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Original Article

Analysis of Forest Cover Over the Years in the Triplet Indian States of Uttarakhand, Chhattisgarh, and Jharkhand: Insights Based on the Data From 2001 to 2019

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ABSTRACT

The study analyses, compares, and contrasts the forest cover of three Indian states of Uttarakhand, Chhattisgarh, and Jharkhand that were carved out in November 2020 from their parent states of Uttar Pradesh, Madhya Pradesh, and Bihar, respectively, with a vision to give an expected boost regional development. Using the forest cover data from Forest Survey of India, Dehradun, Ministry of Environment, Forests and Climate Change, Government of India, sponsored by the Government of India State of Forest Reports (2001–2019), statistical techniques such as analysis of variance are used to compare variance and analyze and draw information and insights about the forest green cover, which is reflective of the environmental development during their 19 years development journey. The analysis of variance results were significant, demonstrating that there were substantial differences in forest cover between year and state levels. Year was a significant main effect, showing that there were significant changes in forest cover levels by year. State was a significant main effect, showing that there were substantial differences in forest cover by state levels.

Keywords: ANOVA, Bihar, Chhattisgarh, development, environment, forest cover, Jharkhand, Madhya Pradesh, Uttarakhand, Uttar Pradesh

Introduction

World over, forest covers are decreasing due to deforestation owing to development agenda (Achard et al., 2002). The environmental Kuznets curve (EKC) hypothesis states that the environment degrades as economic income increases to a point after which environmental degradation decreases due to reforestation (Govindarajan & Ganesh, 2021). Amidst ongoing debates about detrimental effects of development on environment such as global warming and climate change, sustainable development targeting a balance between economic development, social development, and environmental development has come to the fore (Swetnam et al., 2011). When three new states (Uttarakhand, Jharkhand, and Chhattisgarh) were carved out from their parent states (Uttar Pradesh, Bihar, and Madhya Pradesh, respectively) in the year 2000 with a rational of more focused regional development, it also becomes important to have a balanced approach toward development so as to conserve and preserve our natural environment. On November 1, 9, and 15 of 2000, Chhattisgarh, Uttarakhand, and Jharkhand were created as new states. The number of Indian states went from 25 to 28 as a result. Madhya Pradesh was restructured into Chhattisgarh, Uttarakhand became Uttar Pradesh, and Jharkhand into Bihar. These states' origins are thought to have been sociopolitical, not linguistic. The ancient state's seven districts were merged in Chhattisgarh, which also produces a significant amount of rice and has vast mineral resources. Uttarakhand was created from the 2 plain districts and the 11 hill districts. The 18 districts of southern Bihar were divided off to form Jharkhand. While some studies argue that the division of the mother states has had more detrimental repercussions than beneficial ones, others contend that the opposite is true. One such area that has been harmed is the environment. Thus, research on forest cover as a gauge of environmental impact is conducted for the three states. In view of this necessity, this study tries to trace the first two decades journey of these three states in terms of environment conservation and development reflected through their forest cover area over the year, as they stepped out from their teenage into twenties.

All lands with a tree canopy density of 10% or more and a minimum area of 1 ha are included in the forest cover. The Indian State of Forest Report makes no distinction between the sources of forest stands (natural or man-made) or tree species and includes all sorts of lands, regardless of ownership, land use, or legal status. As

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a result, forest cover refers to all tree species, including bamboos, fruit-bearing trees, coconut, palm, and so on, as well as all regions, including forest, private, community, or institutional properties, that match the abovementioned criteria.

High-resolution global maps are historically used to study forest cover changes (Hansen et al., 2013). Aerial photographs, satellite images, and field surveys are also utilized to monitor forest covers (Vidal et al., 2014). In this article, the forest cover evaluation was carried out using Linear Imaging Self-Scanning Sensor (LISS)-III satellite-based remote-sensing data. The mapping was done on a 1:50,000 scale with a 1-ha minimum mapping unit (MMU). The reflectance behavior of different tree coverings is taken into account when digital image analysis of satellite data for forest cover mapping is done. The amount of chlorophyll in the leaves that are exposed to the sun's incident radiation determines the reflectance of the trees. The leaf area index (LAI) defines the amount of leaf area exposed to radiation and so reflected back to the sensor in technical terms.

There are other factors as well that influence the reflectance behavior of the various features on the ground. The use of LISS-III sensor data of 23.5 m × 23.5 m pixel size and choice of a 1:50,000 map scale and 1-ha area as MMU is based on various considerations such as large area of the country to be mapped, short periodicity of 2 years between successive cycles, country-level perspective of reporting, and data availability. The MMU of 1 ha may be described as the cartographic limit of the stated map scale corresponding to a discernible polygon of 2 mm by 2 mm in size on the map.

Forest Cover Classification in India

The forest cover in India has been classified into five different classes as shown in Table 1.

Forest-Based Livelihood

In India's ancient past, forests were revered as a precious resource. However, during the past couple of centuries, forests have been viewed solely as a source of commercial lumber, and all forestry practices have been tailored to that aim. It is past time to recognize the value of the forest as a key source of livelihood based on non-timber forest products (NTFPs), as an environmental necessity, as an esthetic need, as a source of recreation, and as the home of valuable wildlife heritage. All of these other benefits of forests, other from timber, are finally being realized.

The importance of NTFPs in generating livelihoods is becoming increasingly apparent as a result of a better understanding of their economic and environmental worth. This appreciation has been aided by the burgeoning trend of market preference for natural products and the growing emphasis on the efficient and sustainable use of natural resources.

