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Regional disparities in Forest Coverage in India: Convergence or Divergence?

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Abstract: India has committed to enhance its forest and tree cover to achieve a target of 33% of its geographical area designated as forested under National Forest Policy, 1988 and aim to establish an extra carbon absorption capacity of 2.5-3 billion tonnes of CO_2 equivalent by the year 2030 under Paris Agreement. Analyzing convergence patterns is essential for evaluating the uniform effectiveness of national policies and identifying any existing regional disparities. This study examines whether regional disparities in forest cover among Indian states have reduced over the period 2001-2023 by employing sigma and beta convergence frameworks commonly used in growth economics literature and found substantial evidence of absolute and sigma convergence. We utilize state-level forest cover biennial data from the Indian State of Forest Reports (ISFR) to test for two kinds of convergence.

Keywords: *Absolute Convergence, Sigma Convergence, Regional Disparities, Forest Area, CO_2 Emissions.*

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I. INTRODUCTION

The environmental and social challenges arising from the rapid global advancement of the economy and society have grown significantly more severe and are now a matter of considerable concern. Sustainable development is the best approach to balance environmental protection, social well-being, and economic growth. The Brundtland report, Our Common Future published in 1987 defines sustainable development as "Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs." A significant and recent global initiative in this area is the United Nations 2030 Agenda for Sustainable Development (UN Agenda 2030), which includes 17 Sustainable Development Goals (SDGs) and 169 associated targets, which were implemented on January 1, 2016. The United Nations clarified that the Sustainable Development Goals, and their associated targets, are interconnected and cannot be separated. These goals and targets aim to achieve a harmonious balance among the three pillars of sustainable development: economic, social, and environmental.

The global economy has quintupled in the previous 50 years, primarily via the utilization of resources from nature and energy, according to the United Nations Environment Programme (UNEP). The economic sector is a significant contributor to global warming from its different activities (Udeagha and Breitenbach, 2023). Environmental quality has been deteriorated by climate change, biodiversity loss and other forms of contaminations. Climate precipitation patterns are altered by excessive global warming rates while increased frequency of extreme natural disaster endanger humanity (Qiao et al. 2022). The main cause of the greenhouse gas effect, which leads to global warming, is emissions of carbon dioxide. Between 1990 and 2024, emissions of carbon dioxide rose from 1.96 billion tonnes to 38.60 billion tonnes, according to statistics from our world in data.. Furthermore, the amount of CO_2 in the atmosphere has increased from 280 parts per million (PPM) in 1750 to 422.7 PPM in 2024 (NOAA Global Monitoring Lab).Consequently, environmental issues linked to the rise in CO_2 emissions have become a priority for the international community. In this regard, many countries implemented different strategies to tackle climate change and among these measures forest cover is an effective pathway for mitigating CO_2 emissions. Forests functions as a sink for carbon by sequestering carbon dioxide during photosynthesis, transforming it into matter that is organic and emitting oxygen in the process. The Kyoto Protocol, adopted in 1997 aimed at reducing greenhouse gas emissions acknowledges the essential function of forests in alleviating climate change and establishes mechanism for the managing and safeguarding forested areas. Globally, forests sequester substantial amount of atmospheric carbon and store it in biomass and soil. However, emissions of carbon from human endeavours such as the combustion of fossil fuels and deforestation, which raise atmospheric CO_2 levels, outpace the absorption by natural sinks (Whitehead, D. 2011).

The factors affecting the environment and measures to improve environmental sustainability have received widespread attention and forest area are included among

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such factors. Forest cover is defined as the total area of land, covered by trees which is more than 1 hectare with a canopy density greater than ten percent, regardless of ownership or legal status. Forests are categorized according to their density; if the density of the forest area is more than or equivalen to 70%, they are classified as very dense forest cover; if density is between 40 to 70%, they are classified as moderately dense forest cover; and if density is less than 10%, they are considered as open forests. In India total forest and tree cover is 715342.61 km^2 which is 25.17% of geographical area of India (FSI, 2023). However, India's cultural, economic, social and environmental dynamics are greatly influenced by its geographical diversity, which spans from the Himalayas to tropical coastlines. This diversity includes rich agricultural areas in the Indo-Gangetic plains, vibrant tropical rainforest on the western coast and temperate forests in the Himalayas leads to regional disparity in forest cover throughout the nation (Shekhar, 2024).

