarcity, increased healthcare expenditure, reduced labour efficiency, and slower improvements in human development. These costs are rarely reflected in conventional measures of economic performance, resulting in a systematic undervaluation of ecological assets and an overestimation of economic progress.

A key contribution of this study is the demonstration that biodiversity loss functions as a negative economic externality with implications for development planning, public finance, and long-term economic resilience. By integrating ecological, health, and economic dimensions within a unified analytical framework, the study extends the discourse on biodiversity beyond conservation and positions it within the broader domains of commerce, economic governance, and sustainable development. The findings suggest that investments in biodiversity conservation and ecosystem restoration should be viewed not as environmental expenditures but as investments in natural capital capable of generating social, economic, and developmental returns.

The Aravalli Range provides a particularly important case study because it illustrates how ecological degradation in a resource-dependent landscape can translate into wider economic vulnerabilities. As pressures from urbanisation, land-use change, resource extraction, and climate variability continue to intensify, the costs of biodiversity loss are likely to become increasingly visible within health systems, labour markets, and public finances. Consequently, safeguarding ecological assets is essential not only for environmental sustainability but also for maintaining economic productivity and human well-being.

In conclusion, the study argues that biodiversity conservation is fundamentally an economic imperative. The Ecology-Commerce Nexus demonstrated in the Aravalli Range reveals that the protection and restoration of natural capital are integral to sustaining productivity, strengthening human development, improving fiscal efficiency, and supporting long-term sustainable growth. Future economic policy, business strategy, and development planning must therefore move beyond viewing biodiversity as a peripheral environmental concern and recognise it as a foundational asset underpinning economic prosperity and societal welfare.

10. Policy Implications

The findings of this study have important implications for economic policy, environmental governance, and sustainable development planning.

The evidence suggests that biodiversity loss within the Aravalli Range generates substantial ecological, health, and economic costs that are insufficiently reflected in conventional development frameworks. Accordingly, biodiversity conservation should be recognised not merely as an environmental expenditure but as an investment in natural capital that supports long-term economic productivity and human well-being.

First, biodiversity considerations should be systematically integrated into economic and development planning. Policymakers should recognise ecosystem services such as groundwater recharge, climate regulation, soil conservation, and biodiversity maintenance as productive assets that contribute directly to economic activity. Development projects within ecologically sensitive landscapes such as the Aravalli Range should therefore incorporate biodiversity valuation and environmental cost assessments as part of decision-making processes.

Second, ecosystem restoration should be prioritised alongside conservation efforts. The district-level evidence of declining forest cover and continuing ecological stress indicates that protection measures alone may be insufficient. Large-scale restoration initiatives, including the Aravalli Green Wall programme and landscape-based ecological restoration projects, should be strengthened to improve ecosystem resilience, enhance groundwater recharge, and restore biodiversity. Such investments are likely to generate long-term economic returns through improved water security, reduced environmental risk, and enhanced productivity.

Third, environmental policy and public health policy should be more closely integrated. The findings indicate that ecological degradation contributes indirectly to health vulnerabilities through water scarcity and environmental stress. Preventive investment in ecosystem protection may therefore reduce future healthcare expenditure and improve public health outcomes. Integrating biodiversity considerations into health planning can improve policy efficiency by addressing environmental determinants of health rather than focusing exclusively on treatment-based approaches.

Fourth, stronger mechanisms are required to internalise biodiversity-related externalities. Economic and regulatory instruments such as natural capital accounting, ecosystem service valuation, ecological compensation mechanisms, and stricter enforcement of land-use regulations can help ensure that environmental costs are incorporated into economic decision-making. Such measures would reduce market distortions and encourage more sustainable patterns of production and resource use.

Fifth, improved monitoring and governance of the Aravalli ecosystem are essential. The forest-cover declines observed across several Aravalli districts and the increase in forest-fire incidents within the Delhi Ridge

highlight the need for stronger institutional coordination across states. Since the Aravalli Range spans Gujarat, Rajasthan, Haryana, and Delhi, a coordinated landscape-level management approach is necessary to ensure effective conservation and restoration outcomes.

Finally, the findings support India's commitments under the Convention on Biological Diversity, the Kunming-Montreal Global Biodiversity Framework, and the Sustainable Development Goals. Protecting and restoring the Aravalli ecosystem can contribute simultaneously to biodiversity conservation, water security, climate resilience, public health improvement, and sustainable economic growth. From a commerce perspective, safeguarding the Aravallis represents an investment in natural capital that yields long-term economic, social, and environmental returns for present and future generations.

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