Table 1.
Forest Cover Classification in India

S. No.	Class	Description
1	Very dense forest	All lands with tree canopy density of 70% and above.
2	Moderately dense forest	All lands with tree canopy density of 40% and more but less than 70%.
3	Open forest	All lands with tree canopy density of 10% and more but less than 40%.
4	Scrub	Degraded forest lands with canopy density less than 10%.
5	Non-forest	Lands not included in any of the above classes.

Source: Forest Survey of India, Dehradun. State of Forest Report (2013).

The NTFPs can be classified into different categories based on their intended use (e.g., as food, fuel, medicine, household utensils, and farm implements), the plant parts harvested (leaf, fruit, stem, and roots), and the level of use (e.g., as food, fuel, medicine, household utensils, and farm implements) (self-supporting and commercial). Food supplements, traditional remedies, fuel and fodder, low-cost building materials, and a source of employment and revenue production are all provided by NTFPs to a large percentage of the population. In certain circumstances, the earnings obtained through NTFPs are the only source of monetary income, increasing people's reliance on commercially valuable NTFP resources. During the last century, the forests in India have undergone significant changes due to several policies undertaken by government in view of increasing population and development (Kumar et al., 2021; Reddy et al., 2012). Current socioeconomic changes stimulate urbanization, abandonment of agriculture, and forest regrowth (Crk T et al., 2009)

Joint Forest Management

There are numerous examples of local communities successfully participating in forest management around the country. Van Panchayats began managing forests in Uttarakhand in 1931, and they today manage 5450 km^2 of land. The Forest Department, however, began a pilot project in Arabari village, West Bengal, in 1971–1972, to implement a participatory management regime involving the government and local communities for the regeneration of degraded forests through effective protection, sharing of produce, and improving the livelihood opportunities of forest-dependent communities. The initiative was a huge success, covering approximately 1270 ha of degraded forest and involving 618 households from 11 villages. The woodlands were recovered as a result of this collaborative effort, and it became a model to follow. Similar effective community involvement programs emerged in other states, such as Odisha, where it began in the 1980s in Budhikhamari, Mayurbhanj district.

Through the National Forest Policy of 1988 and enabling guidelines on Joint Forest Management (JFM) in 1990, the Government of India's Ministry of Environment, Forests and Climate Change consolidated the intervention on participatory forest management. On the JFM program, states followed their own rules. Joint Forest Management's growth was slow in the early years, as it is with any change in management regime, since various policy, technical, and institutional challenges arose in the field. Joint Forest Management only covered about 4 million hectares of forest in 17 states until 1998. In August 1998, a JFM cell was established in the Ministry of Environment and Forests (MoEF) to track the program's success and serve as a clearinghouse for JFM-related information. The MoEF issued a new set of guidelines in February 2000, following extensive consultations with all stakeholders through a committee of experts. This includes, among other things, standard nomenclature and legal support for Joint Forest Management Committees (JFMCs) across the country, as well as the extension of JFM to good forest regions with a focus on NTFP management. In December 2002, additional recommendations were given on establishing a conflict resolution system with Panchayat Raj Institutions in order to assure their assistance in forest management.

When the JFM cell and the National Afforestation and Eco-Development Board (NAEB) developed the concept of Forest Development Agencies (FDAs) as an autonomous federation of JFMCs registered under the Societies Act 1860 for the empowerment of local communities for forest regeneration and livelihood creation activities, the JFM program received a boost. The Government of India provided financial support to the JFM initiative, and NAEB facilitated fund transfer to the implementing agency (FDA) straight to their bank account. In addition, financial assistance for JFM's activities came from a variety of sources in several states, including World Food Programme, Hariyali Yojana, District Rural Development Agency, Tribal Development Schemes, externally aided programs, and so on. Joint Forest Management activities are limited to forest plantation areas in particular states, such as Arunachal Pradesh, Mizoram, Meghalaya, and Nagaland, which are completely funded under FDA. Joint Forest Management has been in use in India for about 20 years, and it has been accepted by all of the Andaman and Nicobar Islands' states and Union Territory (UTs).

There were 112,896 JFMCs in the country as of 2010, with 24.6 million hectares of forest brought under their control as of March 2010. Though the number of JFMCs has increased overall, the area covered by forests has decreased since 2006. There has been a downward correction in the number of JFMCs and forest area covered in the states of Andhra Pradesh, Himachal Pradesh, Mizoram, and Punjab because many registered JFMCs have been found to be non-functional. Due to the termination of these projects in Jammu and Kashmir, JFMCs for Integrated Watershed Development and Eco-restoration of Degraded Catchments have become non-functional, but Social Forestry programs have seen an increase in JFMCs and forest area.

Methods

Forest Cover Mapping Methodology

As illustrated in Figure 1, forest cover mapping entails a series of steps. For the months of October to January, National Remote Sensing Corporation provides cloud-free satellite data for the whole country. The image data were geometrically rectified (co-registered) principally in comparison to prior cycle geo-referenced imageries to ensure that subsequent forest cover maps have a high degree of image-to-image connection from the perspective of mapped features.

The hybrid classification strategy used in forest cover mapping makes use of the algorithms' ability to construct clusters of pixels with close associations before assigning an information class, such as the proper forest cover density class, to each cluster. The interpreter's knowledge, information from secondary sources, and observations obtained during ground truthing all corroborate this. The training data generation and accuracy assessment of the interpreted picture data are based on periodic ground data gathered by field parties and other ground truth information.

Analysis of Variance

In the research literature, analysis of variance (ANOVA) is a widely used technique for understanding forest cover increase or decline (Khalid et al., 2019; Santos et al., 2020), forest fires (Guisuraga et al., 2021; Manso et al., 2016;), canopy covers (Delgado et al., 2007), and forest soil contamination (Kadam et al., 2004).

