

## Drivers of Deforestation and Degradation of Forest Land in India

**Somaiya Begum**

Research Fellow

Department of Economics

Rabindra Bharati University, 56 A, B.T. Road, Kolkata 700 050, W.B., India.

Email ID: [somaiyabegum@gmail.com](mailto:somaiyabegum@gmail.com),

**Debolina Saha**

Professor of Economics

Department of Economics

Rabindra Bharati University, 56 A, B.T. Road, Kolkata 700 050, W.B., India.

Email ID: [debolina120@gmail.com](mailto:debolina120@gmail.com)

### Abstract

*Forests provide several ecosystem services for the survival of human beings. However, worldwide deforestation is one of the most pressing environmental issues in recent times. India is also facing this challenge; in fact, stood right after Brazil in terms of forest loss during 2015-2020, and experienced a biggest increase in deforestation in the last 30 years globally (India Today Report, 2023). Although, Forest Survey of India Report (2021) shows a slight increase in forest cover in the last few years, the quality of plantation to increase tree cover in India is in question. The present study, therefore, attempts to identify the major factors under the three dimensions - socio-economic, climatic and governance accountable for forest loss at a Pan India level for the major States and Union Territories during 2005-2019, using a panel framework. Even, forest depletion and degradation due to collection of various forest produces, and variations in regional characteristics for different geographical zones in India bear serious policy implications for forest conservation. This study criticizes mono plantation, since it is not a viable practice for safeguarding biodiversity and assisting local livelihoods. Lastly, the study examines the Forest Conservation (Amendment) Bill, 2023, of India, which has permitted additional economic activities for nation building, withdrawing adequate legal protection for forests.*

**Keywords:** Deforestation, Forest Degradation, Climate Change, Forest Policy, Forest Conservation.

**JEL classification:** C1, F1, Q53, Q56.

### Introduction

Forests are fundamental to mitigate climate change since they act as carbon sink; inducing atmosphere, hydrologic cycle and terrestrial energetics by their biological, chemical and physical interplay (Bonan, 2008). Forests have the potential to neutralize global CO<sub>2</sub> concentrations through their secured, natural and economical carbon trapping and storage mechanism (Roy, 2020; Negi, 2022) than any other terrestrial ecosystems. During 2001-2019, forests absorbed 7.6 gigatonnes of CO<sub>2</sub> every year from the atmosphere (Harris et al., 2021). However, due to deforestation, only 24 percent of tropical forests are still unharmed (Lewis et al., 2015). Deforestation causes for about 10 percent of worldwide emissions.<sup>i</sup> For many decades, forests are clear-felled to convert them into agricultural and grazing lands and, to procure wood for fuel, development and manufacturing purposes.<sup>ii</sup> Tropical Forest loss in 2022 amounted to 4.1 million hectares (Mha) despite several International Commitments aiming to end up deforestation. While coming to India, the country is endowed with rich biological

diversity; however, this biodiversity is being jeopardized by continual deforestation. Globally India comes at 3<sup>rd</sup> place in terms of annual net gain in total forest area<sup>iii</sup>; however, the gain is nominal and the type of plantation done in India is not connected to biodiversity conservation. In contrast, it has also been estimated that during 2002-2022, India lost 393 kilohectares (kha) of humid primary forest, making up 18 percent of its tree cover loss in the same time period.<sup>iv</sup> Around 14,000 square kms (km<sup>2</sup>) of forests were wrecked in the last 3 decades to promote 23,716 developmental and manufacturing projects throughout India.<sup>v</sup> Loss of forest density or, deforestation is also detrimental in the sense that this demotes the organic carbon of the soil, and thereby reduces the carbon storage capacity of the ecosystem. Larger the green cover of the forests and, older and healthier the trees are, carbon sequester capacity makes better (Roy, 2020). Usually, people living in and proximity to the forest areas depend on variety of forest produces for their livelihoods (Saha and Agarwalla, 2021). Apart from timber, the non-timber forest products (NTFP) which the forest-fringe people collect from the forests include several food items like fruits and vegetables, seeds, mushrooms, honey, etc., for the human beings and fodder for the animals, and also many non-food items like medicinal plants, gums and resins, oils, perfumes, fibers, wax, and other marketable products. However, often it becomes difficult to assess the economic, cultural and traditional values of forests, and their roles in preserving ecological balance due to the lack of appropriate methodologies (Saha and Taron, 2023). A study conducted in TERI (The Energy and Resource Institute) showed that forest degradation expropriated 1.4 percent of India's GDP annually (Sethi, 2018). Although the estimated total economic value of Indian forests was at INR 6,96,000 million yearly, roughly 6.86 percent of the GDP depicted the mere minimal approximate values of products spawned by forests (Bahuguna and Bisht, 2013). Degeneration of forest cover can be quantitative as well as qualitative. At present, the costs of forest degradation are mounting, affecting the local and global economy with severe consequences on environment. One more apparent outcome of forest degradation is that it intimidates the long-run food security (Reddy et al., 2001). Roy et al. (2013) and Forman et al. (2003) discussed how construction of roads for better connectivity invariably resulted in forest fragmentation. Drohan et al. (2012) and Roy et al. (2013) found socio-economic and infrastructural development to be the other major factors behind forest disintegration. In the study of Anthwal et al. (2010), half of the forest landscape was found scrappy due to dearth of social and institutional protection. Also, the study findings like Haughan et al. (2022) indicated that loss of forests was more influenced by climate change. Over the issues discussed, this study is an attempt to explain the issue of forest depletion and degradation in India. The study, at first, attempts to identify the major factors which are critical to forest loss, and thereby examines the existing forest policies to restore forests and, to increase the tree cover. According to the Forest Survey of India (FSI) Report 2021, Forest Cover assessment encompasses all lands with tree canopy density more than 10 percent, including tree orchards, bamboo and palms, etc. for larger than one hectare (ha) of area, existing inside the Recorded Forest and other public lands, private neighbourhood or, society lands.<sup>vi</sup> No such works have been done yet which address the three major dimensions - socio-economic, climatic and governance accountable for forest loss, apart from the collection of timber and NTFPs by the forest dwellers, in India for the 27 major States and Union Territories (UT) bearing very dense forests (in more than 50 km<sup>2</sup> of total area) during 2005-2019, using a panel framework and utilizing the Environmental Kuznets Curve (EKC) hypothesis. Even, the assessment of forest loss across five regional zones - East, North-East, Central-West, North and South with having varying geographical characteristics has serious policy implications for forest conservation. It sheds light on the issue that whether the present way of forest conservation is effective for environmental sustainability or, only this aims to cover one third of the country's land as per the international commitments made by the Indian Government.

## Methodology

### Data

The study is mainly based on secondary data. Thus, this section initially briefs the data sources, and then the conceptual framework of the study is illustrated with descriptive statistics of the variables used, which is followed by the empirical model with necessary econometric tests applied for model validation. Since the objective of the study is limited to Indian forests and its degradation due to socio-economic, climatic and governance factors, hence, secondary data were gathered from various websites of the Indian Ministries such as Ministry of Environment, Forest and Climate Change, Ministry of Agriculture & Farmers Welfare, Ministry of Home Affairs. Data were also collected from Datamet India Private Limited (Indiastat.com), various reports of Forest Survey of India, Global Forest Watch, and Reserve Bank of India.

### Conceptual Framework of the Study

Climate change is a bitter truth for the entire humanity, and it vehemently calls for thoughtful means for environmental protection along with sustainable economic advancements. The linkage between economic growth and environmental deprivation has been empirically examined by many economists since the 1950s. The idea of the EKC gained momentum in the 1990s with the path breaking work of Grossman and Krueger (1991), on potential impacts of the North American Free Trade Agreement (NAFTA).<sup>vii</sup> The EKC hypothesis affirms that though developing nations face a growth-environment trade-off in their initial phases of development, this is not applicable for the developed nations. Therefore, the hypothesis recommends an inverted U-shaped association between environmental degradation and income in per capita, suggesting that environmental standards would deteriorate in the initial phase of economic expansion, and improve in the later phase of development, i.e. once a threshold level of income is realized. Although the original EKC hypothesis might not hold true for all the countries as the studies are conducted in various contexts, the existence of an environmental-friendly growth could be reviewed through this theory. In our study, to verify this occurrence, we have tried to assess the significance of changes in per capita income (in linear and non-linear forms) with other control variables on the rate of change in forest cover. Based upon the data availability on forest cover, biennial data from 2005 to 2019<sup>viii</sup> is obtained for the 27 major States and UTs of India which are further classified under five regional zones: East, North, North-East, Central-West and South.<sup>ix</sup> The member States and UTs under the five zones are listed in Table 1.