India has witnessed substantial economic growth throughout the past 30 years, transforming into one of the world's fastest-growing major economies. However, this accelerated expansion has commonly been coupled with environmental challenges, including rising greenhouse gas emissions and pollution. Striking a balance between economic progress and nature's sustainability remains a top priority for the country. India has pledged to cut its emissions intensity per GDP by 33 to 35% from 2005 levels and increasing the amount of forest and tree cover in order to create an extra sink for carbon of 2.5 to 3 billion tonnes of carbon dioxide equivalent by 2030 as per its updated NDCs. Government of India had launched several initiatives to increase its forest cover. Under the National Forest Policy enacted in 1988 a goal was established to ensure 33% of the nation's land remains forested. A community-based forest conservation Initiative Joint Forest Management set forth to combat forest degradation and enhance sustainable resources management The 12th Finance Commission acknowledge the inconsistency regarding disparity between the cost incurred and the benefits received in relation to the preservation of natural assets and allocate 10 billion rupees to corresponding state governments for their forest conservation. Furthermore, in 2014 the Green India mission launched, seeks to expands forest and tree coverage by 5 million hectares while also restoring an additional 5 million hectares of degraded land. It provides support to states via financial assistance, technical expertise, and livelihood opportunities to improve forest cover, biodiversity, and resilience to climate change. As these policies are uniformly applied across all states, investigating whether the states converge towards a singular pattern is a pertinent research topic.

The amount of forest cover in India has witnessed a consistent and gradual rise in the past 15 to 20 years as we can see from fig 1 based on FSI data.

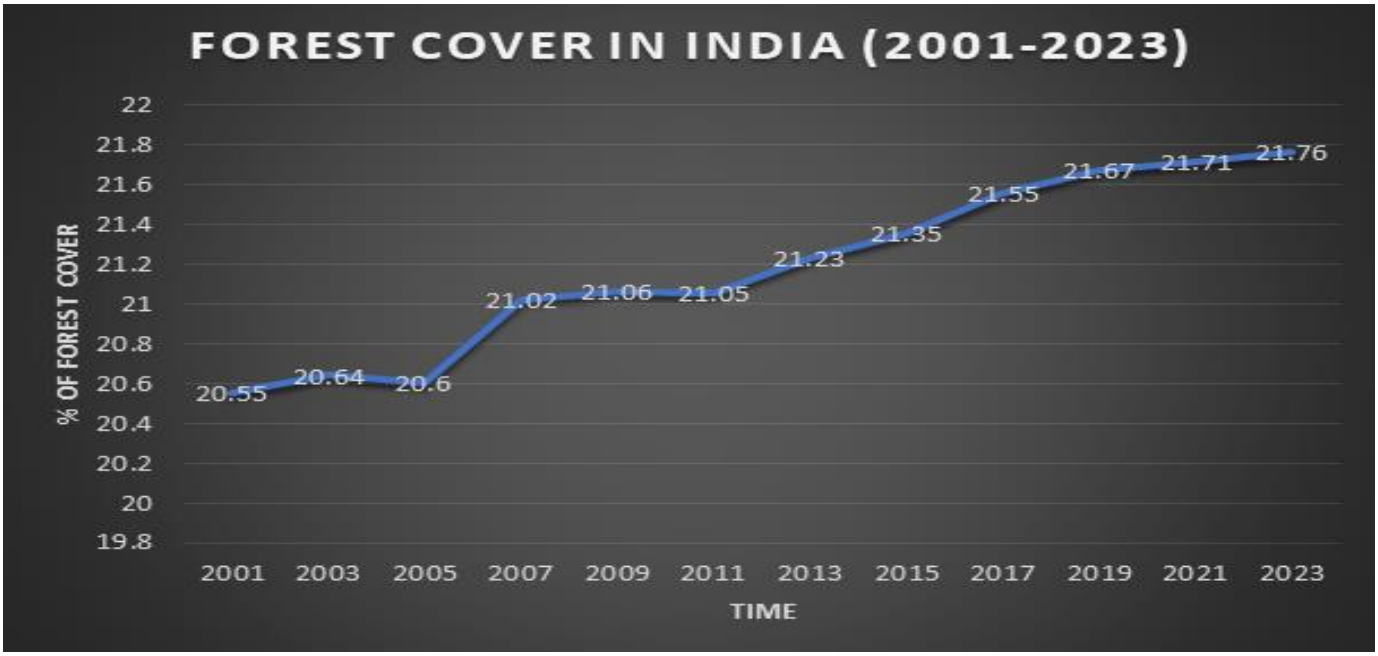

Fig 1
Source: forest survey of India reports

The subsequent section of this study is delineated as follows. The literature review is presented in section 2, and the data and methodology are presented in section 3. The findings are shown in section 4, and section 5 concludes.