To see if there were any significant differences in forest cover by year and state, an ANOVA was used. The ANOVA is a statistical method for determining differences in a dependent variable caused by a particular independent variable(s). If the independent variable(s) has more than two levels and the ANOVA finds statistical significance, pairwise comparisons (also known as post-hoc tests) are used to find the paired differences. The following are some of the key aspects in this regard:

Degrees of freedom (*df*). This is used to calculate the *p*-value using the *F*. The two *dfs* are obtained from the sample size and number of groups.

F ratio (*F*). This is calculated by dividing the between-subject mean square (MS) by the residual MS and used with the two *df* values to determine the *p*-value.

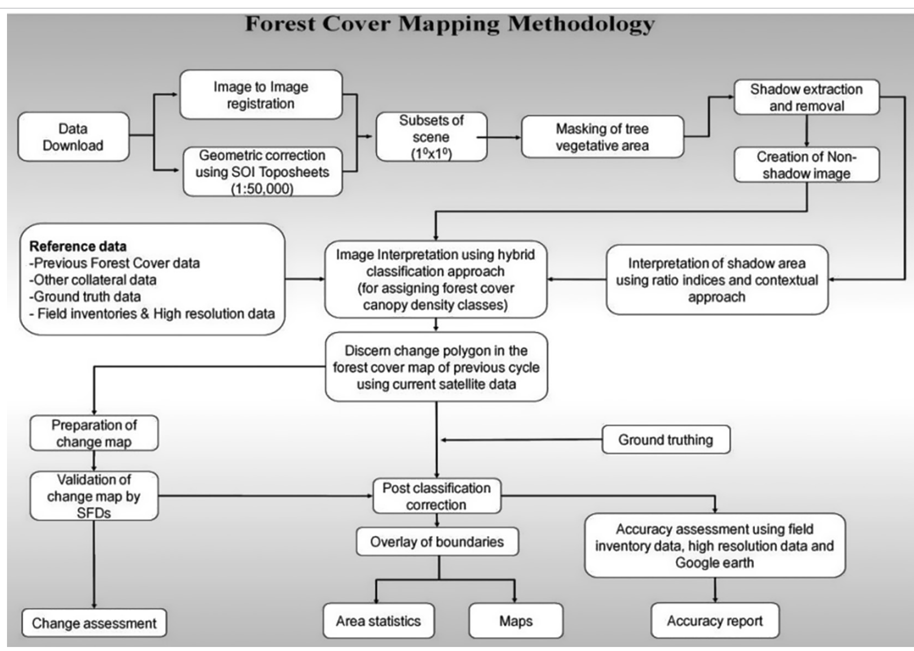

Figure 1.
Schematic Diagram of the Methodology Followed in Forest Cover Mapping. Source: Forest Survey of India, Dehradun. State of Forest Report (2015).

Mean square (MS). This is used to estimate the *F* ratio, which is computed by dividing sum of squares (SS) by *df*.

Normality. The term "normality" refers to the data's distribution. The data are assumed to be distributed in a bell-shaped curve. The results may not be reliable if the data are not regularly distributed.

Outlier. A data point that is abnormally far from a group of observations is called an outlier.

Studentized residuals. Residuals that are scaled by dividing each residual by the estimated standard deviation of the residuals are known as studentized residuals.

Sum of squares (SS). This is a method for calculating the MS that is used in conjunction with *df*.

Assumptions

Normality

The model residuals' quantiles were plotted against the quantiles of a chi-square distribution, popularly known as a Q–Q scatterplot, to test the assumption of normality (DeCarlo, 1997). The residual quantiles must not deviate significantly from the theoretical quantiles in order to meet the normality requirement. The parameter estimates could be erroneous if there are large variations. A Q–Q scatterplot of model residuals is shown in Figure 2.

Homoscedasticity

The residuals were plotted against the anticipated values to determine homoscedasticity (Bates et al., 2014; Field, 2017; Osborne & Walters, 2002). If the points appear to be randomly distributed with a mean of zero and no visible curvature, the homoscedasticity requirement is met. A scatterplot of projected values and model residuals is shown in Figure 3.

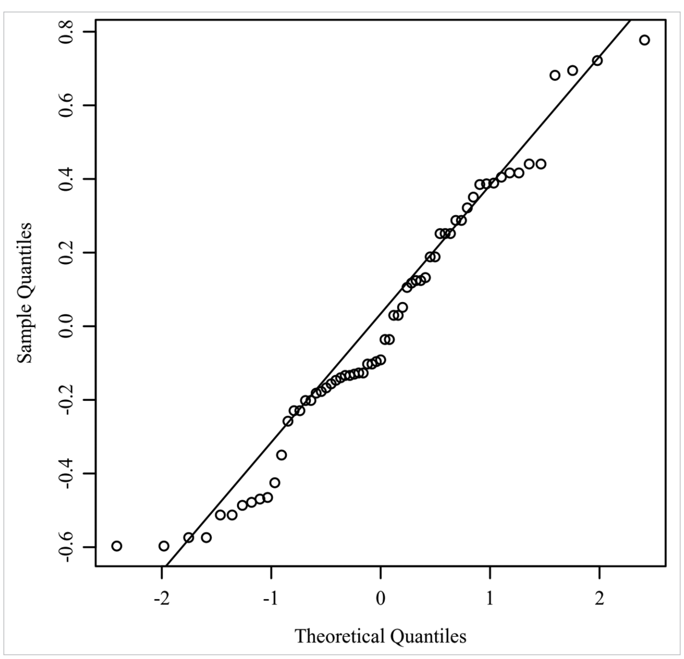

Figure 2.
For the Regression Model, a Q–Q Scatterplot Was Used to Test the Normality of the Residuals.