**Table 1: Zones with the Member States and UTs in India**

Group	Zone	Member States and UTs in the zone
1	East	Bihar, Jharkhand, Odisha, and West Bengal
2	North	Himachal Pradesh, Jammu and Kashmir, Rajasthan, Uttar Pradesh, and Uttarakhand
3	North-East <sup>x</sup>	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura
4	South	Andaman and Nicobar Islands, Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu
5	Central-West	Chhattisgarh, Goa, Gujarat, Madhya Pradesh, and Maharashtra

Source: Prepared by authors

Note: The study considers dataset of 2005-2019. The States - Telangana and Andhra Pradesh got separated in 2014. Since in 2005, these two States were of a single entity, i.e., Andhra Pradesh, so the data for all the variables for these two States are clubbed together in this study.

There are some UTs such as Dadra & Nagar Haveli and Daman & Diu, Ladakh for which we obtained data only for certain variables, while the data for remaining ones (urban population, national highways, per capita net state domestic product at factor cost, temperature, and rainfall) were unavailable. Thus, we excluded these UTs from our analysis.

The other States/UTs which are eliminated from this study have less dense forest area (less than 50 km<sup>2</sup> area). These are Chandigarh, Delhi, Haryana, Pondicherry, Punjab, and Lakshadweep.

In the study, to capture degeneration of forests, the log value of (which represents a rate of change) percentage share of forest cover to geographical area of the State/UT has been considered as dependent variable. Our study draws cues from the study of Barbier and Burgess (2001), where  $(F_{it} - F_{it-1})$  was considered as a measure of deforestation; which was the change of forest stock over the last period. In another study by Scricciu (2007), expansion of agricultural/arable land (AL) was considered as a proxy for deforestation. The dependent variable of the study was the natural log of AL, and was expressed as a percentage of total land area. Following the past literatures, the independent variables used in our study have either direct, or indirect effects on the change in forest cover. However, beyond the existing literature, our study categorizes the factors responsible for forest loss under the three important dimensions - socio-economic, climatic, and forest governance. In the socio-economic dimension, we have the factors like per capita net state domestic product (PCNSDP), urban population, net sown area and extent of total transport. Climatic factors include rainfall and temperature. Lastly, under the dimension of forest governance, number of Forest Protection Committees (FPC) and occurrence of forest fires are considered. The data were collected at State and/or UT levels.<sup>xi</sup> Additionally, timber and NTFP collection by the forest dwellers and, regional characteristics which account for forest loss in a vast country like India were considered. The outcome and explanatory variables of our study are presented in Table 2 with their descriptive statistics.

**Table 2: Summary Statistics of the Variables**

Variable	Description	Mean	Minimum	Maximum	Standard Deviation
<i>Dependent variable</i>					
LnShr_FC	Log of percentage share of forest cover to geographical area of the State/UT (Area is in km <sup>2</sup> )	3.361777	1.53283	4.513789	0.875809
<i>Independent variables</i>					
LnPCNSDP ( $x_1$ )	Log of PCNSDP of a State/UT; for a linear relationship (in INR with Base: 2011-12 constant prices) <sup>xii</sup>	4.822821	4.098694	5.496892	0.2451501
LnPCNSDP_Sq ( $x_2$ )	[For a non-linear (square) relationship]	23.31942	16.79929	30.21583	2.379072
LnPCNSDP_Cb ( $x_3$ )	[For a non-linear (cubic) relationship]	113.0455	68.85515	166.0931	17.3845
Shr_UrbPop ( $x_4$ )	Percentage share of urban population to total	31.87574	10.05	95.2	15.53225

	population of the State/UT (Population is in number)				
Shr_NetSownAr (x <sub>5</sub> )	Percentage share of net sown area to agricultural land area of the State/UT (Net Sown area is in thousand ha)	69.53653	20.03781	98.45475	19.94176
Shr_TtTrans (x <sub>6</sub> )	Percentage share of transportation route of a State/UT to total transportation route of the country <sup>xiii</sup> (Length of transport is in km)	11.23125	0.4625713	81.32751	10.63485
LnAMTemp (x <sub>7</sub> )	Log of annual mean temperature of a State/UT (in Celsius)	1.347159	1.103804	1.477121	0.0947725
Shr_AnRainfall (x <sub>8</sub> )	Percentage share of annual rainfall received to geographical area of the State/UT (in Millimeter)	5.670547	0.1678651	63.89519	11.08827
Shr_FFire (x <sub>9</sub> )	Percentage share of occurrences of forest fire to total area under Joint Forest Management of the State/UT (Occurrence of forest fire is in number)	245.1017	0.00	3685.243	644.8839
Shr_FPC (x <sub>10</sub> )	Percentage share of the number of FPCs in a State/UT to country's total FPCs	3.703704	0.0063239	19.4729	5.266475
D <sub>i</sub> s (x <sub>11</sub> , x <sub>12</sub> , x <sub>13</sub> and x <sub>14</sub> .)	These are the zonal dummies for the States/UTs belonging to a particular regional zone to capture the impact of the zonal characteristics on forest cover change - D1 stands for the Southern region, D2 stands for the Central-West region, D3 stands for the North-East region and D4 stands for the Eastern Region; yes = 1, otherwise = 0. (Northern region belongs to the reference category)				

Source: Prepared by authors

The mentioned dimensions affect the integrity of forest ecosystem in numerous ways. Changes in land-use pattern display several aspects like tropical deforestation and agricultural extension,

modest reforestation, and urbanization (Song et al., 2018). According to Aggarwal et al. (2009), in India, the yield of an approximated 15 Metric Ton (Mt) of timber, 850 Mt of fodder and 100 Mt of fuel wood, annually over the threshold limit, resulted in disintegration of forests. Acres of forest lands are now being cleared for farming, mining, and hefty developmental ventures, to tackle the demand of large population (Roy, 2020). Further, the climatic factors - temperature and rainfall play momentous roles in composition and functioning of forests<sup>xiv</sup>, and effective Forest Governance cannot be ignored for an environment-friendly growth.<sup>xv</sup>

### Model Description

In the study, the estimated reduced linear pooled regression equation is

$$Y_{it} = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t}^2 + \beta_3 X_{3t}^3 + \beta_4 X_{4t} + \beta_5 X_{5t} + \beta_6 X_{6t} + \beta_7 X_{7t} + \beta_8 X_{8t} + \beta_9 X_{9t} + \beta_{10} X_{10t} + \beta_{11} X_{11t} + \beta_{12} X_{12t} + \beta_{13} X_{13t} + \beta_{14} X_{14t} + u_{it}$$

Where  $Y$  is the outcome variable,  $X$ s are the explanatory variables which have impact on forest cover change.  $\alpha$  is constant and  $\beta_k$  is the coefficients of  $k$  explanatory variables which show the changes in outcome variable for one unit change in the explanatory variables. In addition,  $i$  and  $t$  refer to cross-sectional and time series aspects of data;  $i = 1, 2, \dots, 27$  and  $t =$  biennial data from 2005 to 2019.  $u_{it}$  is the error term which is assumed to be independently, identically, and normally distributed ( $u_{it} \sim \text{i.i.d}(0, \sigma^2)$ ).

The key explanatory variable (PCNSDP) in our study is expected to show a non-linear relationship with the outcome variable. Following Dinda (2004), this model provides us to test for the different forms of relationship between forest cover change and economic growth, where the EKC is only one of the possible outcomes of the model.<sup>xvi</sup> The problem of heteroscedasticity in the econometric model is dealt with using robust estimation procedure. Multicollinearity is also taken well care of. Although there are 14 explanatory variables which influence the change in forest cover in our study, the Exploratory Factor Analysis (EFA) technique was applied in search of the key variables. The EFA assigns weight to each derived variable responsible for forest loss. In the EFA, Kaiser-Meyer-Olkin (KMO) tests for sample adequacy, whereas, Bartlett's Test is used to check the redundancy between the variables so that we can detect the most important factors.

### Results and Discussion

This section, at first, examines how and to which extent the variables under the different dimensions are accountable for forest loss in India during 2005-2019. Therefore, when the EFA technique was applied to detect the prime factors of forest impairment, the two test results which indicate the suitability of data for structure detection are presented in Table 3.

