DEFORESTATION AND CLIMATE CHANGE: ENVIRONMENTAL IMPACTS AND SUSTAINABLE SOLUTIONS.

Abstract

Deforestation is one of the most serious environmental challenges of the twenty-first century because forests are closely connected with climate regulation, biodiversity, water resources, soil conservation and human livelihoods. Forests absorb and store carbon dioxide, regulate local and regional rainfall, protect soils and provide habitat for a large share of terrestrial biodiversity. When forests are cleared or severely degraded, this ecological balance is disturbed. Carbon stored in vegetation and soils can be released into the atmosphere, while the capacity of landscapes to remove carbon from the atmosphere is reduced. At the same time, deforestation can increase soil erosion, alter water cycles, reduce biodiversity and make local communities more vulnerable to floods, droughts and extreme temperatures.

This paper examines the relationship between deforestation and climate change, focusing on environmental impacts and sustainable solutions. The study is based on secondary information from international organisations and peer-reviewed research, particularly the Food and Agriculture Organization (FAO), scientific literature on forest-cover change, REDD+, forest restoration and climate mitigation. The analysis uses a descriptive and comparative approach, supported by a year-wise review of major developments in forest and climate research and global forest statistics. Recent evidence indicates that the global rate of deforestation has declined, but forest loss remains substantial. FAO's Global Forest Resources Assessment 2025 reports that forests cover approximately 4.14 billion hectares, around 32% of global land area, while annual deforestation during 2015–2025 remained about 10.9 million hectares.

The paper argues that planting trees alone cannot solve the problem. Protecting existing natural and primary forests, restoring degraded landscapes, promoting sustainable agriculture and forestry, strengthening community participation, improving forest governance, using satellite-based monitoring, and developing credible economic incentives such as REDD+, payments for ecosystem services and high-integrity carbon finance are necessary components of a sustainable response. The study concludes that forest conservation should be treated not only as an environmental priority but also as an important element of climate policy, rural development and long-term economic sustainability.

Keywords: Deforestation, Climate Change, Forest Conservation, Carbon Sequestration, Biodiversity, REDD+, Forest Restoration, Sustainable Development, Climate Mitigation.

Introduction

Forests are much more than collections of trees. They are living ecological systems that connect the atmosphere, soil, water, plants, animals and human communities. For millions of people, forests provide food, fuel, medicines, timber, non-timber forest products and employment. At the global level, forests regulate important ecological processes, including carbon storage, water cycling and climate regulation.

Despite their importance, forests continue to experience pressure from agricultural expansion, livestock production, infrastructure development, mining, logging, urbanisation, forest fires and other forms of land-use change. The problem is particularly serious in tropical regions, where forests contain enormous amounts of biodiversity and carbon.

The relationship between forests and climate change is two-way. On one side, deforestation contributes to climate change because the destruction and degradation of forests can release stored carbon and reduce future carbon absorption. On the other side, climate change itself can damage forests through increasing temperatures, droughts, wildfires, storms, pests and changes in rainfall patterns. Thus, deforestation and climate change can reinforce one another.

The latest FAO assessment provides an important perspective. Global forests covered approximately 4.14 billion hectares in 2025, equal to around 32% of global land area. Although the rate of deforestation has declined, approximately 10.9 million hectares of forest were still lost annually during 2015–2025. At the same time, forest expansion has slowed, meaning that reductions in gross deforestation do not automatically translate into rapid recovery of global forest resources.

Earlier FAO evidence also demonstrates the long-term scale of the problem. Between 1990 and 2020, approximately 420 million hectares of forest were lost through deforestation, although the rate of net forest loss declined substantially over this period.

The challenge, therefore, is not simply to increase the number of trees. A sustainable approach must protect existing forests, particularly natural and primary forests, while restoring degraded ecosystems and reducing the economic pressures that encourage forest conversion.

This paper examines these issues from an environmental and sustainable-development perspective.

Review of Literature

This section synthesizes findings from previous studies that form the foundation of this research, organized thematically to reflect the interconnected nature of deforestation and climate change research.

Oliveras Menor and et al. (2025) conducted a systematic review following PRISMA guidelines to synthesize understanding of carbon emissions from forest disturbances under global change. Their analysis screened 519 records, ultimately including 90 studies published between 2020 and early 2025. The review revealed that recent research has predominantly focused on high-severity disturbances such as forest fires and deforestation, which are being amplified under climate change. However, the carbon impacts of low-intensity disturbances like forest degradation and selective harvesting remain poorly understood. Importantly, compound disturbances often interact synergistically, amplifying their effects. The study also identified significant geographic bias, with remarkable underrepresentation of the Global South in forest carbon research. Most studies quantify only aboveground carbon pool estimates, with limited research on total ecosystem carbon, representing a critical knowledge gap.

A **systematic review** published in **Environmental Research Letters (2025)** examined land cover change impacts in West Africa, providing the first multidisciplinary synthesis in this region. Analyzing data from 26 selected publications, the researchers found that deforestation has contributed to significant historical temperature increases of +0.26 ± 0.12°C, with projected increases of +0.88 ± 0.25°C under future scenarios. Conversely, afforestation could have cooled the climate by -0.24 ± 0.14°C historically. Deforestation decreased regional precipitation by 80 ± 58 mm per year historically, while large-scale afforestation could substantially reduce droughts with increased precipitation averaging +40 ± 67 mm per year. These findings emphasize the need to integrate land cover change-induced climate effects into land-based mitigation strategies and climate policy frameworks, recognizing that forests influence climate through both carbon-cycle and biophysical mechanisms.

The National Science Foundation (2025) revisited the concept of an Amazon tipping point, assessing forest collapse risk from an ecological perspective. The research synthesized evidence showing that environmental stressors can drive critical ecosystem transitions either gradually through incremental loss of resilience or abruptly via synergistic feedbacks. The interplay between climate and land-use change amplifies risks to biodiversity, ecosystem services, and livelihoods. However, limited evidence exists for a single, system-wide tipping point. The most immediate strategies to support forest resilience include slowing forest loss, mitigating climate change, reducing fire activity, curbing defaunation, and restoring degraded ecosystems. Preserving the Amazon's ecological integrity requires urgent, sustained conservation efforts in collaboration with local and Indigenous communities.

West and et al. (2025) provided an overview of global deforestation footprinting approaches, identifying global trends and drivers to inform zero-deforestation policies. Their analysis revealed that agriculture is the dominant driver, with 86% of global deforestation occurring between 2001 and 2022 attributed to crop and cattle production. Major economies including Brazil, Indonesia, China, the United States, and Europe are responsible for most commodity-linked deforestation. Brazil alone experienced over 12.8 million hectares of agriculture-linked deforestation between 2005 and 2015. Although forest loss to agriculture is relatively well documented, lack of data on non-agricultural drivers—such as mining and mangrove clearance for aquaculture—limits footprint assessments in fully attributing total global forest loss to human activities.

Researchers from Shahjalal University of Science and Technology (2025) examined how sustainable forest management in the tropics can address anthropogenic disturbances and climatic changes. Tropical forests constitute almost half of the global forest cover, account for 35% of global net primary productivity, and have substantial potential to sequester atmospheric CO_2. However, deforestation and degradation led by unsustainable management contribute to unprecedented species losses and limit ecosystem services. The study argued that securing forest tenure, reducing deforestation, applying reduced impact logging, and implementing appropriate silvicultural systems can enhance tropical forest carbon stock and help mitigate climate change. However, existing dilemmas on sustainable forest management definitions continue to fuel debate on whether climate change mitigation initiatives will be successful.

A comprehensive review from the **University of Seoul (2025)** provided current information about deforestation and its effects on climate change, the impacts of climate change on forests, and the role of forests in climate regulation. The annual rate of deforestation is 0.14% per year, with 2.3 million square kilometers lost between 2000 and 2012. Net carbon emissions from deforestation and forest degradation remain high and have not changed significantly over the last two decades. The world's forests store approximately 650 billion tons of carbon. Temperature, drought, precipitation, and fire affect forest health, particularly for young trees. Fire frequency affects regeneration of tropical moist deciduous and Amazonian forest types more significantly than temperate and tropical dry deciduous types. Non-equilibrium species distribution has been occurring, and species frequency has changed throughout the world.

A review in **Nature Reviews Biodiversity (2025)** examined drivers and benefits of natural forest regeneration in tropical regions. Natural regeneration offers significant potential for carbon sequestration and biodiversity recovery. Studies show that forest regrowth improves people's dietary quality in Nigeria, and tropical forests are home to over half of the world's vertebrate species. However, recovery of biodiversity follows multidimensional trajectories, with different attributes recovering at different rates. Regeneration success is influenced by landscape composition, site land-use intensity, and connectivity with primary forest. Agricultural practices and landscape-level forest cover dictate secondary forest recovery in deforested tropical landscapes, and frugivores enhance potential carbon recovery in fragmented landscapes.