II. LITERATURE REVIEW

The concept of convergence emerges from neoclassical growth model which argues that countries tend to converge as they develop. Neoclassical growth model (Solow, 1956) based on the assumption of declining marginal productivity asserts that poor economies tend to grow faster than rich ones. The concept of β and σ convergence was first introduced by Baumol (1986). From 1991 to 2020 Sinha (2024) examined economic development and convergence in

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26 Indian states and discovered no evidence of absolute and sigma convergence across Indian states. However, their research shows conditional convergence. Cherodian & Thirlwall (2015) investigated regional differences in per capita income across 32 Indian regions from 1999 to 2010 by estimating beta and sigma convergence and found no evidence unconditional convergence however, it reveals weak conditional convergence. Nag et al. (2023) explored the regional convergence in health outcomes in 15 major states in India from 1990 to 2018 by using σ test, Kernel density and log-t test methods and observe sigma convergence in life expectancy at birth across all states. However, divergence pattern experienced in the domains of the rate of deaths among newborns and infants in their early stages of life and total fertility rate. Jangam et al., (2020) found the evidence of convergence in electricity consumption among 18 Indian states spanning over the period 1970 and 2014 through Phillips and Sul panel convergence methodology. Using the same methodology Akram & Rath (2022) confirmed convergence in government revenue across 22 Indian states from 1980 to 2014.

In recent years, convergence analysis in relation to environmental quality indicators has seen considerable growth, concentrating on whether regional differences in environmental performances are diminishing or increasing. Van (2005) employed non parametric methods and concludes that CO_2 emissions have converged between industrial economies, while there is limited indication of convergence for the entire sample of 100 countries from 1966 and 1996. Westerlund & Basher (2008) applied panel unit root testing approached and examined the convergence in CO_2 emissions among developed and emerging nations from 1870 to 2002 and evidenced the existence of stochastic convergence. Jobert et al., (2010)verified that, between 1971 and 2006, the per capita CO_2 emissions of 22 European nations exhibited absolute convergence. Apart from these Nicolli (2012) investigated the convergence of waste related indicators across 103 provinces in Italy from 1999 to 2008, utilized both β-convergence and σ-convergence frameworks and concludes that convergence exist across Italian provinces' waste indicators. Li & Lin (2013) investigated the global convergence pattern among 110 countries in per capita CO_2 emissions from 1971 to 2008 and found little evidence of absolute convergence. Additionally, the study validated that countries with analogous income levels exhibited a robust tendency towards economic convergence. Ulucak et al. (2020) examined the convergence of ecological footprints among Sub-Saharan Africa by using log-t test panel club methodology from 1961 to 2014.the results show that while there are some convergent clubs in subcomponents, there is no evidence of overall club convergence. It is evident that in all the above mentioned literature, the matter pertaining to convergence has been approached and addressed with a primary emphasis on CO_2 emissions and ecological footprints in environmental indicators while there is limited attention given to other indicators of environmental quality such as forest ecosystem which serves as a key factor in both mitigating and adapting to climate change, making forest conservation a beneficial strategy for managing climate- related risks (Ingalls & Dwyer 2016). Also, most of the studies are cross country in nature and research at regional level is scarce in India. In context of India Akram et al. (2023) explore per capita CO2 emissions convergence by employing Phillips and Sul club convergence approach from 2003 to 2018 and found three distinct clubs. To the best of author's knowledge there is no study at regional level which examine convergence among Indian states forest cover. To fill this gap, we will examine convergence among 26 Indian states forest cover area from 2001 to 2023. Understanding convergence pattern among Indian states will be helpful for policy formulation as India to attain the designated targets of creating an extra carbon absorption capacity of 2.5 to 3 billion tonnes of CO_2 by 2030 under the Paris agreement and reviving 26 million hectares of deteriorated land as a component of the Bonn Challenge by 2030

III. DATA AND METHODOLOGY

As the forest area expands in India, and there is vast disparity in forest covered area across various Indian states it becomes crucial to assess whether this growth increases the disparity between well-forested and poorly forested regions or mitigates that gap. To check convergence, we use total forest area of states as a percentage of their geographical area from India state of Forest reports released by the Forest Survey of India biennially from 2001 to 2023 across 26 Indian states. We utilize the sigma and absolute beta convergence framework, which is commonly used in growth literature. The σ convergence tests the convergence by identifying whether the standard deviation or coefficient of variation among group of countries or regions decrease over time. To measure dispersion, we have estimated the standard deviation and the coefficient of variation. Additionally, the coefficient of variation has been regressed over time. β convergence seeks to determine whether a catch-up process happens. The "catch-up" process means that, states with initially lower level of forest cover area would experience higher growth in forest cover and eventually both the high forested and low forested states just converge to the same forest area. β convergence will be tested by regressing the average growth rate on initial level of forest cover.