**Table 3: Results of KMO and Bartlett's Tests**

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	<b>0.546</b>
Bartlett's Test of Sphericity	4.950E3
Appropriate ChiSqr.	Df = 91
	<b>Sig = 0.000</b>

Source: Estimated by authors

In Table 3, the KMO test result is 0.546, based on the correlation matrix. The higher KMO values indicate sample adequacy, and the minimum acceptable value is 0.50. The significance level (0.000) of the Bartlett's test directs us not to accept the null hypothesis and, concludes that not all the groups have the same variance in our study. Therefore, after validating the use of the EFA technique, the calculated eigenvalues and percentage of variances of the derived variables are presented in Table 4.

**Table 4: Determination of Weight for the Studied Explanatory Variables**

Components	Initial Eigenvalues		
	Total	Percentage of Variance	Cumulative Percentage of Variances
<b>LnPCNSDP</b>	<b>4.235</b>	<b>30.250</b>	<b>30.250</b>
<b>LnPCNSDP_Sq</b>	<b>2.445</b>	<b>17.466</b>	<b>47.716</b>
<b>LnPCNSDP_Cb</b>	<b>1.411</b>	<b>10.078</b>	<b>57.794</b>
<b>Shr_UrbPop</b>	<b>1.220</b>	<b>8.711</b>	<b>66.505</b>
<b>Shr_NetSownAr</b>	<b>1.156</b>	<b>8.254</b>	<b>74.760</b>
Shr_TtTrans	.910	6.502	81.262
LnAMTemp	.759	5.422	86.683
Shr_AnRainfall	.549	3.923	90.606
Shr_FFire	.529	3.780	94.386
Sh_FPC	.352	2.512	96.898
D1	.300	2.140	99.038
D2	.133	0.950	99.987
D3	.002	0.013	100.000
D4	5.356E-7	3.825E-6	100.000

Source: Estimated by authors

In Table 4, the components or derived variables, which were extracted from the original set of variables (considering variance and covariance), are orthogonal to each other and have their respective Eigenvalues. The Eigenvalues are the variants' estimates signifying the percentage of variations of the measured variables. The Eigenvalue cut-off rule specifies that the components with initial Eigenvalues greater than one would be retained in the analysis. In Table 4, the Eigenvalues are greater than one up to the fifth component, with the cumulative percentage of variances 74.760 percent. Thus, we might work very well with taking only the first five variables in the regression analysis. It is also apparent that until the 6<sup>th</sup> component (which too is a socio-economic variable), only 81 percent of the total variance of the conditional variables is addressed. But, the selection of only first five to six variables would limit the study to socio-economic variables only, and therefore it might lead to omission of certain significant variables under the dimensions - climatic (would explain another 9 percent of the variance) and governance (would explain near to 7 percent of the variance) which have impact on forest loss in the study. The regional dummies also account for 3 percent of the variance. Hence, we preferred to incorporate all the variables in the regression analysis, to consider their effects on forest loss. The estimated regression result for the 216 observations is presented in Table 5.

**Table 5: Estimated Regression Results**


---

N = 216  
F (14,201) = 109.27  
Prob > F = 0.0000  
R-squared = 0.7542

---

Variable	Coefficient	Standard Error	p-value
LnPCNSDP	-16.02063	55.78235	0.774
LnPCNSDP_Sq	4.800636	11.77895	0.684
LnPCNSDP_Cb	-0.4252062	0.827372	0.608
Shr_UrbPop	-0.0042119	0.0029718	0.158
Shr_NetSownAr	-0.0060518***	0.0018037	0.001
Shr_TtTrans	-0.0133952***	0.0023168	0.000
LnAMTemp	-1.202212	0.6140977	0.052
Shr_AnRainfall	0.0352845***	0.0030866	0.000
Shr_FFire	-6.79e-06	0.0000499	0.892
Shr_FPC	0.0409798***	0.0074845	0.000
D1	0.7902948***	0.1750468	0.000
D2	0.5666361***	0.1644971	0.001
D3	1.774086***	0.1153401	0.000
D4	0.5345052***	0.1393516	0.000
Constant	17.86479	87.93617	0.839

---

Source: Estimated by authors

Note: \*\*\*significant at 1% level; \*\*significant at 5% level

The R<sup>2</sup> value of the estimated model is 0.7542, which suggests that approximately 75 percent of the variation in data of the dependent variable is captured by the independent variables collectively. The F-statistic is 109.27, and the related p-value (0.000) specifies that in over-all, the regression result statistically significantly foresees the dependent variable, and thus a good fit for the data. The fitted model also shows that the explanatory variables like rate of change in PCNSDP, LnPCNSDP<sup>3</sup>, Shr\_UrbPop, Shr\_NetSownAr, Shr\_TtTrans, LnAMTemp and Shr\_FFire have negative coefficients, and the coefficients of the remaining variables like LnPCNSDP\_Sq, Shr\_AnRainfall, Shr\_FPC, D1, D2, D3, D4 and the constant term are positive. It is likely that with the increase in mean temperature, urban population, net sown area, length of transportation, and forest fires, forest cover would affect adversely; and this claim is confirmed in our study with the negative signs of the coefficients of the respective variables. Further, with a surge in average rainfall and forest protection committees, forest cover would be positively influenced; and this claim is also approved by the positive signs of the coefficients of those variables. Tilahun et al. (2022) pointed out in their study that one of the major facets of land cover change was forest degradation due to expansion of agricultural land. Wang and Qiu (2017) also demonstrated that around 70 percent of deforestation was linked to the augmentation of agricultural land; with the impact being stronger with increased availability of forest cover. The study by Suratman et al. (2020) showed how regional farmers steadily extended their farming lands every year, causing speedy dissolution of forests; and thereby extension of agricultural lands was one of the prime causes of deforestation. Our study strongly supports all these prerogatives, and thereby, the negative relation between net sown area and forest cover change is statistically significant at 1 percent level. Further, our study exhibits urbanization is also a prime factor of rapid forest loss. Revi et al. (2014) indicated how urban areas inflated globally for sheltering ever increasing population, coping with migration trends

from rural to urban areas. According to Tilahun et al. (2022), the peri-urban areas were most vulnerable due to rampant urban growth and forest deterioration. Another such study by Lin et al. (2019) also demonstrated that urbanization was one of the key factors of land use/land cover change (LULCC)<sup>xvii</sup>, and anticipated as the cause of forest loss for human activities. Alike our study, many prior research works established that construction of new roads added to deforestation.<sup>xviii</sup> This claim is statistically significant at 1 percent level in our study. Constructions of new roads leads to enhanced human activities and unregulated damaging occurrences.<sup>xix</sup> A study by Kleinschroth et al. (2019) exhibited how rate of forest destruction quadrupled since 2000 in Congo Basin for the expansion of roadways by 60 percent during 2003-2018. Under the climatic dimension, our study considers two variables - changes in temperature and annual rainfall for the alterations of forest cover in India. Panday et al. (2014) once opined that increase in temperature reduces moisture content of soil in the post-rainy season and impedes water requisites of crops, and thereby results in low vegetation growth. On the contrary, rainfall aids to retaining suitable ground moistness, such that the roots of plants can extract adequate water from the soil while growing. The association between rainfall and forest cover change was found positive, with statistical significance at 1 percent level, in our study. Also, our study finds that forest loss amplifies with the increase in temperature, and this claim is statistically significant at 5 percent level. Forests possess the natural characteristics of enhancing community persistence to heat resulting from climate change (Wolff et al., 2021). Alike our study, the works of Gohain et al. (2021) and Thakur et al. (2021) also illustrated a negative association between vegetation cover and Land Surface Temperature (LST). However, some studies have found an ambiguous relationship between the change in temperature and forest cover. In the study of Hasnat (2021), in Dudpukuria-Dhopachari Wildlife Sanctuary (DDWS) of Bangladesh during 1990-2020, the author revealed that the relationship was perplexing. During the first two decades, this association stood negative; however, in the last decade, the association seemed positive. In another study by Palmate et al. (2017), the authors depicted that temperature in the pre-monsoon season was positively related to vegetation and forest cover. However, in the post-monsoon season, even though rain displayed a favorable response to forest cover, temperature was unfavorable to vegetation in the river basin of Betwa, India. Forest fire is also considered as one of the leading factors volunteering to forest cover losses. About 9.3 Mha of tree cover was lost alarmingly due to forest fires in 2021, which accounted for 33 percent of all tree cover loss for the same year globally.<sup>xx</sup> At present, forest fires are responsible for burning almost twice as much tree cover as compared to the two decades ago.<sup>xxi</sup> Our study keeps the similar views regarding the occurrence of forest loss due to incessant and widespread forest fires. Tyukavina et al. (2022) exposed that globally forest fires resulted in more (by 3 Mha) annual tree cover loss in 2019, as compared to 2001. Subsequently, our study examines the role of FPCs on the change in forest cover, and the study result goes exactly with the study conducted in West Bengal Forest by Roy (1992), where the author illustrated how 1,800 rural community-based FPCs protected more than 2,40,000 ha of natural sal (*Shorea robusta*) forest and shared the forest produce with the Forest Department (FD). According to Dutta et al. (2005), collection of NTFP was a major incentive for forest preservation by the FPCs (on average, NTFP incomes constituted nearly 30 percent of total income). In addition, with reference to enhancing forest health and for environmental sustainability, women's participation in FPCs and, cooperation between FPC members and field officers of the forests were appeared as key recommendations in the study of Chattopadhyay and Datta (2010). In a State-level analysis by Damodaran and Stefanie (2003), the authors pointed out the fundamental role of FPCs in the States like Andhra Pradesh, Haryana, Madhya Pradesh and West Bengal, to bring a higher proportion of degraded forests under the JFM system. However, Das (2020) exhibited the disinterest of JFM members in forest management due to the dearth of income and employment opportunities to fulfill their needs