A**ScienceDirect review (2026)** deciphered mechanistic linkages between carbon sequestration, biodiversity, and land system transformation toward actionable recommendations. Three key conclusions emerged: First, ecological principles that promote long-term stability of carbon stocks also encourage biodiversity, benefiting ecosystem services from hydrological cycles to soil fertility. Second, land degradation reflects socioeconomic and governance structures influencing land allocation, management, and restoration. The critical issue is not availability of data but isolated domains of knowledge production on ecological, climatic, and socioeconomic processes that ignore feedback mechanisms apparent only when studied together. Future research must couple models of these interconnected systems to address these challenges.

Across these reviews, persistent gaps include geographic bias toward the Global North and specific regions, limited quantification of soil and total ecosystem carbon, understudied low-intensity disturbances, insufficient understanding of compound disturbance effects, poor documentation of non-agricultural deforestation drivers, and inadequate integration of socioeconomic and ecological research domains.

Research Methodology

The present study, titled **"Deforestation and Climate Change: Environmental Impacts and Sustainable Solutions,"** adopts a descriptive and analytical research design to examine the relationship between forest loss, environmental degradation, and climate change, while identifying sustainable policy solutions. The study is primarily based on secondary data collected from reliable national and international sources, including the Food and Agriculture Organization (FAO), World Bank, United Nations Environment Programme (UNEP), Intergovernmental Panel on Climate Change (IPCC), Ministry of Environment, Forest and Climate Change (MoEFCC), Forest Survey of India (FSI), and other government publications, research articles, and peer-reviewed journals.

The analysis focuses on key indicators such as forest-cover change, deforestation rates, carbon dioxide emissions, average temperature, rainfall variability, biodiversity loss, and land-use changes. Data are examined over an appropriate time period to identify long-term trends and changes. Descriptive statistical techniques, including percentage change, growth rates, averages, trend analysis, tables, and graphical presentation, are used to assess the magnitude and direction of deforestation and climate-related changes.

To examine the relationship between deforestation and climate change, the study employs correlation and regression analysis, where appropriate. Deforestation is considered a major explanatory variable, while climate indicators such as temperature and carbon emissions are used as dependent variables. Qualitative analysis is also undertaken to assess the environmental consequences of forest loss, including biodiversity degradation, soil erosion, disruption of the hydrological cycle, and increased vulnerability to extreme climatic events.

Finally, the study undertakes a policy and sustainability analysis of measures such as afforestation, reforestation, agroforestry, sustainable forest management, community participation, REDD+, renewable energy adoption, and carbon pricing. The findings are synthesized to propose practical and economically viable strategies for reducing deforestation, mitigating climate change, and promoting sustainable development.

Trends and Patterns of Deforestation: Global, Regional and India-Specific Analysis

Deforestation is one of the most important environmental changes associated with agricultural expansion, infrastructure development, urbanisation, mining, timber extraction and other forms of land-use change. However, the global pattern is not uniform. Some regions continue to experience rapid forest loss, while others have achieved forest expansion through afforestation, natural regeneration and improved forest management.

For the present analysis, FAO Global Forest Resources Assessment (FRA) 2025 is used for global and regional trends, while the Forest Survey of India (FSI), India State of Forest Report (ISFR) is used for India. FRA 2025 covers 236 countries and areas and provides comparable information for 1990–2025.

1. Global Trends in Deforestation

The global trend indicates a substantial slowdown in deforestation, although forests continue to decline overall. In 2025, the world's forests covered approximately 4.14 billion hectares, equivalent to about 31.8–32% of global land area. Forest area has declined from about 4.34 billion hectares in 1990 to 4.14 billion hectares in 2025.

Table 1. Global Forest-Cover Change, 1990–2025

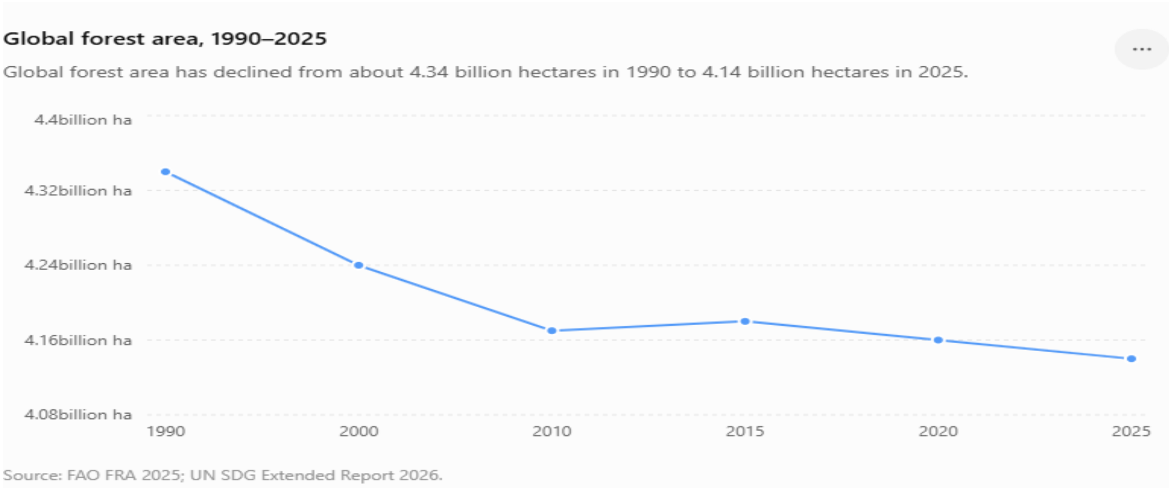
Year	Global forest area (billion ha)	Forest area as % of global land
1990	4.34	33.3
2000	4.24	32.5
2010	Approx. 4.17	Approx. 32.2
2015	4.18	32.1
2020	Approx. 4.16	Approx. 32.0
2025	4.14	31.8

Source: FAO FRA 2025 and United Nations SDG Extended Report 2026.

The data demonstrate that global forest area has fallen by approximately 203 million hectares since 1990, representing a decline of about 4.7%.

Global forest area, 1990–2025

Global forest area has declined from about 4.34 billion hectares in 1990 to 4.14 billion hectares in 2025.



Source: FAO FRA 2025; UN SDG Extended Report 2026.

2. Global Deforestation Rate

An important distinction should be made between deforestation and net forest loss.

- **Deforestation** refers to conversion of forest to another land use.
- **Forest expansion** includes afforestation and natural expansion.
- **Net forest loss** reflects the balance between forest losses and gains.

According to FRA 2025, annual deforestation declined from 17.6 million hectares per year during 1990–2000 to 13.6 million hectares during 2000–2015 and 10.9 million hectares during 2015–2025.

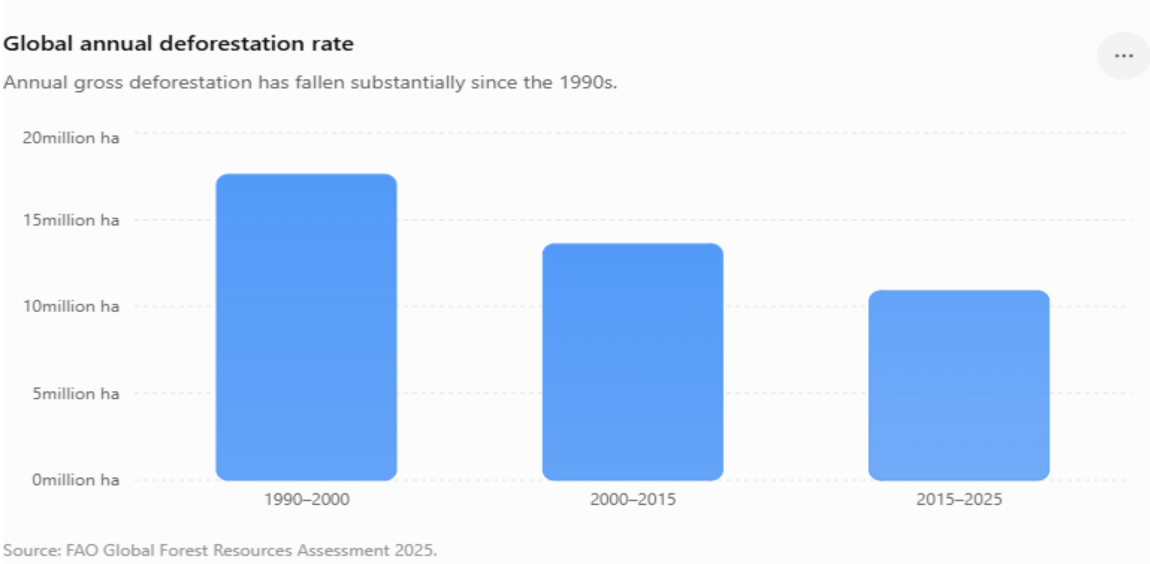
Table 2. Year/Period-wise Global Deforestation Rate

Period	Deforestation	Forest expansion	Net forest loss
1990–2000	17.6 million ha/year	~6.9 million ha/year	10.7 million ha/year
2000–2015	13.6 million ha/year	9.88 million ha/year	3.68 million ha/year
2015–2025	10.9 million ha/year	6.78 million ha/year	4.12 million ha/year

Source: FAO, Global Forest Resources Assessment 2025.