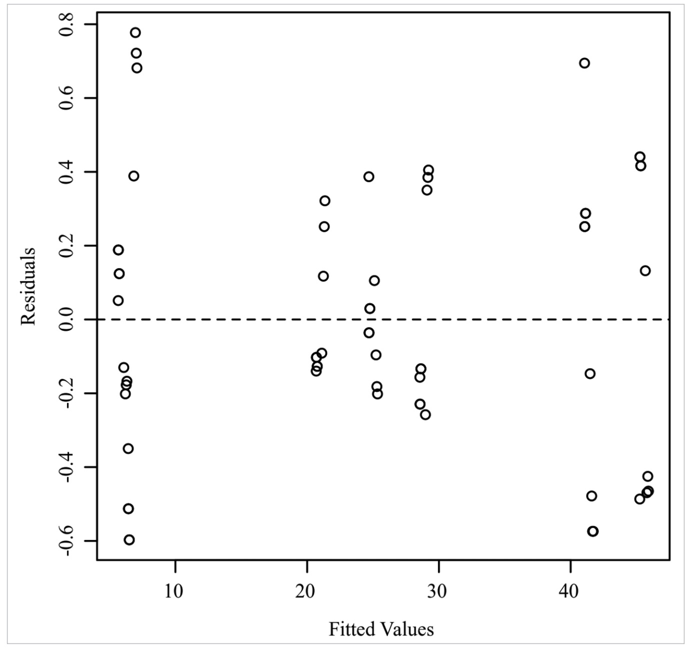

Figure 3.
Residual Scatterplot for Homoscedasticity Testing.

Outliers

Standardized residuals were generated and the absolute values were plotted against the observation numbers to identify influential locations (Field, 2017; Pituch & Stevens, 2015). By dividing the model residuals by the estimated residual standard deviation, standardized residuals are calculated. An observation with a studentized residual bigger than 3.23 in absolute value, corresponding to the 0.999 quantile of a *t* distribution with 62 degrees of freedom, was regarded to have a significant impact on the model's conclusions. The studentized residual plot of the observations is shown in Figure 4. Each point with

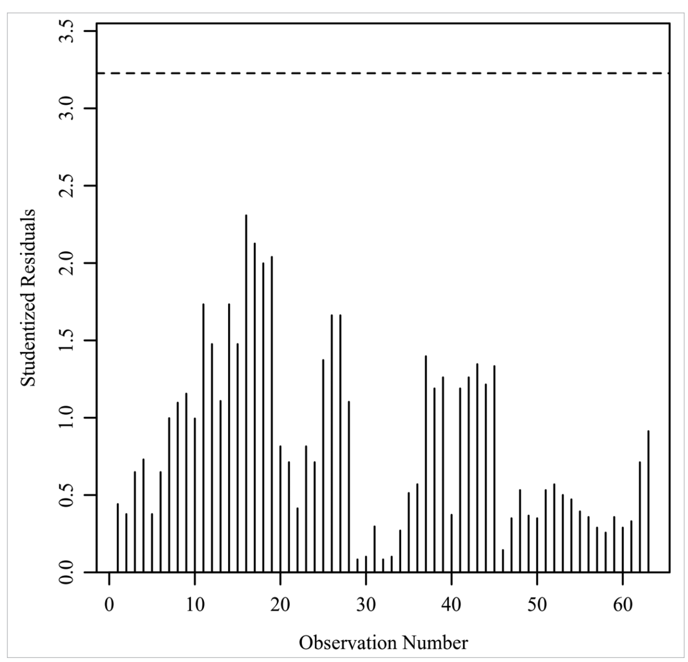

Figure 4.
A Visualization of Studentized Residuals for Detecting Outliers.

a studentized residual greater than 3.23 has an observation number specified next to it.

Results

The data of state-wise forest cover in square kilometer over the years 2001 to 2019 were compiled and consolidated from State Forest Reports and are given in Table 2. The sum of very dense forest area, moderately dense forest area, and open forest area was taken to estimate the total forest cover. Thereafter, state-wise forest area as a percent of geographical area in square kilometer was calculated as given in Table 3.

Figure 5 shows the trend over the years in the select states under study. As can be seen from Figure 5, slight variations are seen over the years in the forest covers in the select states under study. While Uttarakhand has the highest percentage of forest cover, Chhattisgarh, Jharkhand, Madhya Pradesh, Bihar, and Uttar Pradesh follow in the same order. While the three new states of Uttarakhand,

Table 2.
From 2001 to 2019 Select State-wise Category-wise Forest Area and Geographical Area in Square Kilometers