in West Bengal. Only a meager share of financial benefits gained by the FD was rationed amongst the members of JFM. Thus, the FPCs were spotted as ineffective at large in forest management. However, our study result is in sharp contrast with the findings of Das (2020), and proposes a positive relationship between the increase in number of FPCs and forest health, with statistical significance at 1 percent level. India Today Report (2023) exposed that India stood just after Brazil in terms of forest loss during 2015-2020. Even, India experienced a biggest surge in deforestation between 1990-2000 and 2015-2020.<sup>xxii</sup> Although FSI report (2021) showed a minor increase in forest cover in India in the last few years, still there were some regions that reported a loss in forest cover like Punjab, Madhya Pradesh, Odisha.<sup>xxiii</sup> Hence, while assessing the zonal impacts on the change in forest cover, Northern zone is considered as the reference category;<sup>xxiv</sup> the impact of which is represented by the constant term in the regression model. The positive coefficient of the constant term (17.86) implies that the States and UTs in this zone are likely to impact the rate of change in forest cover. The coefficients of the other zonal dummies - D1, D2, D3 and D4 represent the differences of this likely impact between the North and the respective regional zones. Thus, the positive coefficients of D1, D2, D3 and D4 (such as 0.79, 0.57, 1.77 and 0.53, respectively) show that the States/UTs in these regional zones are certain to have influence on the rate of change in forest cover than the reference category. This claim is statistically significant at 1 percent level for the regional zones like South, Central-West, North-East and East. Furthermore, North-Eastern States have been found most vulnerable for the forest loss in India. During 2001-2020, nearly 1.93 Mha of tree cover was lost in the North-Eastern States, which accounted for 76 percent of tree cover loss in India.<sup>xxv</sup> Among the North-East States, Assam lost 269 kha, Mizoram 247 kha, Nagaland 225 kha, Arunachal Pradesh 222 kha, Manipur 196 kha, Meghalaya 195 kha and Tripura 102 kha tree cover, in this 20-year period.<sup>xxvi</sup>

Moreover, in our study, the coefficients of LnPCNSDP and LnPCNSDP\_Cb are negative and that of LnPCNSDP\_Sq is positive, which signify forest loss in the initial and later phases of economic growth; however, the coefficients are not statistically significant as inferred from the p-values. Hence, the results are contradictory to the original EKC of inverted U-shape and support the evidence of an opposite to the N-shaped EKC ( $\beta_1 < 0$ ,  $\beta_2 > 0$  and  $\beta_3 < 0$ ). The results suggest that the drivers of development initially lead to forest exhaustion. Although people might be contemplating on forest conservation in consistent with sustainable development in the mid-phase, population explosion and high demand for food, amenities, etc. would again cause for forest losses in the advanced stage of development. Panayotou (1994) disclosed that the EKC hypothesis was more prone to produce ambiguous outcome when to analyze deforestation, unlike the common environmental challenges like air pollution. Afterwards, Barbier and Burgess (2001) also pointed out mixed outcomes while examining deforestation through the lens of EKC hypothesis, and concluded that though it might be applicable to certain regions, not pertinent to every tropical country. Many other studies are also in cohesion with our study, such as Leblois et al. (2017), where the authors found a non-conventional EKC for the 128 nations. Andrée et al. (2019) also confirmed a different result than the conventional EKC. But, while analyzing the influence of certain macroeconomic variables on deforestation, Ahmed et al. (2015) found the presence of EKC, manifested by the declining effect of economic advancement on deforestation. Similarly, in a few other country level studies like Waluyo and Terawaki (2016) for Indonesia, and Maji (2017) for Nigeria, the authors confirmed the existence of EKC hypothesis. Apart from the mentioned indicators, one of the important indicators of rapid forest loss is the collection of timber and NTFPs from forests.<sup>xxvii</sup> Collection of dry leaves and fire-woods over the safe limit razes the forest foliage and cuts down the shrubs, which sequentially reduces forest reclamation. Moreover, requirement of softwood in plywood industry, and thereby unlawful chopping down of softwood trees decreases the supply

of food for wild animals. These phenomena are very much common in India. In 1996, the Honourable Supreme Court of India issued a directive, leading to a complete bar on the unrestricted felling of trees in public forest areas, with certain exceptions (Ghosh and Sinha, 2016). Environmental activists went on protesting the illegal felling of trees in the Reserve Forests like Shahbad, Manohar Thana and Bakani in Rajasthan<sup>xxviii</sup>; and also, in the forest areas of Madhya Pradesh which lost trees amounting to lakhs<sup>xxix</sup> of INR swiftly overnight from the isolated areas.<sup>xxx</sup> The unlawful clearing of trees in private lands is also common in Kerala, due to the nexus between forest officials and timber mafias. There the trees were cut down from private plantations in environmentally fragile areas.<sup>xxxi</sup> Likewise, about 150 jungle wood trees were cut down in the Balur Reserve Forests of Chikkamagaluru Circle in Bengaluru, in guise of felling trees in private land.<sup>xxxii</sup> Timber production in the *Trees Outside Forests* (TOFs) fulfill 45 percent, and forest areas meet about 3.35 percent of total demand for timber in India. In recent times, India's demand for timber has gone up for the population explosion, expansion of industries and infrastructure development (Ghosh and Sinha, 2016). Although India's total forest cover is now taken well care of, timber production is far below the consumption requirement, and therefore a huge portion of timber demand is amassed through imports. The study by Kant and Nautiyal (2021) forecasted that the demand for round-wood would shoot up almost by 70 percent in the next 10 years due to gigantic expansion of construction sector in India; from 57 million cubic metre (million m<sup>3</sup>) in 2020 to 98 million m<sup>3</sup> in 2030. Hence, the growing demand for timber products in various sectors might be responsible for more forest loss in near future. The collection of NTFPs of tribal communities, such as mahua, sal, karanj and kaunch seeds; tendu leaves; chironjee; bael; jamun; wild honey; etc. are annually estimated to be worth around INR two trillion.<sup>xxxiii</sup> Therefore, sustainable NTFP extraction would also be a way to prevent forests from being put to more destructive uses (Panday et al., 2016).