Global annual deforestation rate

Annual gross deforestation has fallen substantially since the 1990s.



Source: FAO Global Forest Resources Assessment 2025.

The reduction from 17.6 to 10.9 million hectares represents a decline of approximately 38% in the annual rate of gross deforestation between the first and latest periods.

However, the net-loss figure increased from 3.68 million hectares per year during 2000–2015 to 4.12 million hectares during 2015–2025 because forest expansion slowed more rapidly than deforestation.

3. Regional Trends of Deforestation

Deforestation is geographically concentrated. Africa and South America remain the principal regions of forest loss, whereas Europe and parts of Asia have experienced forest expansion.

Table 3. Regional Annual Net Forest Change

Region	1990–2000	2000–2015	2015–2025	General trend
Africa	−3.28 million ha/yr	−3.64	−2.96	Persistent loss
Asia	−0.43	+2.40	+1.62	Net gain
Europe	+0.82	+1.24	+1.44	Continuous gain
North & Central America	−0.34	+0.71	−0.26	Mixed
Oceania	−0.14	−0.04	+0.14	Recent improvement
South America	−7.34	−4.36	−4.10	Major persistent loss
World	−10.70	−3.68	−4.12	Net loss

Negative values represent net forest loss; positive values represent net forest gain.

Source: FAO FRA 2025.

South America

South America remains one of the world's most important deforestation hotspots. It has the highest proportion of forest cover among the major regions, with forests accounting for approximately 49% of regional land area, but it continues to experience substantial forest loss.

Agricultural expansion, cattle ranching, commercial crops, infrastructure and other land-use changes are important drivers.

Africa

Africa has experienced persistent forest loss, although the rate has declined in the latest assessment period. The continent's tropical forests are particularly important for biodiversity, carbon storage and local livelihoods. FAO reports that Africa experienced one of the world's largest annual net forest losses in the latest period.

Asia

Asia presents a more diverse pattern. Some parts of Southeast Asia continue to face deforestation pressures, while East Asia and parts of South Asia have recorded forest expansion. The UN reports particularly strong forest-area expansion in Eastern Asia and Central and Southern Asia.

Europe

Europe represents one of the clearest examples of long-term forest expansion. Forest area has increased through natural regeneration, afforestation and forest management. According to FRA 2025, Europe had the largest share of global forest area, approximately 25% of the world's total.

4. India-Specific Trends

India provides an interesting contrast to the global trend. According to the Forest Survey of India, forest cover is assessed approximately every two years using satellite data and related methods. The first national forest-cover assessment was conducted in 1987.

It is important to distinguish between forest cover and recorded forest area. ISFR forest cover includes land of more than one hectare having tree canopy density above 10%, irrespective of ownership or legal status.

Table 4. India's Forest Cover: Long-Term Trend

Assessment year	Forest cover (sq. km)	Forest cover (% of geographical area)
1987	640,819	19.49
1989	638,804	19.43
1991	639,364	19.45
1993	639,386	19.45
1995	638,819	19.43

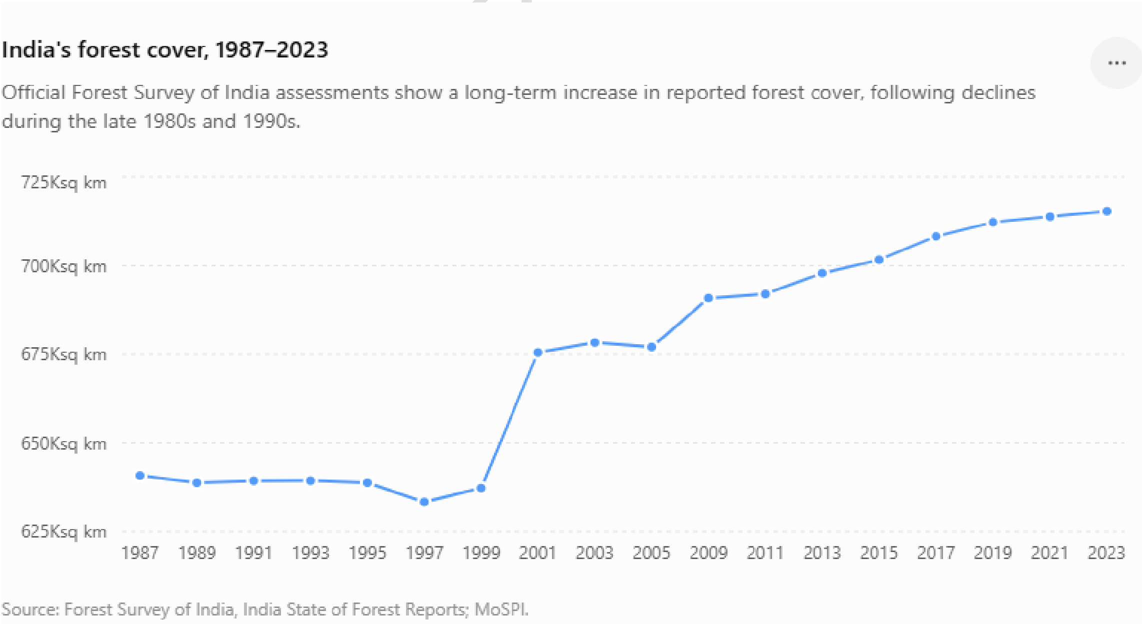
1997	633,397	19.27
1999	637,293	19.39
2001	675,538	20.55
2003	678,333	20.64
2005	677,088	20.60
2009	690,899	21.02
2011	692,027	21.05
2013	697,898	21.23
2015	701,673	21.34
2017	708,273	21.54
2019	712,249	21.67
2021	713,789	21.71
2023	715,343	~21.76

Sources: Forest Survey of India; Ministry of Statistics and Programme Implementation; ISFR 2023.

Note: The assessment years are not strictly annual observations. ISFR is a periodic assessment, generally biennial in recent decades. Therefore, the table should be described as assessment-year data, not continuous annual observations.

India's forest cover, 1987–2023

Official Forest Survey of India assessments show a long-term increase in reported forest cover, following declines during the late 1980s and 1990s.



Source: Forest Survey of India, India State of Forest Reports; MoSPI.

The long-term data show three broad phases:

1. **1987–1997:** decline in forest cover.

2. **1999–2013:** gradual recovery and expansion.

3. **2015–2023:** continued increase in reported forest cover.

Between 2015 and 2023, India's reported forest cover increased by approximately 13,670 sq. km.

5. Recent India Forest-Cover Changes

The recent trend is particularly important for the research paper.

Table 5. India: Recent Forest-Cover Change

Assessment year	Forest cover (sq. km)	Change from previous assessment (sq. km)
2011	692,027	+1,128
2013	697,898	+5,871
2015	701,673	+3,775
2017	708,273	+6,600
2019	712,249	+3,976
2021	713,789	+1,540
2023	715,343	+1,554

The figures show a continuous increase in reported forest cover after 2011, although the size of the increase varies between assessment periods.

The latest ISFR 2023 dataset provides forest-cover, tree-cover, mangrove-cover, growing-stock and carbon-stock information at national and subnational levels.

6. India: Forest and Tree Cover

Forest cover alone does not capture the complete vegetation situation. India also reports tree cover outside forests.

According to ISFR 2023, India's:

- **Forest cover:** about 715,343 sq. km
- **Tree cover:** about 112,014 sq. km
- **Forest + tree cover:** about 827,357 sq. km
- **Forest + tree cover as share of geographical area:** approximately 25.17%

The ISFR 2023 assessment reports an increasing trend in forest and tree cover.

Table 6. India: Forest and Tree Cover, Recent Years

Year	Forest cover (sq. km)	Tree cover (sq. km)	Forest + tree cover (sq.

			km)
2011	692,027	90,844	782,871
2013	697,898	91,266	789,164
2015	701,673	92,572	794,245
2017	708,273	93,815	802,088
2019	712,249	95,027	807,276
2021	713,789	95,748	809,537
2023	715,343	112,014	827,357

The 2023 tree-cover figure reflects the latest ISFR assessment and should be used as the current official observation.