States/UTs		Jharkhand	Bihar	Chhattisgarh	Madhya Pradesh	Uttarakhand	Uttar Pradesh	Total India
Geographical area in square kilometers (*A*)		79,714	94,163	1,35,191	3,08,245	53,483	2,40,928	32,87,263
Forest cover in 2001 (area in square kilometers)	Dense forest (i)	11,787	3372	37,880	44,384	19,023	8965	4,16,809
	Open forest (ii)	10,850	2348	18,568	32,881	4915	4781	2,58,729
	Total = (i)+(ii)	22,637	5720	56,448	77,265	23,938	13,746	6,75,538
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	28.40	6.07	41.75	25.07	44.76	5.71	20.55
Forest cover in 2003 (area in square kilometers)	Very dense forest (i)	2544	76	1540	4000	4002	1297	51,285
	Moderate dense forest (ii)	9137	2951	37,440	37,843	14,420	4699	3,39,279
	Open forest (iii)	11,035	2531	17,018	34,586	6043	8122	2,87,769
	Total = (i)+(ii)+(iii)	22,716	5558	55,998	76,429	24,465	14,118	6,78,333
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	28.50	5.90	41.42	24.79	45.74	5.86	20.64
Forest cover in 2005 (area in square kilometers)	Very dense forest (i)	2544	110	2256	4239	4002	1297	54,569
	Moderate dense forest (ii)	9078	3004	36,472	36,843	14,396	4682	3,32,647
	Open forest (iii)	10,969	2465	17,135	34,931	6044	8148	2,89,872
	Total = (i)+(ii)+(iii)	22,591	5579	55,863	76,013	24,442	14,127	6,77,088
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	28.34	5.92	41.32	24.66	45.70	5.86	20.60
Forest cover in 2007 (area in square kilometers)	Very dense forest (i)	2590	231	4162	6647	4762	1626	83,510
	Moderate dense forest (ii)	9899	3248	35,038	35,007	14,165	4563	3,19,012
	Open forest (iii)	10,405	3325	16,670	36,046	5568	8152	2,88,377
	Total = (i)+(ii)+(iii)	22,894	6804	55,870	77,700	24,495	14,341	6,90,899
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	28.72	7.23	41.33	25.21	45.80	5.95	21.02
Forest cover in 2011 (area in square kilometers)	Very dense forest (i)	2544	76	1540	4000	4002	1297	51,285
	Moderate dense forest (ii)	9137	2951	37,440	37,843	14,420	4699	3,39,279
	Open forest (iii)	11,035	2531	17,018	34,586	6043	8122	2,87,769
	Total = (i)+(ii)+(iii)	22,716	5558	55,998	76,429	24,465	14,118	6,78,333
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	28.50	5.90	41.42	24.79	45.74	5.86	20.64
Forest cover in 2013 (area in square kilometers)	Very dense forest (i)	2544	110	2256	4239	4002	1297	54,569
	Moderate dense forest (ii)	9078	3004	36,472	36,843	14,396	4682	3,32,647
	Open forest (iii)	10,969	2465	17,135	34,931	6044	8148	2,89,872
	Total = (i)+(ii)+(iii)	22,591	5579	55,863	76,013	24,442	14,127	6,77,088
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	28.34	5.92	41.32	24.66	45.70	5.86	20.60

(*Continued*)

Table 2.
From 2001 to 2019 Select State-wise Category-wise Forest Area and Geographical Area in Square Kilometers (Continued)

States/UTs		Jharkhand	Bihar	Chhattisgarh	Madhya Pradesh	Uttarakhand	Uttar Pradesh	Total India
Forest cover in 2015 (area in square kilometers)	Very dense forest (i)	2588	248	4152	6629	4754	2195	85,904
	Moderate dense forest (ii)	9663	3376	34,846	34,902	13,602	4060	3,15,374
	Open forest (iii)	11,227	3664	16,588	35,931	5884	8206	3,00,395
	Total = (i)+(ii)+(iii)	23,478	7288	55,586	77,462	24,240	14,461	7,01,673
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	29.45	7.74	41.12	25.13	45.32	6.00	21.35
	Scrub	685	120	117	6383	307	803	41,362
Forest cover in 2017 (area in square kilometers)	Very dense forest (i)	2598	332	7064	6563	4969	2617	98,158
	Moderate dense forest (ii)	9686	3260	32,215	34,571	12,884	4069	3,08,318
	Open forest (iii)	11,269	3707	16,268	36,280	6442	7993	3,01,797
	Total = (i)+(ii)+(iii)	23,553	7299	55,547	77,414	24,295	14,679	7,08,273
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	29.55	7.75	41.09	25.11	45.43	6.09	21.55
	Scrub	669	228	552	6279	383	551	45,979
Forest cover in 2019 (area in square kilometers)	Very dense forest (i)	2603	333	7068	6676	5047	2617	99,278
	Moderate dense forest (ii)	9687	3280	32,198	34,341	12,805	4080	308,472
	Open forest (iii)	11,321	3693	16,345	36,465	6451	8109	304,499
	Total = (i)+(ii)+(iii)	23,611	7306	55,611	77,482	24,303	14,806	7,12,249
	Forest area as a percent of geographical area = [{(i)+(ii)}/*A*] × 100	29.62	7.76	41.14	25.14	45.44	6.15	21.67
	Scrub	688	250	610	6002	383	587	46,297

Chhattisgarh, and Jharkhand and the state of Madhya Pradesh have a higher percentage of forest cover as compared to all the Indian states average, Bihar and Uttar Pradesh have a lower forest cover. Figure 6 denotes the state-wise percent change in forest area in the year 2019 for the states of (Jharkhand, Bihar, Chattisgarh, Madhya Pradesh, Uttarakhand, Uttar Pradesh) and total India compared to the respective percent forest area in the year 2001.

Further, state-wise percent change in forest area in 2019 compared to percent forest area in 2001 indicates that Bihar has increased the forest cover by the highest percentage followed by Jharkhand, Uttarakhand, Uttar Pradesh, and Madhya Pradesh. Only one state among these, i.e., Chhattisgarh, has shown a decrease in forest area.

However, compared to 2011 assessment, assessment of the year 2013 shows that there is a slight increase in forest cover of Bihar, which is mainly attributed to plantation and protection activities. Rest of the states have in general witnessed a decrease in forest cover. In case of Chhattisgarh, encroachment, degradation of forest, mining, felling, and diversion of land for irrigation are cited to be the primary reasons for decrease in forest cover. Similarly, in case of Uttarakhand, rotational fellings and diversion of forest lands for development activities are cited to be the major reasons for downfall in forest cover. While for Bihar there has been a net decrease due to interpretational changes, rotational fellings as well as submergence of forest cover, encroachment, mining, and so on are the key reasons for decrease in forest cover in Madhya Pradesh.