As stated by the World Resources Institute, about 122,748 ha of prime forest in India became irretrievable during 2014-2018.<sup>xxxiv</sup> Among the several major driving forces of deforestation, urbanization, mining activities and commodity-driven deforestation linked with commercial agricultural expansion cause for permanent deforestation. However, the tree cover loss is not always permanent. Shifting agriculture, forest fires and forestry (harvesting and planting of trees in a planned manner for supplying forest products) – usually allow forests to rejuvenate on their own, and therefore, the forest loss is temporary.<sup>xxxv</sup> In the last twenty years, India had witnessed rapid deforestation, resulting into the loss of 1.6 Mha of its forest cover, which also accounted for dreadful conditions of over one third of its land.<sup>xxxvi</sup> Hence, India has planned to create supplementary carbon sink of 2.5-3.0 billion tonnes (Bt) of CO<sub>2</sub>e through increasing forest cover by 2030.<sup>xxxvii</sup> According to Borah et al. (2018), the Government of India in support of *Bonn challenge* (an initiative to restore degraded forest lands, launched by the International Union on Conservation of Nature (IUCN) and Germany, in 2011) has decided to restore 13 Mha of degraded land by 2020, and supplementary 8 Mha by 2030. A Joint Progress Report of the IUCN and Ministry of Environment, Forest and Climate Change (MoEFCC's) revealed that although 9.8 Mha of denuded, or degenerated land was reclaimed since 2011 and up to 2019, forest cover hardly expanded collectively; signifying the defeat of forest revival schemes in India. Roy (2020) pointed out that around 12.7 percent of the area under the India's definition of total forest cover was comprised of produces, such as tea, coffee, eucalyptus, areca nut, oil palm, rubber and mango, which were under the plantation or monoculture. But, allowing the natural forests to thrive and rejuvenate on their own would be the best mechanism to mitigate global warming. In connection to *Bonn Challenge*<sup>xxxviii</sup>, India has adopted plantation schemes where a single species like eucalyptus or bamboo is planted in a specific area. These plants grow fast and increase the tree cover in a short span of time. However, this type of plantation on grasslands, or in other ecosystems harm the livelihoods of locals who are dependent on

forests. Eucalyptus plantation depletes the nutrients and moisture reserves of the soil, and suppresses the undergrowth. Since eucalyptus trees are coupled with high water demand for extremely high rate of transpiration, so they reduce local water table and prevent groundwater recharge. In bamboo plantation, while it helps avoiding fossil fuel use, it spreads quickly into neighbouring yards and becomes a threat to biodiversity. Even, it takes years to get rid from bamboo. Hence, the success of forest restoration cannot be justified only through mono plantation practice; rather maintaining the quality of forests is equally important. In this context, our study emphasizes the fact that population proliferation and unchecked human activities which destroy natural forests should be dealt with stringent policies. In addition to the above findings, the most alarming issue is the summary of Forest Conservation (Amendment) Bill, 2023, in India; aiming to affirmative changes in the Forest (Conservation) Act, 1980.<sup>xxxix</sup> India, in its planned Forest Conservation (Amendment) Bill, 2023, has proposed permit for more ventures related to mining and infrastructural development. In consistent with the Bill, forest lands can be released from the legal protection for fast-track accomplishment of strategic and security-related ventures, which possess national significance (The Forest Declaration Assessment, October 2023). Apart from the projects of 'strategic importance' that come within 100 kilometers of international borders, the Bill excuses expanse along the railway lines. Even, the Bill provides justifications for ecotourism activities, zoos and expeditions. Hence, the latest Bill might put 15 percent of forest lands (which are 'unclassified'<sup>xl</sup>) at risk owing to lack of articulated directives for mining and commercial activities.

## Conclusions

Our study identifies the major factors responsible for forest loss in India, at national and sub-national levels, and then examines the practices of forest conservation and recent Forest Policies, in India. The study points out that the socio-economic factors contributed largely to the forest loss during 2005-2019, in India. Ever expanding population, and thereby proliferation of human activities over the 'safe limit' should need a proper control by the government. Otherwise, global climate change would aggravate and make the planet more vulnerable for human existence than ever before. The study also exposes that though forest cover has gone up by 0.56 percent, or 3,976 km<sup>2</sup> since 2017<sup>xli</sup> in India, the strategy of mono plantation is not ideal for maintaining biodiversity and assisting livelihoods of the locals. Natural regeneration of forests is always helpful in mitigating global climate change. The region like North-East of India needs additional attention for forest preservation. Lastly, our study focuses on the Forest Conservation (Amendment) Bill, 2023, of India, which has allowed added economic activities meant for nation building, withdrawing adequate legal fortification for forests. The study suggests for sustainable forest management practices like alternatives to shifting cultivation, promotion of plantation (however, other than monoculture), usage of certified forest products, etc., to cope up with deforestation. It is expected that sustainable forest operations would retard the global climate change, and eventually, natural calamities like forest fires would slow down. Although our study contributes to the existing literature, expansion of time horizon, inclusion of more control variables under each dimension might strengthen the study result.

## References

Abraham, B. (2022). The Roots of Forest Loss and Forest Governance. International Institute for Sustainable Development. <https://www.iisd.org/articles/forest-loss-and-governance>

- Ahmed, K., Shahbaz, M., Qasim, A. & Long, W. (2015). The linkages between deforestation, energy and growth for environmental degradation in Pakistan. *Ecological Indicators*, 49, 95–103. <https://doi.org/10.1016/j.ecolind.2014.09.040>
- Aggarwal, M. and Ghosh, S. (2020, February 19). *India urgently needs to streamline multi-billion rupees worth NTFP market*. Mongabay. <https://india.mongabay.com/2020/02/india-urgently-needs-to-streamline-multi-billion-rupees-worth-ntfp-market/>
- Aggarwal, P. and Tiwari, A. (2023, August 31). *India's forests: A tale of growth, loss and revival*. India Today. <https://www.indiatoday.in/diu/story/india-forests-a-tale-of-growth-loss-and-revival-2429324-2023-08-31>
- Aggarwal, A., Varghese, P. & Das, S. (2009). Forest resources: Degradation, livelihoods, and climate change. *The Energy and Resources Institute: Looking back to change track*, 219, 91-108.
- Andrée, B.P.J., Chamorroa, A., Spencera, P., Koomenb, E. and Dogoa, H. (2019) Revisiting the relation between economic growth and the environment; a global assessment of deforestation, pollution and carbon emission. *Renewable and Sustainable Energy Reviews*, 114: 109221. <https://doi.org/10.1016/j.rser.2019.06.028>
- Anthwal, A., Gupta, N., Sharma, A., Anthwal, S. & Kim, K-H. (2010). Conserving biodiversity through traditional beliefs in sacred groves in Uttarakhand Himalaya, India. *Resources, Conservation and Recycling*, 54(11), 962–971. <https://doi.org/10.1016/j.resconrec.2010.02.003>
- Barbier, E. B., & Burgess, J. C. (2001). The economics of tropical deforestation. *Journal of Economic Surveys*, 15(3), 413–433. <https://doi.org/10.1111/1467-6419.00144>
- Bahuguna, V.K. & Bisht, N.S. (2013). Valuation of Ecosystem Goods and Services from forests in India. *The Indian Forester*, 139(1), 1-13. <https://api.semanticscholar.org/CorpusID:166281479>
- Bhardwaj, M. (2021, February 17). *Illegal tree felling: Seven foresters suspended*. The New Indian Express. <https://www.newindianexpress.com/states/karnataka/2021/feb/17/illegal-tree-felling-seven-foresters-suspended-2265013.html>
- Bonan, G.B. (2008). Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests. *Science*, 320(5882), 1444–49.
- Borah, B., Bhattacharjee, A. & Ishwar, N.M. (2018). *Bonn Challenge and India: Progress on restoration efforts across states and landscapes*. New Delhi, India: UCN, Ministry of Environment, Forest and Climate Change, Government of India. <https://doi.org/10.2305/IUCN.CH.2018.12.en>
- Chattopadhyay, R.N. & Datta, D. (2010). Criteria and indicators for assessment of functioning of forest protection committees in the dry deciduous forests of West Bengal, India. *Ecological Indicators*, 10(3), 687–695. <https://doi.org/10.1016/j.ecolind.2009.11.008>
- Choudhary, S. (2020, March 8). *Just like the economy, India's forests too are thriving only on paper*. Ecologies.in. <https://ecologise.in/2020/03/08/indian-forests-are-doing-very-well-on-paper/>
- Damodaran, A.N. & Stefanie, E. (2003). Joint forest management in India: Assessment of performance and evaluation of impacts. *ZEF-Discussion Papers on Development Policy, Bonn, Germany: ZEF*. <https://doi.org/10.22004/ag.econ.18752>
- Das, T. (2020). Socio-economic characteristics of forest villagers in Alipurduar district of West Bengal. PhD thesis, *University of North Bengal, India*. <http://ir.nbu.ac.in/handle/123456789/4366>
- Dinda, S. (2004). Environmental Kuznets Curve Hypothesis: A Survey. *Ecological Economics*, 49, 431-455. <https://doi.org/10.1016/j.ecolecon.2004.02.011>