7. Deforestation Rates in India

India's situation requires greater caution when discussing a single "deforestation rate." The FSI primarily reports changes in forest cover, while gross and net deforestation can be calculated or obtained from different datasets using different definitions.

For example, research based on FSI data for 2001–2011 demonstrated that net and gross forest-cover changes could differ considerably because forest gains and losses occur simultaneously.

Therefore, for your research paper, it is better to present:

Forest-cover change = Forest cover in current assessment − Forest cover in previous assessment

rather than incorrectly treating every reduction in forest cover as equivalent to gross deforestation.

8. Regional Pattern within India

India's national increase also masks substantial state-level differences.

For example, during 2015–2021, substantial increases occurred in states such as:

State	2015 forest cover (sq. km)	2021 forest cover (sq. km)	Change
Andhra Pradesh	26,006	29,784	+3,778
Karnataka	36,449	38,730	+2,281
Kerala	19,278	21,253	+1,975
Odisha	50,460	52,156	+1,696

Himachal Pradesh	14,707	15,443	+736
Arunachal Pradesh	67,154	66,431	−723
Mizoram	18,717	17,820	−897
Nagaland	12,939	12,251	−688
Manipur	17,083	16,598	−485
Meghalaya	17,262	17,046	−216

Source: ISFR/Forest Survey of India data.

This demonstrates that **India's forest-cover trend is spatially uneven**. A national increase does not necessarily mean that every forest ecosystem is recovering.

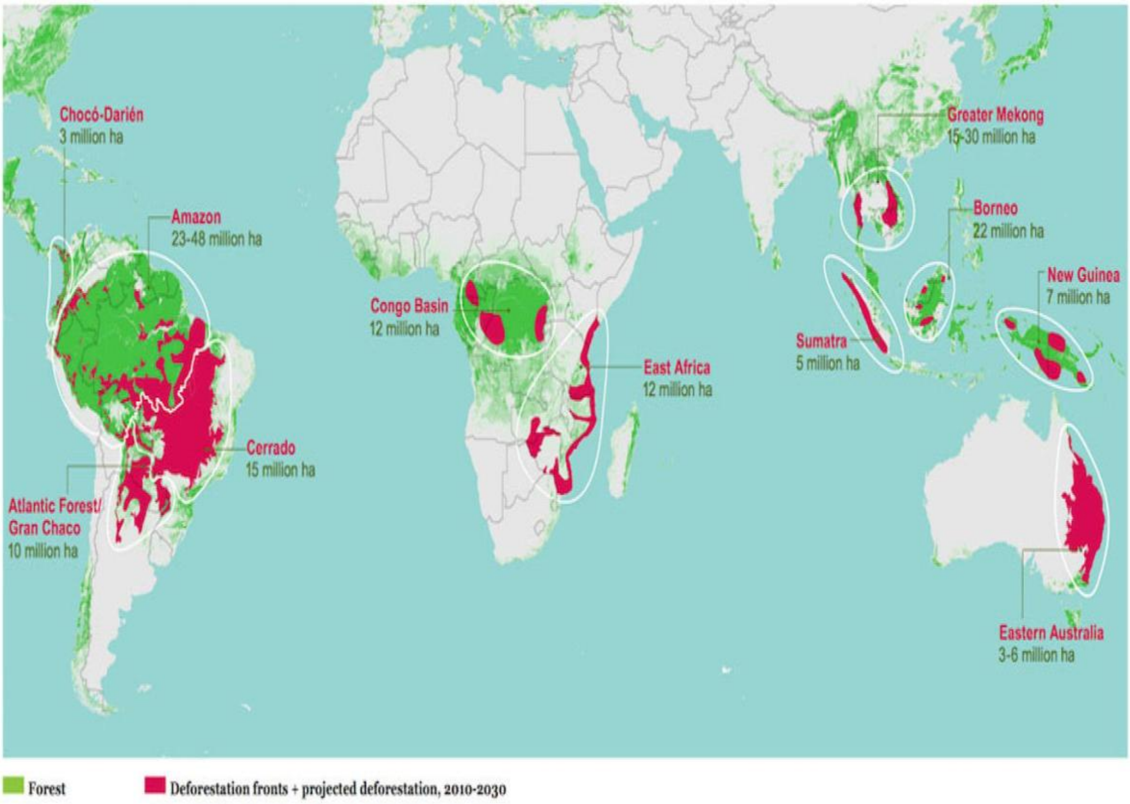
9. Maps: Spatial Pattern of Deforestation

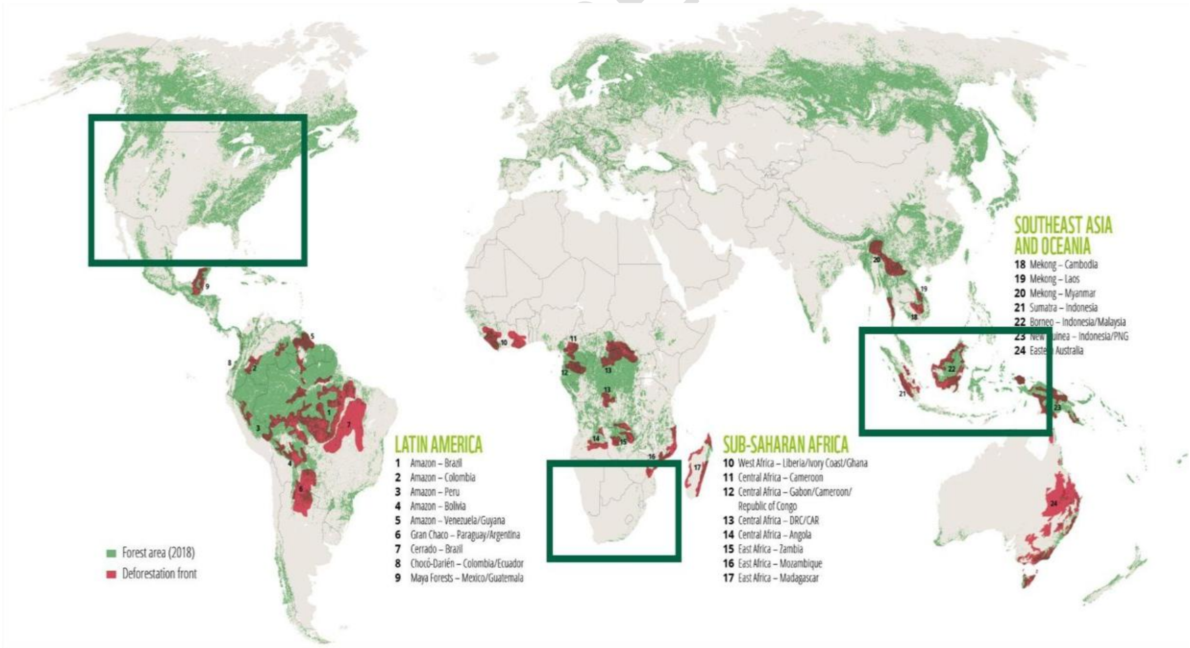
Spatial analysis is essential for understanding deforestation because forest loss is highly concentrated in particular ecological regions. Global evidence identifies the **Amazon Basin, Congo Basin, Southeast Asia, parts of West and East Africa, and several tropical forest regions** as important deforestation fronts. WWF's assessment identifies 24 major deforestation fronts across Latin America, sub-Saharan Africa, Southeast Asia and Oceania.

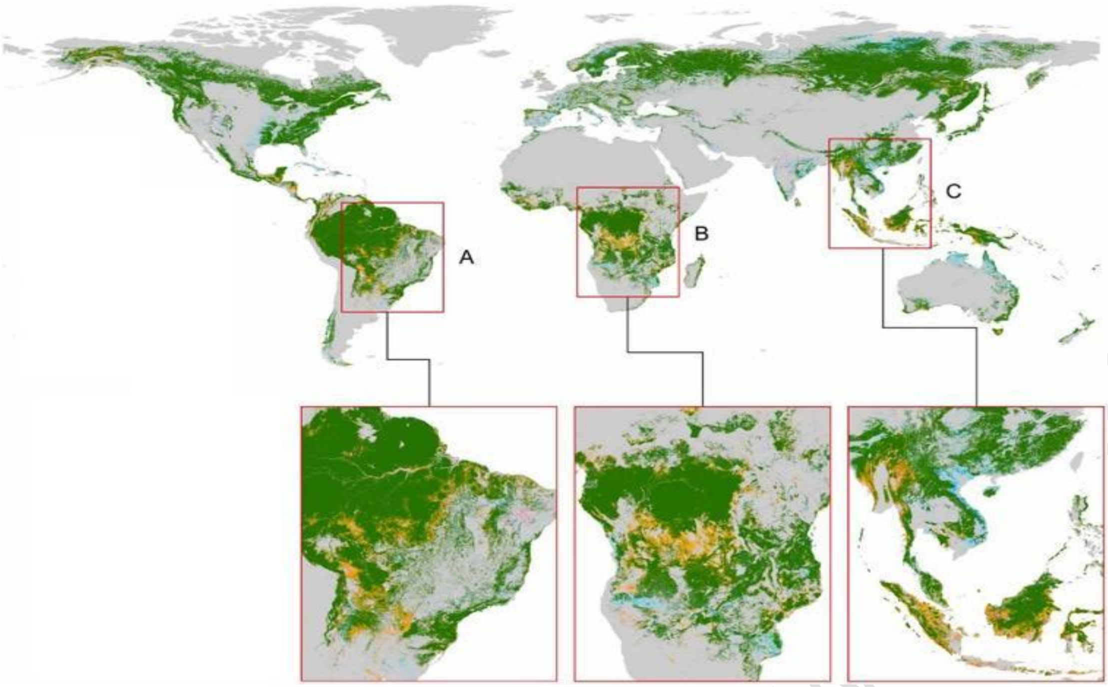
Map 1. Global Deforestation Hotspots

The global map should highlight the following major forest-loss regions:

- **Amazon Basin – South America:** Brazil, Peru, Bolivia, Colombia and neighbouring Amazon countries.
- **Congo Basin – Central Africa:** Democratic Republic of the Congo, Republic of the Congo, Cameroon, Gabon and Central African Republic.
- **Southeast Asia:** Indonesia, Malaysia, Myanmar, Cambodia and Laos.
- **West Africa:** Liberia, Côte d'Ivoire and Ghana.
- **East Africa:** Mozambique, Zambia and Madagascar.
- **Other tropical hotspots:** Gran Chaco, Cerrado, Chocó-Darién, Maya Forest, Sumatra, Borneo and New Guinea.


Chocó-Darién
3 million ha
Amazon
23-48 million ha
Cerrado
15 million ha
Atlantic Forest/
Gran Chaco
10 million ha
Congo Basin
12 million ha
East Africa
12 million ha
Greater Mekong
15-30 million ha
Borneo
22 million ha
Sumatra
5 million ha
New Guinea
7 million ha
Eastern Australia
3-6 million ha
Forest
Deforestation fronts + projected deforestation, 2010-2030


LATIN AMERICA
1 Amazon – Brazil
2 Amazon – Colombia
3 Amazon – Peru
4 Amazon – Bolivia
5 Amazon – Venezuela/Guyana
6 Gran Chaco – Paraguay/Argentina
7 Cerrado – Brazil
8 Chocó-Darién – Colombia/Ecuador
9 Maya Forests – Mexico/Guatemala
SUB-SAHARAN AFRICA
10 West Africa – Liberia/Ivory Coast/Ghana
11 Central Africa – Cameroon
12 Central Africa – Gabon/Cameroon/Republic of Congo
13 Central Africa – DRC/CAR
14 Central Africa – Angola
15 East Africa – Zambia
16 East Africa – Mozambique
17 East Africa – Madagascar
SOUTHEAST ASIA AND OCEANIA
18 Mekong – Cambodia
19 Mekong – Laos
20 Mekong – Myanmar
21 Sumatra – Indonesia
22 Borneo – Indonesia/Malaysia
24 Eastern Australia
Forest area (2018)
Deforestation front



The spatial concentration of these hotspots demonstrates that tropical and subtropical forests are disproportionately exposed to deforestation pressures. WWF estimates that around two-thirds of global forest-cover loss occurs in tropical and subtropical regions.

Map 2. Forest Cover Distribution in India

For India, the preferred map should be based on the India State of Forest Report (ISFR) 2023. The map can classify states and Union Territories according to forest-cover area or forest cover as a percentage of geographical area.

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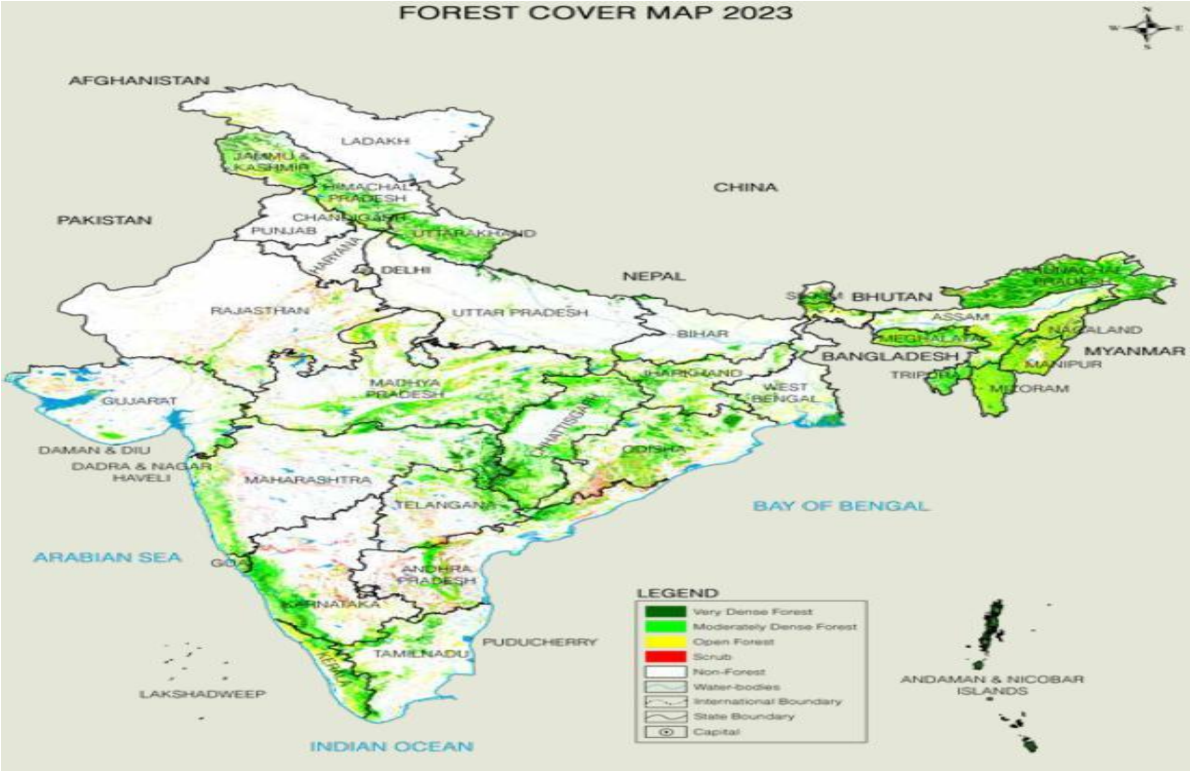
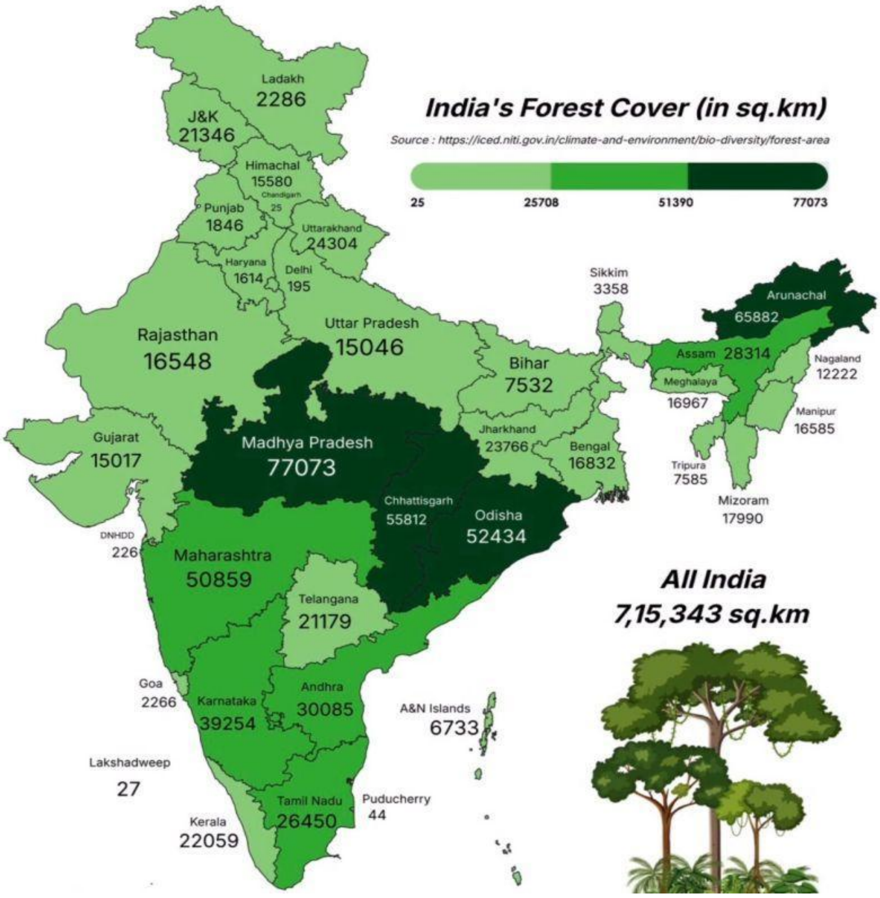
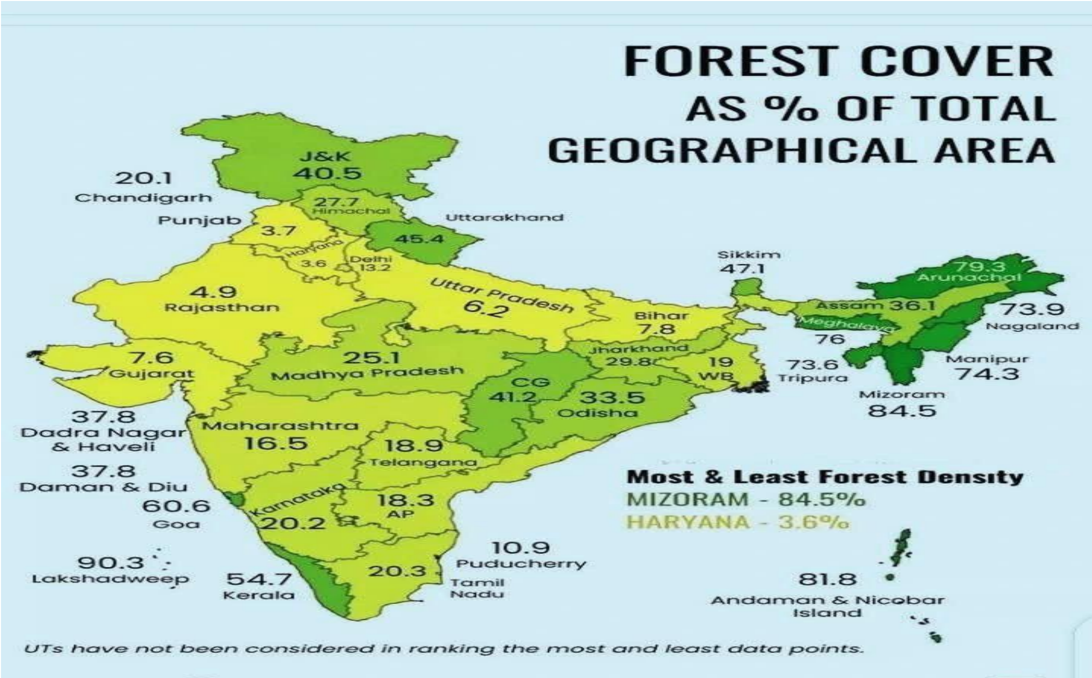