Table 3.
State-wise Forest Area as a Percent of Geographical Area in Square Kilometers

	Years									
States/UTs	2001	2003	2005	2007	2011	2013	2015	2017	2019	% Change Over 2001
Jharkhand	28.40	28.50	28.34	28.72	28.50	28.34	29.45	29.55	29.62	1.22
Bihar	6.07	5.90	5.92	7.23	5.90	5.92	7.74	7.75	7.76	1.68
Chhattisgarh	41.75	41.42	41.32	41.33	41.42	41.32	41.12	41.09	41.14	−0.62
Madhya Pradesh	25.07	24.79	24.66	25.21	24.79	24.66	25.13	25.11	25.14	0.07
Uttarakhand	44.76	45.74	45.70	45.80	45.74	45.70	45.32	45.43	45.44	0.68
Uttar Pradesh	5.71	5.86	5.86	5.95	5.86	5.86	6.00	6.09	6.15	0.44
Total India	20.55	20.64	20.60	21.02	20.64	20.60	21.35	21.55	21.67	1.12

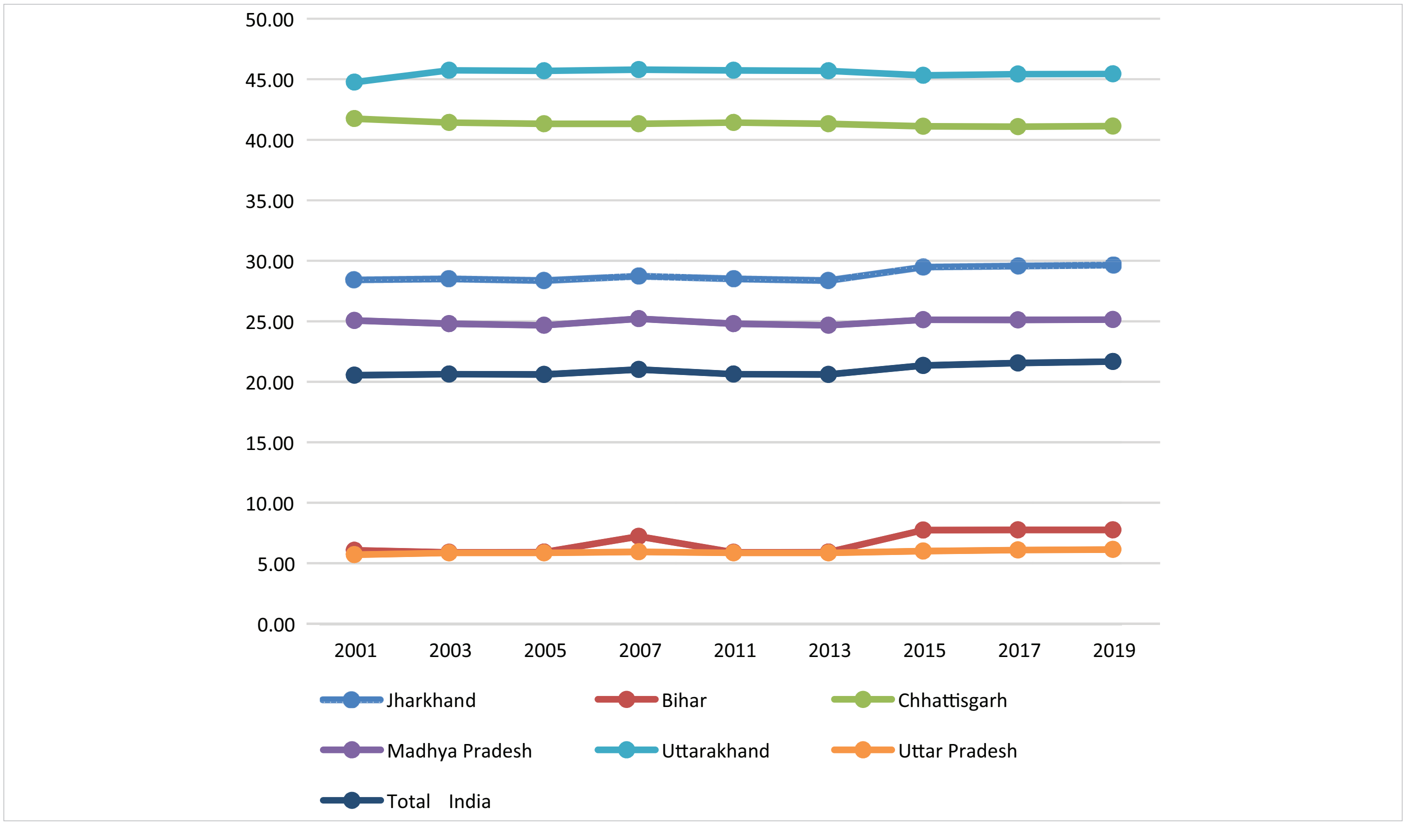

Figure 5.
State-wise Forest Area as a Percent of Geographical Area Over the Years 2001–2019.

An alpha value of 0.05 was used to test the ANOVA. The ANOVA results were significant, $F(14,48) = 5616.22$, $p = .001$, demonstrating that there were substantial differences in forest cover between year and state levels (Table 4). Year was a significant main effect, with $F(8,48) = 3.46$, $p = .003$, and $p2 = .37$, showing that there were significant changes in forest cover levels by year. State was a significant main effect, with $F(6,48) = 13{,}099.90$, $p = .001$, and $p2 = 1.00$, showing that there were substantial differences in forest cover by state levels. Table 5 shows the means and standard deviations of the data. Figure 7 indicates the forest cover means by year with 95% CI error bars. Figure 8 shows the forest cover means by state with 95% CI error bars. Table 5 gives the forest cover mean, standard deviation, and sample size by year and state.