IV. ANALYSIS OF RESULTS

Sigma convergence occurs if there is reduction in dispersion measured across a group of countries or regions. $\sigma t > \sigma t + T$ implies reduction of the dispersion at the level of regions, indicating the convergence of studied phenomena (Sala-i-Martin, 1996).

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Table 1 Temporal Evolution of Forest Cover Dispersion

Year	Mean forest cover	Standard Deviation	Coefficient of Variation
2001	34.13	26.81	0.78
2003	35.05	28.27	0.81
2005	35.11	28.40	0.81
2007	35.66	28.47	0.80
2009	35.64	28.39	0.79
2011	35.56	28.22	0.79
2013	35.73	27.89	0.78
2015	35.75	27.73	0.77
2017	35.84	27.33	0.76
2019	35.89	27.10	0.75
2021	35.78	26.84	0.75
2023	35.86	26.79	0.74

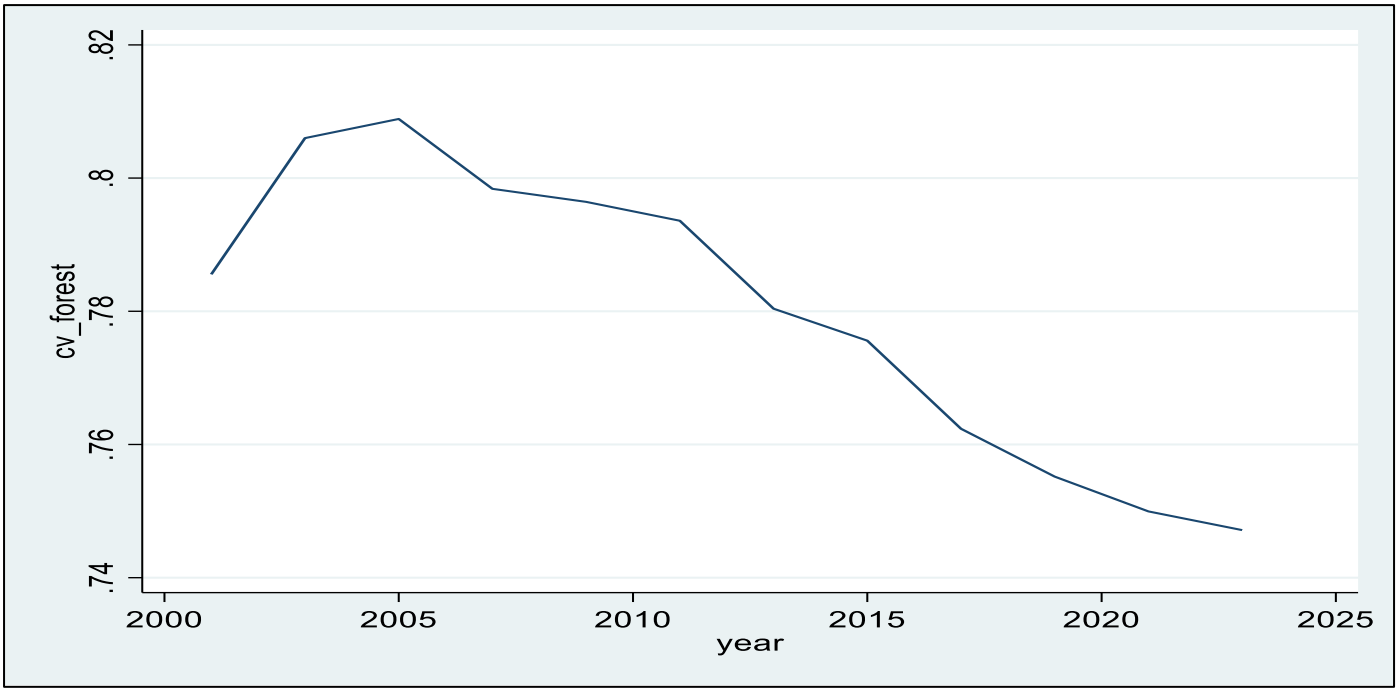

Fig 2 CV Over the Time

The initial rise in CV and SD from 2001 to 2005 was mainly a result of methodological artifacts rather than actual ecological change: In 2001 the Forest Survey of India implemented a significant shift to digital interpretation at a scale of 1:50,000 from visual interpretation at a 1:250,000 scale revealed previously hidden variations. In 2003 the introduction of very dense forest (VDF) category intensified the differences between states rich in forests and those that are forest-poor. (FSI, 2003) The coefficient of variation decreased from 0.786 in 2001 to 0.747 in 2023, indicating a reduction of roughly 4.96% throughout the study period. Additionally, it can be noted that the value has diminished from 0.8088 in 2005 to 0.747 in 2023, reflecting a reduction of around 7.6%. This decrease suggests that the variation in forest cover across Indian states has diminished over time, pointing to a pattern of convergence in the outcomes of forest conservation efforts.

- *To Test the Sigma Convergence CV have been Regressed Over Time*

$CV_t = \alpha + \beta t + \mu$
t refers to the time
μ implies the error term

The positive value of β indicates increasing forest cover dispersion over the years (σ divergence), whereas a negative value of β indicates decreasing dispersion (σ convergence).

Table 2 Sigma Convergence Analysis

Variable (CV)	**Coefficient**	**Std error**	**T**	**p>t**
Time trend	-0.0036	.00018	-19.29	0.000
Const	.809	.0020	402.21	0.000

N=10 R squared =0.9790 Adj. R squared=0.9763

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The negative and highly significant coefficient on the time trend (β = -0.0036346, p < 0.001) provides strong statistical evidence of sigma convergence. The coefficient indicates that the CV declined by approximately 0.36 percentage points per year on average. The high R^2 value (0.98) suggests that the linear time trend captures the convergence pattern effectively.

➢ *Absolute β-convergence*

- *Absolute Convergence*

H_0: β ≥ 0 (there is no absolute convergence)