FOREST COVER MAP 2023
AFGHANISTAN
PAKISTAN
CHINA
NEPAL
BHUTAN
BANGLADESH
MYANMAR
LADAKH
PUNJAB
DELHI
RAJASTHAN
UTTAR PRADESH
BIHAR
GUJARAT
MADHYA PRADESH
WEST BENGAL
ODISHA
MAHARASHTRA
TELANGANA
ANDHRA PRADESH
TAMILNADU
PUDUCHERRY
DAMAN & DIU
DADRA & NAGAR HAVELI
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
LAKSHADWEEP
ANDAMAN & NICOBAR ISLANDS
ASSAM
MEGHALAYA
MANIPUR
MIZORAM
LEGEND
Very Dense Forest
Moderately Dense Forest
Open Forest
Scrub
Non-Forest
Water-bodies
International Boundary
State Boundary
Capital
350

India's Forest Cover (in sq.km)
Source : https://iced.niti.gov.in/climate-and-environment/bio-diversity/forest-area
25
25708
51390
77073
Ladakh 2286
J&K 21346
Himachal 15580
Chandigarh 25
Punjab 1846
Uttarakhand 24304
Haryana 1614
Delhi 195
Rajasthan 16548
Uttar Pradesh 15046
Bihar 7532
Sikkim 3358
Arunachal 65882
Assam 28314
Nagaland 12222
Meghalaya 16967
Manipur 16585
Gujarat 15017
Madhya Pradesh 77073
Jharkhand 23766
Bengal 16832
Tripura 7585
Mizoram 17990
Chhattisgarh 55812
Odisha 52434
DNHDD 226
Maharashtra 50859
Telangana 21179
All India
7,15,343 sq.km
Goa 2266
Karnataka 39254
Andhra 30085
A&N Islands 6733
Lakshadweep 27
Kerala 22059
Tamil Nadu 26450
Puducherry 44

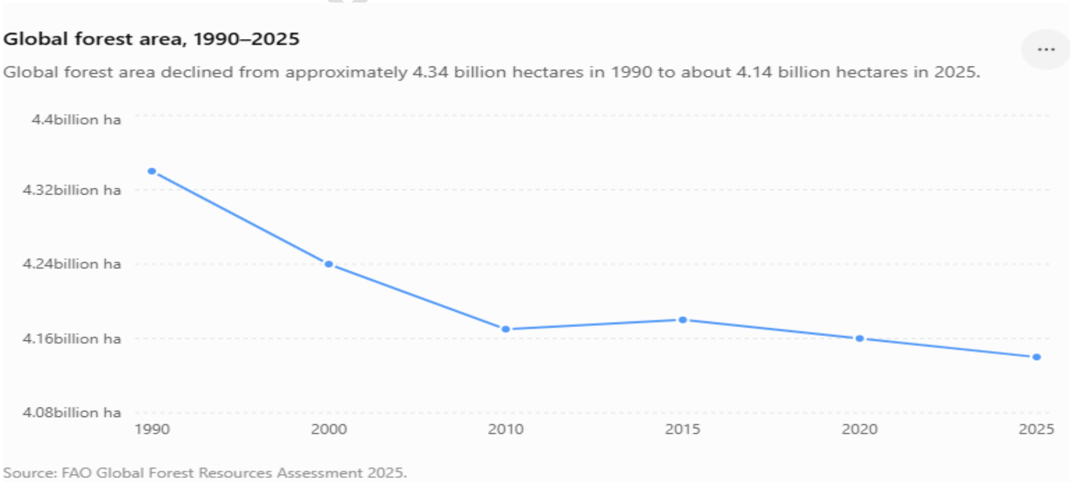


The ISFR 2023 map shows substantial spatial variation. Large forest areas occur in Madhya Pradesh, Arunachal Pradesh, Chhattisgarh, Odisha and Maharashtra, while the northeastern states generally have high forest cover relative to their geographical area. The latest assessment reports India's forest cover at approximately 715,343 sq. km, while forest plus tree cover is approximately 827,357 sq. km.

10. Graphical Analysis of Deforestation Trends

Graph 1. Global Forest Area, 1990–2025

Global forest area, 1990–2025



Source: FAO Global Forest Resources Assessment 2025.

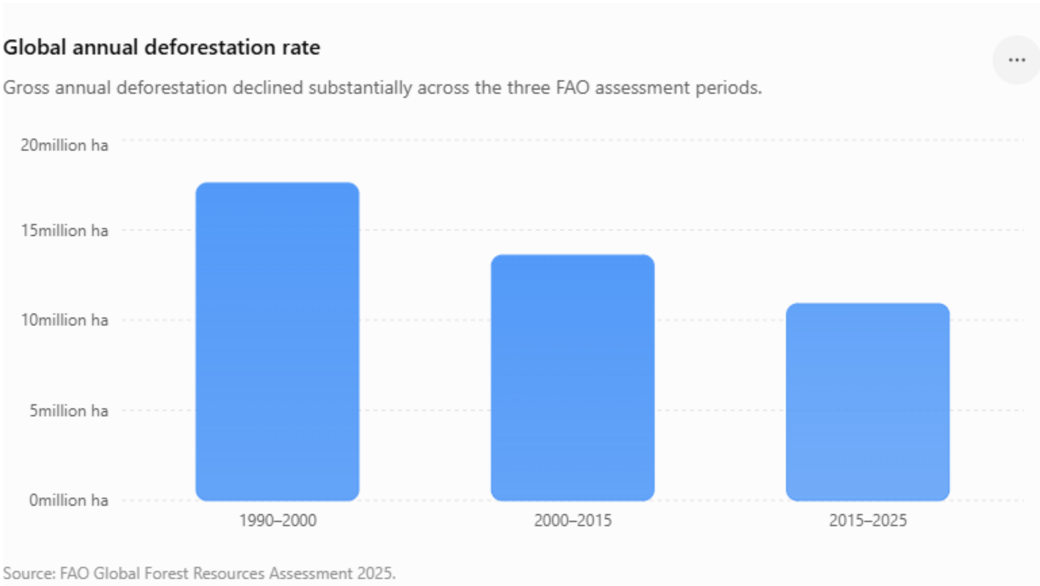
Global forest area declined from approximately 4.34 billion hectares in 1990 to about 4.14 billion hectares in 2025.