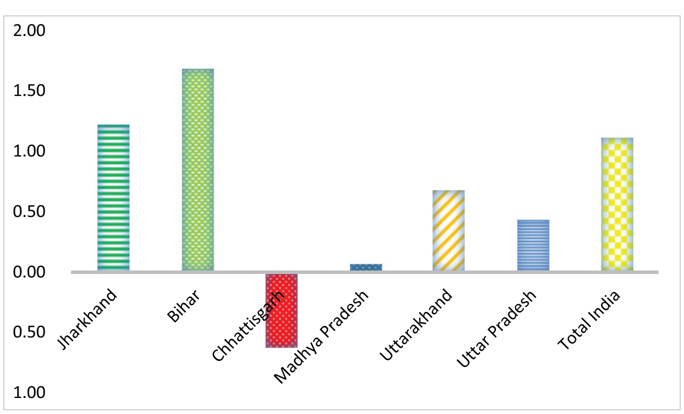

Figure 6.
State-wise Percent Change in Forest Area in 2019 Compared to Percent Forest Area in 2001.

Post-hoc

Based on an alpha of 0.05, paired *t*-tests were calculated between each pair of measurements to further analyze the differences among the variables. To account for the effect of multiple comparisons on the family-wise error rate, the Tukey's HSD (Honestly Significant Difference) test. *p*-value adjustment was applied. Forest cover was substantially higher in Jharkhand ($M = 28.82$, $SD = 0.55$) than in Bihar ($M = 6.69$, $SD = 0.90$), $p = .001$, for the main impact of state. Forest cover was substantially smaller in Jharkhand ($M = 28.82$, $SD = 0.55$) than in Chhattisgarh ($M = 41.32$, $SD = 0.20$), $p = .001$, for the main impact of state. The mean forest cover for Jharkhand ($M = 28.82$, $SD = 0.55$) was considerably higher than for Madhya Pradesh ($M = 24.95$, $SD = 0.22$), $p = .001$, for the main impact of state. Forest cover was substantially smaller in Jharkhand ($M = 28.82$, $SD = 0.55$) than in Uttarakhand ($M = 45.51$, $SD = 0.33$) for the main effect of state, $p = .001$. The mean forest cover for Jharkhand ($M = 28.82$, $SD = 0.55$) was considerably higher than for Uttar Pradesh ($M = 5.93$, $SD = 0.14$), $p = .001$, for the main impact of

Table 4.
Forest Cover by Year and State Analysis of Variance Table

Term	*SS*	*df*	*F*	*p*	η_p^2
Year	4.50	8	3.46	.003	0.37
State	12,755.67	6	13,099.90	<.001	1.00
Residuals	7.79	48			

Table 5.
Forest Cover Mean, Standard Deviation, and Sample Size by Year and State

Combination	*M*	*SD*	*n*
2001: Jharkhand	28.40	–	1
2003: Jharkhand	28.50	–	1
2005: Jharkhand	28.34	–	1
2007: Jharkhand	28.72	–	1
2011: Jharkhand	28.50	–	1
2013: Jharkhand	28.34	–	1
2015: Jharkhand	29.45	–	1
2017: Jharkhand	29.55	–	1
2019: Jharkhand	29.62	–	1
2001: Bihar	6.07	–	1
2003: Bihar	5.90	–	1
2005: Bihar	5.92	–	1
2007: Bihar	7.23	–	1
2011: Bihar	5.90	–	1
2013: Bihar	5.92	–	1
2015: Bihar	7.74	–	1
2017: Bihar	7.75	–	1
2019: Bihar	7.76	–	1
2001: Chhattisgarh	41.75	–	1
2003: Chhattisgarh	41.42	–	1
2005: Chhattisgarh	41.32	–	1
2007: Chhattisgarh	41.33	–	1
2011: Chhattisgarh	41.42	–	1
2013: Chhattisgarh	41.32	–	1
2015: Chhattisgarh	41.12	–	1
2017: Chhattisgarh	41.09	–	1
2019: Chhattisgarh	41.14	–	1
2001: Madhya_Pradesh	25.07	–	1
2003: Madhya_Pradesh	24.79	–	1
2005: Madhya_Pradesh	24.66	–	1
2007: Madhya_Pradesh	25.21	–	1
2011: Madhya_Pradesh	24.79	–	1
2013: Madhya_Pradesh	24.66	–	1
2015: Madhya_Pradesh	25.13	–	1
2017: Madhya_Pradesh	25.11	–	1
2019: Madhya_Pradesh	25.14	–	1
2001: Uttarakhand	44.76	–	1
2003: Uttarakhand	45.74	–	1
2005: Uttarakhand	45.70	–	1
2007: Uttarakhand	45.80	–	1
2011: Uttarakhand	45.74	–	1
2013: Uttarakhand	45.70	–	1

(*Continued*)

Table 5.
Forest Cover Mean, Standard Deviation, and Sample Size by Year and State

Combination	*M*	*SD*	*n*
2015: Uttarakhand	45.32	–	1
2017: Uttarakhand	45.43	–	1
2019: Uttarakhand	45.44	–	1
2001: Uttar_Pradesh	5.71	–	1
2003: Uttar_Pradesh	5.86	–	1
2005: Uttar_Pradesh	5.86	–	1
2007: Uttar_Pradesh	5.95	–	1
2011: Uttar_Pradesh	5.86	–	1
2013: Uttar_Pradesh	5.86	–	1
2015: Uttar_Pradesh	6.00	–	1
2017: Uttar_Pradesh	6.09	–	1
2019: Uttar_Pradesh	6.15	–	1
2001: Total_India	20.55	–	1
2003: Total_India	20.64	–	1
2005: Total_India	20.60	–	1
2007: Total_India	21.02	–	1
2011: Total_India	20.64	–	1
2013: Total_India	20.60	–	1
2015: Total_India	21.35	–	1
2017: Total_India	21.55	–	1
2019: Total_India	21.67	–	1

Note: A "–" shows that the sample size was insufficient to generate the statistic.