- Drohan, P.J., Brittingham, M., Bishop, J. & Yoder, K. (2012). Early Trends in Landcover Change and Forest Fragmentation Due to Shale-Gas Development in Pennsylvania: A Potential Outcome for the Northcentral Appalachians. *Environmental Management*, 49, 1061–75. <https://doi.org/10.1007/s00267-012-9841-6>
- Dutta, M., Roy, S., Maiti, D. and Saha, S. (2005). Protecting India's forests: The effectiveness of forest protection committees, the case of southern west Bengal. *The International Journal of Sustainable Development & World Ecology*, 12(1), 68-77. <https://doi.org/10.1080/13504500509469620>
- EPA (2023). *Climate Change Impacts on Forests*. <https://www.epa.gov/climateimpacts/climate-change-impacts-forests>
- Forman, R., Sperling, D., Bissonette, J., Clevenger, A., Cutshall, C.D., Dale, V., Fahrig, L., Goldman, C., Heanue, K., Jones, J.A., Swanson, F., Turrentine, T. and Winter, T.C. (2002). *Road Ecology: Science and Solutions*. Washington D.C.: Island Press. <https://api.semanticscholar.org/CorpusID:140183391>
- Gohain, K. J., Mohammad, P., & Goswami, A. (2021). Assessing the impact of land use land cover changes on land surface temperature over Pune city, India. *Quaternary International*, 575–576, 259–269. <https://doi.org/10.1016/j.quaint.2020.04.052>
- Ghosh, M. & Sinha, B. (2016). Impact of forest policies on timber production in India: a review. *Natural Resources Forum*, 40, 62-76. <https://doi.org/10.1111/1477-8947.12094>
- Global Forest Watch (2024). <https://www.globalforestwatch.org/dashboards/country/IND/>
- Govindarajulu, D. (2023, August 10). *India was a tree planting laboratory for 200 years – here are the results*. The Conversation. <https://theconversation.com/india-was-a-tree-planting-laboratory-for-200-years-here-are-the-results-211226>
- Grossman, G.M. & Krueger, A.B. (1991). Environmental impacts of a North American free trade agreement. *National Bureau of Economic Research Working Paper*, 3914. <https://core.ac.uk/download/pdf/6853464.pdf>
- Harris, N. L., Gibbs, D. A., Baccini, A., Birdsey, R. A., de Bruin, S., Farina, M., Fatoyinbo, L., Hansen, M. C., Herold, M., Houghton, R. A., Potapov, P. V., Suarez, D. R., Roman-Cuesta, R. M., Saatchi, S. S., Slay, C. M., Turubanova, S. A., & Tyukavina, A. (2021). Global Maps of Twenty-First Century Forest Carbon Fluxes. *Nature Climate Change*, 11(3), 234–240. <https://doi.org/10.1038/s41558-020-00976-6>
- Harris, N. (2018, September 13). *When a tree falls, is it deforestation?* World Resources Institute. <https://www.wri.org/insights/when-tree-falls-it-deforestation#:~:text=Tree%20cover%20loss%20associated%20with%20forestry%2C%20fires%2C%20and,production%2C%20industrial%20agriculture%2C%20and%20urbanization%20is%20typically%20permanent.>
- Hasnat, G.N.T. (2021). A Time Series Analysis of Forest Cover and Land Surface Temperature Change Over Dudpukuria-Dhopachari Wildlife Sanctuary Using Landsat Imagery. *Frontiers in Forests and Global Change*, 4, 687988. <https://doi.org/10.3389/ffgc.2021.687988>
- Haughan, A.E., Pettorelli, N., Potts, S.G. & Senapathi, D. (2022). The role of climate in past forest loss in an ecologically important region of South Asia. *Global Change Biology*, 28(12), 3883–3901. <https://doi.org/10.1111/gcb.16161>
- Hoare, A. (2020, March 3). *Forest Governance and Deforestation: Exploring the Disparity, Forest Governance and Legality*. <https://forestgovernance.chathamhouse.org/publications/forest-governance-and-deforestation-addressing-the-disparity>
- IUCN (2021), *Deforestation and forest degradation*, IUCN Issue Brief. <https://www.iucn.org/resources/issues-brief/deforestation-and-forest-degradation>

- Kant, P. & Nautiyal, R. (2021). India Timber Supply and Demand 2010–2030. *International Tropical Timber Organization (ITTO)*. [https://www.itto.int/direct/topics/topics\\_pdf\\_download/topics\\_id=6813&no=1&disp=inline](https://www.itto.int/direct/topics/topics_pdf_download/topics_id=6813&no=1&disp=inline)
- Kleinschroth, F., Laporte, N., Laurance, W.F., Goetz, S.J. & Ghazoul, J. (2019). Road expansion and persistence in forests of the Congo Basin. *Nature Sustainability* 2: 628–634. <https://doi.org/10.1038/s41893-019-0310-6>
- Kuznets, S. (1955). Economic Growth and Income Inequality. *The American Economic Review*, 45(1), 1-28.
- Leblois, A., Damette, O., & Wolfersberger, J. (2017). What has Driven Deforestation in Developing Countries Since the 2000s? Evidence from New Remote-Sensing Data. *World Development*, 92, 82–102. <https://doi.org/10.1016/j.worlddev.2016.11.012>
- Lewis, S.L., Edwards, D.P. & Galbraith, D. (2015). Increasing human dominance of tropical forests. *Science*, 349(6250), 827–832. <https://doi.org/10.1126/science.aaa9932>
- Lin, W., Chen, Q., Jiang, M., Zhang, X., Liu, Z., Tao, J., Wu, L., Xu, S., Kang, Y. & Zeng, Q. (2019). The effect of green space behaviour and per capita area in small urban green spaces on psychophysiological responses. *Landscape and Urban Planning*, 192: 103637. <https://doi.org/10.1016/j.landurbplan.2019.103637>
- MacCarthy, J., Richter, S., Tyukavina, S., Weisse, M. and Harris, N. (2024, August 13). *The Latest Data Confirms: Forest Fires Are Getting Worse*. Global Forest Watch. The Latest Data Confirms: Forest Fires Are Getting Worse | GFW Blog ([globalforestwatch.org](http://globalforestwatch.org))
- Mahapatra, R. (2020, July 23) *India among top 10 countries gaining forest area in the world: FAO*. Down To Earth. [India among top 10 countries gaining forest area in the world: FAO \(downtoearth.org.in\)](http://indiaamongtop10countriesgainingforestarea.in)
- Maji, I.K. (2017). The link between trade openness and deforestation for environmental quality in Nigeria. *GeoJournal*, 82, 131–138. <https://doi.org/10.1007/s10708-015-9678-7>
- Ministry of Environment, Forest and Climate Change (MOEFCC) (2021), India State of Forest Report (ISFR) 2021. <https://fsi.nic.in/forest-report-2021-details>.
- Ministry of Agriculture & Farmers Welfare (2021), *Agricultural Statistics at a Glance 2021*. [https://eands.dacnet.nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%20-%202021%20\(English%20version\).pdf](https://eands.dacnet.nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%20-%202021%20(English%20version).pdf)
- Nath, B., Wang, Z., Ge, Y., Islam, K., Singh, R. & Niu, Z. (2020). Land Use and Land Cover Change Modeling and Future Potential Landscape Risk Assessment Using Markov-CA Model and Analytical Hierarchy Process. *International Journal of Geo-Information*, 9(2), 134. <https://www.mdpi.com/2220-9964/9/2/134>
- Negi, G.C.S. (2022). Trees, forests and people: The Central Himalayan case of forest ecosystem services. *ScienceDirect*, 8, 100222. <https://doi.org/10.1016/j.tfp.2022.100222>
- Palmate, S. S., Pandey, A., Kumar, D., Pandey, R. P., & Mishra, S. K. (2014). Climate change impact on forest cover and vegetation in Betwa Basin, India. *Applied Water Science*, 7(1), 103–114. <https://doi.org/10.1007/s13201-014-0222-6>
- Panayotou, T. (1994). Empirical tests and policy analysis of environmental degradation at different stages of economic development. *Pacific and Asian Journal of Energy*, 4 (1), 23–42. [http://www.ilo.org/public/libdoc/ilo/1993/93B09\\_31\\_engl.pdf](http://www.ilo.org/public/libdoc/ilo/1993/93B09_31_engl.pdf)
- Pandey, A. K., Tripathi, Y. C., & Kumar, A. (2016). Non Timber Forest Products (NTFPs) for Sustained Livelihood: Challenges and Strategies. *Research Journal of Forestry*, 10(1), 1–7. <https://doi.org/10.3923/rjf.2016.1.7>