Interpretation: The graph shows a long-term decline in global forest area. Although the rate of decline has slowed, the world has still experienced substantial cumulative forest loss since 1990.

Graph 2. Global Annual Deforestation Rate

Global annual deforestation rate

Gross annual deforestation declined substantially across the three FAO assessment periods.



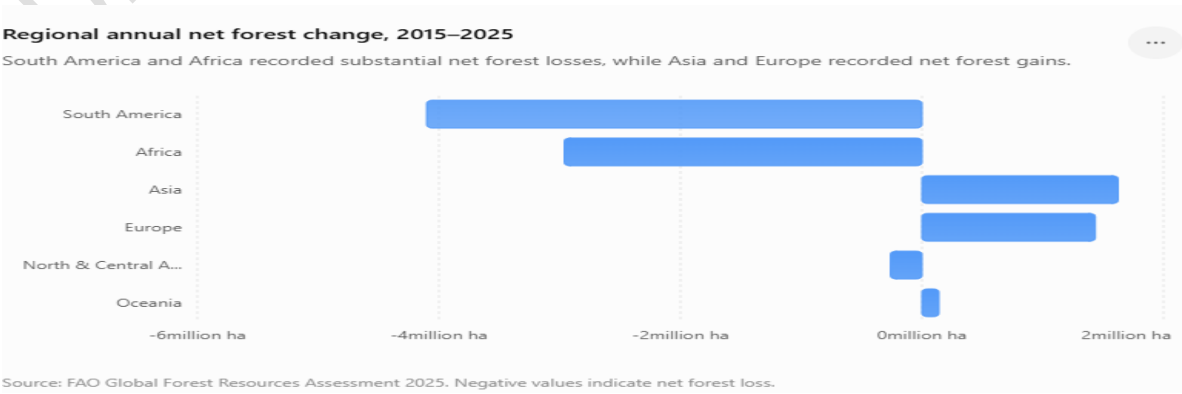
Source: FAO Global Forest Resources Assessment 2025.

The annual rate declined from 17.6 million hectares during 1990–2000 to 10.9 million hectares during 2015–2025, representing a substantial slowdown in gross deforestation.

Graph 3. Regional Net Forest Change

Regional annual net forest change, 2015–2025

South America and Africa recorded substantial net forest losses, while Asia and Europe recorded net forest gains.



Source: FAO Global Forest Resources Assessment 2025. Negative values indicate net forest loss.

Interpretation: The regional comparison clearly demonstrates that deforestation is geographically uneven. South America and Africa remain major forest-loss regions, whereas Europe and Asia have experienced net forest gains.

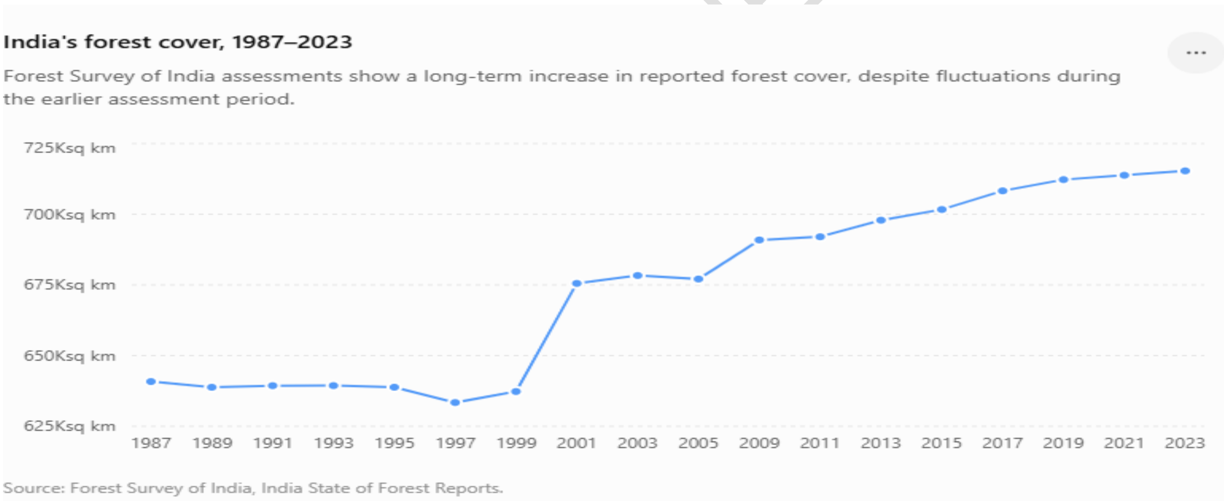
11. India: Forest-Cover Trend, 1987–2023

India's forest-cover statistics provide an important contrast to the global trend. The Forest Survey of India conducts periodic assessments of forest cover using remote sensing and other supporting information.

Graph 4. India's Forest Cover, 1987–2023

India's forest cover, 1987–2023

Forest Survey of India assessments show a long-term increase in reported forest cover, despite fluctuations during the earlier assessment period.



Source: Forest Survey of India, India State of Forest Reports.

Interpretation

The Indian trend can broadly be divided into three phases:

First phase (1987–1997): Forest cover fluctuated and generally declined, reaching approximately 633,397 sq. km in 1997.

Second phase (1999–2013): Forest cover showed a generally increasing trend, reaching approximately 697,898 sq. km by 2013.

Third phase (2015–2023): A continued increase is visible, with forest cover reaching approximately **715,343 sq. km in 2023**.

It is important, however, to distinguishforest-cover increase from ecological recovery. Satellite-based forest-cover measurements can include plantations and other tree-covered areas; therefore, an increase in forest-cover area does not automatically mean that natural-forest biodiversity or ecological quality has improved.

12. India: Forest and Tree Cover

Graph 5. India's Forest + Tree Cover

Assessment Year	Forest Cover (sq. km)	Tree Cover (sq. km)	Forest + Tree Cover (sq. km)
2011	692,027	90,844	782,871
2013	697,898	91,266	789,164
2015	701,673	92,572	794,245
2017	708,273	93,815	802,088
2019	712,249	95,027	807,276
2021	713,789	95,748	809,537
2023	715,343	112,014	827,357

Source: Forest Survey of India, ISFR 2023.

The latest assessment indicates that India's combined forest and tree cover is approximately 827,357 sq. km, equivalent to around 25.17% of the country's geographical area.

13. State-wise Forest-Cover Change

Graph 6. Major State-Level Changes

For the state-level graph, the research paper should distinguish between increase and decrease in forest/tree cover rather than presenting only the absolute forest area.

Category	State	Recent change
Increase	Chhattisgarh	+683.62 sq. km
Increase	Uttar Pradesh	+559.19 sq. km
Increase	Odisha	+558.57 sq. km
Increase	Rajasthan	+394.46 sq. km
Decrease	Madhya Pradesh	−612.41 sq. km
Decrease	Karnataka	Decline
Decrease	Ladakh	Decline
Decrease	Nagaland	Decline

These figures illustrate that India's national forest-cover trend conceals considerable inter-state variation.

Key Findings

The combined map, table and graphical analysis provides the following major conclusions:

1. **Global forest area is declining**, although the pace of loss has slowed substantially since the 1990s.

2. **Gross global deforestation declined** from approximately 17.6 million hectares per year in 1990–2000 to approximately 10.9 million hectares per year in 2015–2025.

3. **South America and Africa remain major forest-loss regions**, particularly the Amazon and Congo Basin regions.

4. **Asia and Europe show comparatively positive forest-area trends**, although important localised deforestation continues in Southeast Asia.

5. **India's reported forest cover has increased** over the long term, reaching approximately 715,343 sq. km in 2023.

6. India's forest cover is **spatially uneven**. Large absolute forest areas are concentrated in Madhya Pradesh, Arunachal Pradesh, Chhattisgarh, Odisha and Maharashtra, while several northeastern states have very high forest cover relative to geographical area.

7. **Forest cover is not equivalent to forest quality.** Natural forests, plantations, fragmented forests and tree cover outside forests have different ecological characteristics.

8. The global evidence therefore presents a **mixed picture**: deforestation rates are slowing, but tropical forest ecosystems remain under serious pressure.