H_1: β < 0 (there is absolute convergence)

The null hypothesis argues that growth rate of forest cover area remains independent of the initial level of forest cover area. However, the alternative hypothesis indicates a negative association between the rate of growth and initial level of forest cover area leading to convergence.

➢ *Empirical Model*

In order to examine the presence of absolute beta convergence in forest cover across Indian states, we employ the standard growth regression framework following Barro and Sala-i-Martin (1992):

- *Model Specification:*

$$\Delta FC_{it} = \alpha + \beta \cdot FC_{it-1} + \varepsilon_{it}$$

ΔFC_{it} = Percentage change in growth rate in forest cover for state i from period t-1 to period t
$FC_{i,t-1}$= Forest cover (as percentage of geographical area) for state i at the beginning of period t
α= Constant term representing autonomous growth rate
β= Convergence coefficient
$\varepsilon_{i,t}$= Error term
i = State identifier (i = 1, 2, ..., N)
t = Time period (biennial observations from 2005 to 2023)

Table 3 Beta Convergence Analysis

Variable	Coefficient	Std. error	T-statistics	P- value
FC_{it}	-0.0002598	.000073	-3.56	0.000
Const	.0170	.0032	5.19	0.000

N = 234 R-squared = 0.0518 Adjusted R-squared = 0.0477 F = 12.67 Prob>F = 0.0004

Strong evidence of absolute beta convergence in forest cover across Indian states is provided by the regression results. The negative and statistically coefficient on base year forest cover (β = -0.000260, p <0.001), reveals that states possessing a comparatively lesser forest coverage at the outset experienced faster subsequent growth rates. This leads to the conclusion that disparities in forest cover between Indian states are gradually diminishing over time.

V. CONCLUSION

This study explored the regional convergence of forest cover area in 26 Indian states from 2001 to 2023. A series of tests on β & σ convergence have been performed, with the aim of understanding whether the poor forested states are catching up with the rich forested ones, and if this process is reducing the difference between the states. The results of the sigma convergence analysis prove that the disparities across the states are decreasing. Also, from the study on beta convergence, we can observe that forest cover area is actually converging across states. Finally, this investigation verified that the adopted policies are effective in augmenting forest cover area and reducing regional disparities, aligning with the findings of Raghavan and Shrimali (2015), who investigated the factors that may affect forest cover at the state level in India across a span of two decades (1990-2008) and found that the implementation of joint forest management policy is positively correlated with forest cover.

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