- Panday, P., Thibeault, J. & Frey, K. (2015) Changing temperature and precipitation extremes in the Hindu Kush-Himalayan region: An analysis of CMIP3 and CMIP5 simulations and projections. *International Journal of Climatology*, 35(10), 3058-3077. <https://doi.org/10.1002/joc.4192>
- Patel, K. (2019). *When a Road Leads to Deforestation*. Earth Observatory. <https://earthobservatory.nasa.gov/images/145907/when-a-road-leads-to-deforestation>
- Press Information Bureau (2022), *India State of Forest Report 2021*, Ministry of Information and Broadcasting Government of India. <https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/jan/doc20221207001.pdf>
- Financial Express. (2019, March 8). *Centre approves strategy to create carbon sink of 3 billion tonnes from forests by 2030*. <https://www.financialexpress.com/lifestyle/science/centre-approvesstrategy-to-create-carbon-sink-of-3-billion-tonnes-from-forests-by-2030/1509824/>
- Rainforest Alliance. (2018, August 12). *What is the Relationship Between Deforestation and Climate Change?* <https://www.rainforest-alliance.org/insights/what-is-the-relationship-between-deforestation-and-climate-change/>
- Reddy, C.S., Koppineedi, S., Jha, C., Diwakar, P., Murthy, Y. & Dadhwal, V. (2016) Development of deforestation and land cover database for Bhutan (1930–2014). *Environmental Monitoring and Assessment*, 188, 658. <https://doi.org/10.1007/s10661-016-5676-6>
- Ratna, R. V., Behera, B., & Mohan, R. D. (2024). Forest Degradation in India: Extent and Determinants. *Indian Journal of Agricultural Economics*, 56(4), 631–652. <https://doi.org/10.22004/ag.econ.297843>
- Revi, A., Satterthwaite, D., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R., Pelling, M., Roberts, D. & Solecki, W. (2014). Urban Areas in Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, 535-612.
- Roy, A. (2020). Harnessing the Power of India's Forests for Climate Change Mitigation. *Observer Research Foundation Issue Brief*, 420, ORF Foundation. [https://www.orfonline.org/wp-content/uploads/2020/11/ORF\\_IssueBrief\\_420\\_Forests-ClimateChange.pdf](https://www.orfonline.org/wp-content/uploads/2020/11/ORF_IssueBrief_420_Forests-ClimateChange.pdf)
- Roy, A. (2020, March 23). *Is the government telling a distorted story of the state of India's forests? Here's what it must do*. The Times of India. <https://timesofindia.indiatimes.com/blogs/toi-edit-page/is-the-government-telling-a-distorted-story-of-the-state-of-indias-forests-heres-what-it-must-do/>
- Roy, P. S., Murthy, M. S. R., Roy, A., Kushwaha, S. P. S., Singh, S., Jha, C. S., Behera, M. D., Joshi, P. K., Jagannathan, C., Karnatak, H. C., Saran, S., Reddy, C. S., Kushwaha, D., Dutt, C. B. S., Porwal, M. C., Sudhakar, S., Srivastava, V. K., Padalia, H., Nandy, S., & Gupta, S. (2013). Forest fragmentation in India. *Current Science*, 105(6), 774–780. <https://www.jstor.org/stable/24097514>
- Roy, S.B. (1992). Forest Protection Committees in West Bengal. *Economic and Political Weekly*, 27(29), 1528-1530. <https://www.jstor.org/stable/4398657>
- Saha, D., & Agarwalla, S. (2021). People's Forest Dependence: A Case Study of Similipal Biosphere Reserve, India. *Review of Development and Change*, 26(1), 63–82. <https://doi.org/10.1177/0972266121998269>
- Saha, D., & Taron, A. (2023). Economic valuation of restoring and conserving ecosystem services of Indian Sundarbans. *Environmental Development*, 46, 100846. <https://doi.org/10.1016/j.envdev.2023.100846>

- Scrieciu, S. S. (2007). Can economic causes of tropical deforestation be identified at a global level? *Ecological Economics*, 62(3–4), 603–612. <https://doi.org/10.1016/j.ecolecon.2006.07.028>
- Sethi, P. (2018). Economics of Desertification, Land Degradation and Drought (DLDD) in India. Vol I: Macroeconomic assessment of the costs of land degradation in India, The Energy and Resources Institute (TERI). [https://www.teriin.org/sites/default/files/2018-04/Vol%20I%20-%20Macroeconomic%20assessment%20of%20the%20costs%20of%20land%20degradation%20in%20India\\_0.pdf](https://www.teriin.org/sites/default/files/2018-04/Vol%20I%20-%20Macroeconomic%20assessment%20of%20the%20costs%20of%20land%20degradation%20in%20India_0.pdf)
- Shaji, K.A. (2021, March 4). *Confusion over a government order facilitated illegal tree felling in Kerala*. Mongabay. <https://india.mongabay.com/2021/03/confusion-over-a-government-order-facilitated-illegal-tree-felling-in-kerala/>
- Sirur, S. (2023, May 25) 'Death knell' for India's forests — experts submit objections to JPC on changes to forest law. The Print. <https://theprint.in/india/governance/death-knell-for-indias-forests-experts-submit-objections-to-jpc-on-changes-to-forest-law/1593650/>
- Sirur, S. (2023, March 30). *Will Modi govt's new bill dilute existing protections for forests? All about proposed law*. The Print. <https://theprint.in/india/governance/will-modi-govts-new-bill-dilute-existing-protections-for-forests-all-about-proposed-law/1484430/>
- Song, X.-P., Hansen, M. C., Stehman, S. V., Potapov, P. V., Tyukavina, A., Vermote, E. F., & Townshend, J. R. (2018). Global land change from 1982 to 2016. *Nature*, 560(7720), 639–643. <https://doi.org/10.1038/s41586-018-0411-9>
- None Suratman, Putra, A. U., & A Mardiana. (2020). Landform analysis to arrangement “Land Utilization Type” in Galur Sub-District, Kulonprogo. *IOP Conference Series Earth and Environmental Science*, 451(1), 012028–012028. <https://doi.org/10.1088/1755-1315/451/1/012028>
- Thakur, N. (2021, October 24). *Northeast accounted for 76% tree cover loss in India in 2001-20: Study*. moneycontrol. <https://www.moneycontrol.com/news/environment/tree-cover-loss-heaviest-in-northeast-india-study-7618251.html>
- Thakur, S., Maity, D., Mondal, I., Basumatary, G., Ghosh, P. B., Das, P., & De, T. K. (2021). Assessment of changes in land use, land cover, and land surface temperature in the mangrove forest of Sundarbans, northeast coast of India. *Environment Development and Sustainability*, 23(2), 1917–1943. <https://doi.org/10.1007/s10668-020-00656-7>
- The Quint. (2016, June 3). *Large Forest Cover Lost to 23,716 Industrial Projects in India*. <https://www.thequint.com/news/environment/large-forest-cover-lost-to-23716-industrial-projects-in-india>
- Thiagarajan, S. (2018, September 8). *Trees cut illegally inside reserve forest: Activists*. Times of India. <https://timesofindia.indiatimes.com/city/coimbatore/take-steps-to-curb-illegal-felling-of-tress-in-reserve-forests-activists/articleshow/65726350.cms>
- Tilahun, D., Gashu, K., & Shiferaw, G. T. (2022). Effects of Agricultural Land and Urban Expansion on Peri-Urban Forest Degradation and Implications on Sustainable Environmental Management in Southern Ethiopia. *Sustainability*, 14(24), 16527. <https://doi.org/10.3390/su142416527>
- Tyukavina, A., Potapov, P., Hansen, M. C., Pickens, A. H., Stehman, S. V., Turubanova, S., Parker, D., Zalles, V., Lima, A., Kommareddy, I., Song, X.-P., Wang, L., & Harris, N. (2022). Global Trends of Forest Loss Due to Fire From 2001 to 2019. *Frontiers in Remote Sensing*, 3. <https://doi.org/10.3389/frsen.2022.825190>