Conclusion

Deforestation is one of the most serious environmental challenges facing the world because forests are closely connected with climate regulation, biodiversity conservation, soil protection, water security and human livelihoods. The analysis presented in this paper shows that the relationship between deforestation and climate change is two-way and mutually reinforcing. Forest destruction releases stored carbon into the atmosphere, reduces the capacity of ecosystems to absorb carbon dioxide, and can alter rainfall, temperature and regional climatic conditions. At the same time, climate change increases the vulnerability of forests to drought, wildfire, pests, extreme temperatures and ecosystem degradation.

The analysis of global trends indicates that considerable progress has been made in reducing the rate of deforestation. According to FAO's Global Forest Resources Assessment 2025, annual gross deforestation declined from approximately 17.6 million hectares per year during 1990–2000 to 10.9 million hectares per year during 2015–2025. However, the reduction in the rate of loss should not be interpreted as the elimination of the problem. Global forest area has continued to decline, and tropical forests remain under particularly strong pressure. South

America and Africa continue to experience substantial forest losses, while Europe and parts of Asia have demonstrated that forest restoration and expansion are possible through appropriate policies and forest-management practices.

The India-specific analysis presents a relatively positive picture in terms of reported forest cover. India's forest cover increased from approximately 640,819 sq. km in 1987 to about 715,343 sq. km in 2023 according to Forest Survey of India assessments. The latest assessment also indicates substantial forest and tree cover. Nevertheless, national-level increases conceal considerable regional differences. Some states and ecological regions have experienced forest-cover gains, while others, particularly parts of the Northeast and other ecologically sensitive areas, have experienced declines or degradation. Therefore, forest-cover statistics should not be interpreted simply as evidence that all Indian forests are becoming healthier. Forest quality, biodiversity, fragmentation, natural-forest loss and the distinction between natural forests and plantations must also be considered.

The study further demonstrates that deforestation is driven by multiple interacting economic, social and institutional factors. Agricultural expansion, commercial logging, livestock production, mining, infrastructure development, urbanisation, fuelwood collection and population pressure are among the major direct and indirect drivers. In many developing regions, poverty and dependence on forest resources combine with weak governance and insecure land rights to increase pressure on forests. Consequently, effective solutions cannot depend solely on restrictions on forest use; they must also address the economic and social conditions that encourage unsustainable exploitation.

From a climate-change perspective, forest conservation should be regarded as an important component of climate mitigation and adaptation policy. Protecting existing natural forests is generally more effective than attempting to replace them after destruction. Afforestation, reforestation, agroforestry, sustainable forest management, restoration of degraded landscapes and community-based conservation can complement forest protection. However, tree planting programmes should prioritise ecologically appropriate native species and restoration of functioning ecosystems, rather than relying exclusively on monoculture plantations.

The paper therefore argues for an integrated approach based on forest conservation, sustainable economic development, climate policy and community participation. Governments should strengthen forest governance, improve monitoring through satellite and GIS technologies, control illegal logging and land conversion, promote sustainable agricultural practices, secure community and indigenous land rights, and provide economic incentives for forest conservation. Carbon markets, payments for ecosystem services and REDD+ mechanisms can provide additional financial incentives where they are designed with strong environmental and social safeguards.

Ultimately, the evidence suggests that the future of forests depends not simply on increasing the total number of trees but on protecting natural forests, improving forest quality and ensuring sustainable relationships between people and forest ecosystems. The decline in global deforestation rates provides an encouraging indication that effective policies can produce results. However, continued forest loss, biodiversity decline and climate change demonstrate that existing efforts remain insufficient. A successful long-term strategy must therefore move from a narrow focus on reducing deforestation towards a broader objective of forest conservation, ecological restoration, climate resilience and sustainable livelihoods.

In conclusion, forests should be treated not merely as sources of timber and land but as critical natural infrastructure for climate stability, biodiversity and sustainable development. Achieving the Sustainable Development Goals and long-term climate objectives will require countries to halt avoidable forest loss while restoring degraded ecosystems. The future trajectory of deforestation will ultimately depend on whether economic development can be decoupled from forest destruction and whether governments, communities, businesses and international institutions can work together to create a more sustainable forest economy.

References

I. de-Miguel, S., Birhanu, A., Oliveras Menor, I., Ascoli, D., Spadoni, G. L., &Erdozain, M. (2025). Carbon emissions from forest disturbances under global change. *Current Forestry Reports, 11*, 29. https://doi.org/10.1007/s40725-025-00257-5

II. West, C., Rabeschini, G., Singh, C., Kastner, T., Bastos Lima, M., Dermawan, A., Croft, S., & Persson, U. M. (2025). The global deforestation footprint of agriculture and forestry. *Nature Reviews Earth & Environment, 6*, 325–341. https://doi.org/10.1038/s43017-025-00660-3

III. Yahaya Seydou, A. N., et al. (2025). Biophysical effects of land cover changes in West Africa: A systematic review. *Environmental Research Letters*, *20*, 073001.

IV. Oliveras Menor, I., Prat-Guitart, N., Spadoni, G. L., et al. (2025). Integrated fire management as an adaptation and mitigation strategy to altered fire regimes. *Communications Earth & Environment*, *6*, 202. https://doi.org/10.1038/s43247-025-02165-9

V. Bousfield, C. G., & Edwards, D. P. (2025). The pan-tropical age distribution of regenerating tropical moist forest. *Nature Ecology & Evolution*. https://doi.org/10.1038/s41559-025-02721-8

VI. Food and Agriculture Organization of the United Nations (FAO). (2025). *Global Forest Resources Assessment 2025*. Rome: FAO.

VII. Food and Agriculture Organization of the United Nations (FAO). (2020). *Global Forest Resources Assessment 2020: Main Report*. Rome: FAO.

VIII. Food and Agriculture Organization of the United Nations (FAO). (2018). *The State of the World's Forests 2018: Forest Pathways to Sustainable Development*. Rome: FAO.

IX. Food and Agriculture Organization of the United Nations (FAO). (2022). *The State of the World's Forests 2022: Forest Solutions for Green Recovery and Inclusive, Resilient and Sustainable Agrifood Systems*. Rome: FAO.

X. Forest Survey of India (FSI). (2023). *India State of Forest Report 2023*. Dehradun: Ministry of Environment, Forest and Climate Change, Government of India.

XI. Forest Survey of India (FSI). (2021). *India State of Forest Report 2021*. Dehradun: Ministry of Environment, Forest and Climate Change, Government of India.

XII. Forest Survey of India (FSI). (2019). *India State of Forest Report 2019*. Dehradun: Ministry of Environment, Forest and Climate Change, Government of India.

XIII. Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Mitigation of Climate Change*. Contribution of Working Group III to the Sixth Assessment Report. Cambridge University Press.

XIV. Intergovernmental Panel on Climate Change (IPCC). (2021). *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report. Cambridge University Press.

XV. Intergovernmental Panel on Climate Change (IPCC). (2019). *Climate Change and Land: An IPCC Special Report*. Geneva: IPCC.

XVI. United Nations Environment Programme (UNEP). (2023). *State of Finance for Nature 2023*. Nairobi: United Nations Environment Programme.

XVII. United Nations Environment Programme (UNEP). (2021). *Becoming #GenerationRestoration: Ecosystem Restoration for People, Nature and Climate*. Nairobi: UNEP.

XVIII. World Bank. (2022). *Forests and Climate Change*. Washington, DC: World Bank.

XIX. World Bank. (2021). *The Changing Wealth of Nations 2021: Managing Assets for the Future*. Washington, DC: World Bank.

XX. WWF. (2021). *Deforestation Fronts: Drivers and Responses in a Changing World*. World Wide Fund for Nature.

XXI. Curtis, P. G., Slay, C. M., Harris, N. L., Tyukavina, A., & Hansen, M. C. (2018). Classifying drivers of global forest loss. *Science, 361*(6407), 1108–1111. https://doi.org/10.1126/science.aau3445

XXII. Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., et al. (2013). High-resolution global maps of 21st-century forest cover change. *Science, 342*(6160), 850–853. https://doi.org/10.1126/science.1244693

XXIII. Hosonuma, N., Herold, M., De Sy, V., De Fries, R. S., Brockhaus, M., Verchot, L., Angelsen, A., & Romijn, E. (2012). An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters, 7*(4), 044009. https://doi.org/10.1088/1748-9326/7/4/044009

XXIV. Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., Phillips, O. L., Shvidenko, A., Lewis, S. L., Canadell, J. G., et al. (2011). A large and persistent carbon sink in the world's forests. *Science, 333*(6045), 988–993. https://doi.org/10.1126/science.1201609

XXV. Lewis, S. L., Wheeler, C. E., Mitchard, E. T. A., & Koch, A. (2019). Restoring natural forests is the best way to remove atmospheric carbon. *Nature, 568*, 25–28. https://doi.org/10.1038/d41586-019-01026-8