- Waluyo, E.A. & Terawaki, T. (2016). Environmental Kuznets Curve for deforestation in Indonesia: An ARDL bounds testing approach. *Journal of Economic Cooperation and Development*, 37(3), 87-108.
- Wang, H., & Qiu, F. (2017). Investigating the Impact of Agricultural Land Losses on Deforestation: Evidence From a Peri-urban Area in Canada. *Ecological Economics*, 139, 9–18. <https://doi.org/10.1016/j.ecolecon.2017.04.002>
- Weisse, M., Goldman, L. and Carter, S. (2023, June 27). *Tropical Primary Forest Loss Worsened in 2022, Despite International Commitments to End Deforestation*. Global Forest Watch. <https://www.globalforestwatch.org/blog/data-and-research/global-tree-cover-loss-data-2022/>
- Wolff, N. H., Zeppetello, L. R. V., Parsons, L. A., Aggraeni, I., Battisti, D. S., Ebi, K. L., Game, E. T., Kroeger, T., Masuda, Y. J., & Spector, J. T. (2021). The effect of deforestation and climate change on all-cause mortality and unsafe work conditions due to heat exposure in Berau, Indonesia: a modelling study. *The Lancet Planetary Health*, 5(12), e882–e892. [https://doi.org/10.1016/S2542-5196\(21\)00279-5](https://doi.org/10.1016/S2542-5196(21)00279-5)

<sup>i</sup><https://www.rainforest-alliance.org/insights/what-is-the-relationship-between-deforestation-and-climate-change/>

<sup>ii</sup><https://www.iisd.org/articles/forest-loss-and-governance>

<sup>iii</sup><https://www.downtoearth.org.in/news/forests/india-among-top-10-countriesgaining-forest-area-in-the-world-fao-72454#:~:text=India%20has%20ranked%20third%20among,the%20United%20Nations%20has%20said>

<sup>iv</sup><https://www.globalforestwatch.org/dashboards/country/IND/>

<sup>v</sup><https://www.thequint.com/news/environment/large-forest-cover-lost-to-23716-industrial-projects-in-india>

<sup>vi</sup><https://fsi.nic.in/forest-report-2021-details>

<sup>vii</sup>EKC derives its name and idea from the pioneering work of Simon Kuznets (1955) who postulated an ‘inverted-U’ shaped curve for the association between economic development and income disparity.

<sup>viii</sup>The Kyoto Protocol was enacted from 2005, where it operationalizes the United Nations Framework Convention on Climate Change (UNFCCC) by accomplishing advanced nations to trim down greenhouse gases (GHG) emissions in conformity with pre-determined individual targets. Being a member country, India has to report periodically the adopted policies and measures on mitigation. The latest data are available (for all the studied variables simultaneously) for 2019.

<sup>ix</sup>According to Agricultural Statistics at a Glance 2021, the Indian States are classified into five zones: East, North-East, North, South & Central-West.

<sup>x</sup>FSI considers the mentioned eight States to be in the North-East zone of India. Since our primary focus is on forestry, so our study follows FSI report for inclusion of States in that zone.

<sup>xi</sup>This study uses data on forests which do not differentiate between genuine and plantation forests; a known problem with the other forest datasets as the FSI dataset (Reddy et al. 2016).

<sup>xii</sup>In 2011, 1\$ = 46.6226 INR.

<sup>xiii</sup>Transport includes railway route, State Highways and National Highways of the respective States/UTs.

<sup>xiv</sup><https://www.epa.gov/climateimpacts/climate-change-impacts-forests#:~:text=Natural%20Disturbances,species%2C%20wildfires%2C%20and%20storms.&text=Some%20disturbances%2C%20like%20a%20wildfire%2C%20take%20place%20quickly>

<sup>xv</sup><https://forestgovernance.chathamhouse.org/publications/forest-governance-and-deforestation-addressing-the-disparity>

<sup>xvi</sup> Dinda (2004) proposed the relationships as

- (i)  $\beta_1 = \beta_2 = \beta_3 = 0$ ; no association between x and y.
- (ii)  $\beta_1 > 0$  and  $\beta_2 = \beta_3 = 0$ ; a monotonic increasing and linear association between x and y.
- (iii)  $\beta_1 < 0$  and  $\beta_2 = \beta_3 = 0$ ; a monotonic decreasing and linear association between x and y.
- (iv)  $\beta_1 > 0$ ,  $\beta_2 < 0$  and  $\beta_3 = 0$ ; an inverted-U-shaped relationship which goes with the original EKC hypothesis.
- (v)  $\beta_1 < 0$ ,  $\beta_2 > 0$  and  $\beta_3 = 0$ ; a U-shaped relationship between x and y.
- (vi)  $\beta_1 > 0$ ,  $\beta_2 < 0$  and  $\beta_3 > 0$ ; a cubic polynomial N-shaped curve.

<sup>xvii</sup> LULCC refers to the earth’s territorial surface modification by human activities (Nath et al. 2020).

<sup>xviii</sup><https://www.iucn.org/resources/issues-brief/deforestation-and-forest-degradation>

<sup>xix</sup><https://earthobservatory.nasa.gov/images/145907/when-a-road-leads-to-deforestation>

- <sup>xx</sup><https://www.globalforestwatch.org/blog/insights/data-trends-forest-fires-getting-worse/>
- <sup>xxi</sup><https://www.globalforestwatch.org/blog/insights/data-trends-forest-fires-getting-worse/>
- <sup>xxii</sup><https://www.indiatoday.in/diu/story/india-forests-a-tale-of-growth-loss-and-revival-2429324-2023-08-31>
- <sup>xxiii</sup><https://www.indiatoday.in/diu/story/india-forests-a-tale-of-growth-loss-and-revival-2429324-2023-08-31>
- <sup>xxiv</sup> Northern zone has the lowest percentage share of forest cover to total geographical area of the region.
- <sup>xxv</sup><https://www.hindustantimes.com/india-news/ne-states-accounted-for-76-of-india-s-tree-cover-loss-in-past-20-years-study-101634468182379.html>
- <sup>xxvi</sup><https://www.moneycontrol.com/news/environment/tree-cover-loss-heaviest-in-northeast-india-study-7618251.html>
- <sup>xxvii</sup> Data on timber and NTFP for the reference time period of this study at the State level was not available. Therefore, though timber production and collection of NTFP are equally important variables; those were kept out of regression analysis.
- <sup>xxviii</sup><https://timesofindia.indiatimes.com/city/jaipur/illegal-felling-of-khair-trees-rampant-in-rajsthans-forests/articleshow/74451924.cms>
- <sup>xxix</sup> 1 lakh = 0.1 million
- <sup>xxx</sup><https://timesofindia.indiatimes.com/city/coimbatore/take-steps-to-curb-illegal-felling-of-tress-in-reserve-forests-activists/articleshow/65726350.cms>
- <sup>xxxi</sup><https://india.mongabay.com/2021/03/confusion-over-a-government-order-facilitated-illegal-tree-felling-in-kerala/>
- <sup>xxxii</sup><https://newindianexpress.com/states/karnataka/2021/feb/17/illegal-tree-felling-seven-foresters-suspended-2265013.html>
- <sup>xxxiii</sup><https://india.mongabay.com/2020/02/india-urgently-needs-to-streamline-multi-billion-rupees-worth-ntfp-market/>
- <sup>xxxiv</sup><https://www.orfonline.org/research/harnessing-the-power-of-indias-forests-for-climate-change-mitigation/>
- <sup>xxxv</sup><https://www.wri.org/insights/when-tree-falls-it-deforestation#:~:text=Tree%20cover%20loss%20associated%20with%20forestry%2C%20fires%2C%20and.production%2C%20industrial%20agriculture%2C%20and%20urbanization%20is%20typically%20permanent.>
- <sup>xxxvi</sup><https://timesofindia.indiatimes.com/blogs/toi-edit-page/is-the-government-telling-a-distorted-story-of-the-state-of-indias-forests-heres-what-it-must-do/>
- <sup>xxxvii</sup><https://www.financialexpress.com/lifestyle/science/centre-approvesstrategy-to-create-carbon-sink-of-3-billion-tonnes-from-forests-by-2030/1509824/>
- <sup>xxxviii</sup> According to the ambitious worldwide goal of “The Bonn Challenge”, 150 Mha of deforested and degraded terrains should be restored by 2020, and 350 Mha by the year 2030.
- <sup>xxxix</sup><https://theprint.in/india/governance/will-modi-govts-new-bill-dilute-existing-protections-for-forests-all-about-proposed-law/1484430/>
- <sup>xl</sup> Those areas which haven't been proclaimed as “Reserved Forests” or “Protected Forests” officially as per the Indian Forest Act (1927), are labeled as the “Unclassed Forests”.
- <sup>xli</sup><https://ecologise.in/2020/03/08/indian-forests-are-doing-very-well-on-paper/>