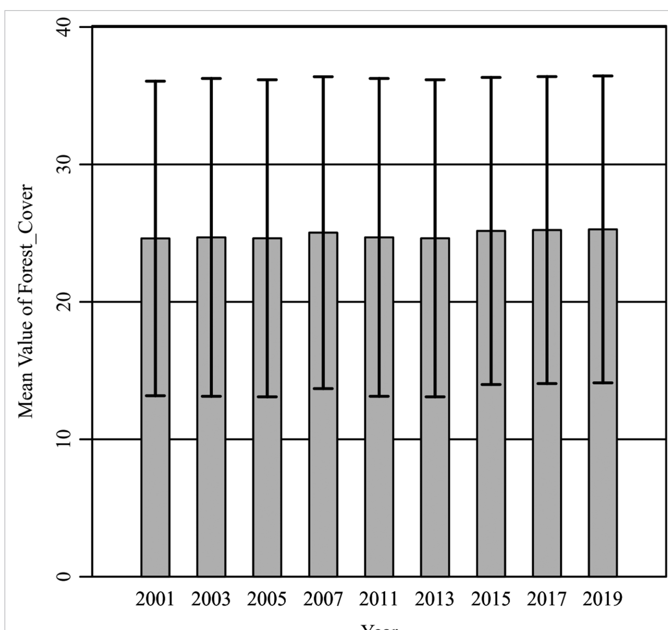

Figure 7.
Forest Cover Means by Year with 95% CI Error Bars.

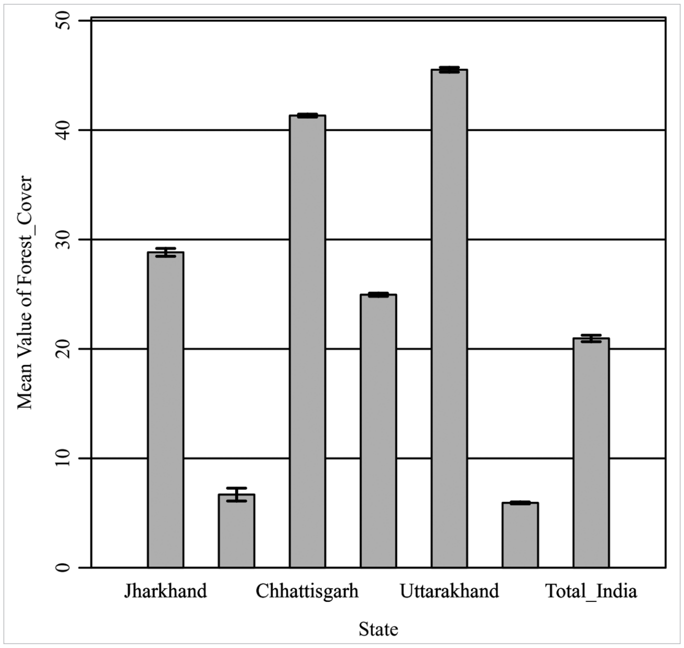

Figure 8.
Forest Cover Means by State with 95% CI Error Bars.

state. Forest cover for Jharkhand (*M* = 28.82, SD = 0.55) was considerably higher than for total India (*M* = 20.96, SD = 0.45), *p* = .001, for the main impact of state. The mean forest cover for Bihar (*M* = 6.69, SD = 0.90) was considerably lower than for Chhattisgarh (*M* = 41.32, SD = 0.20), *p* = .001, for the main impact of state. The mean forest cover for Bihar (*M* = 6.69, SD = 0.90) was substantially lower than for Madhya Pradesh (*M* = 24.95, SD = 0.22), *p* = .001, for the main impact of state. The mean forest cover for Bihar (*M* = 6.69, SD = 0.90) was substantially lower than for Uttarakhand (*M* = 45.51, SD = 0.33), *p* = .001, for the main impact of state. Forest cover was substantially higher in Bihar (*M* = 6.69, SD = 0.90) than in Uttar Pradesh (*M* = 5.93, SD = 0.14), *p* = .004. The mean of forest cover for Bihar (*M* = 6.69, SD = 0.90) was significantly lower than for total India (*M* = 20.96, SD = 0.45), *p* = .001, for the main impact of state. The mean forest cover for Chhattisgarh (*M* = 41.32, SD = 0.20) was considerably higher than for Madhya Pradesh (*M* = 24.95, SD = 0.22), *p* = .001, for the main impact of state. The mean of forest cover for Chhattisgarh (*M* = 41.32, SD = 0.20) was considerably lower than for Uttarakhand (*M* = 45.51, SD = 0.33), *p* = .001, for the main impact of state. The mean forest cover for Chhattisgarh (*M* = 41.32, SD = 0.20) was considerably higher than for Uttar Pradesh (*M* = 5.93, SD = 0.14), *p* = .001, for the main impact of state. The mean forest cover for Chhattisgarh (*M* = 41.32, SD = 0.20) was considerably higher than for total India (*M* = 20.96, SD = 0.45), *p* = .001, for the main impact of state. The mean forest cover for Madhya Pradesh (*M* = 24.95, SD = 0.22) was substantially lower than for Uttarakhand (*M* = 45.51, SD = 0.33), *p* = .001, for the main impact of state. The mean forest cover for Madhya Pradesh (*M* = 24.95, SD = 0.22) was considerably higher than for Uttar Pradesh (*M* = 5.93, SD = 0.14), *p* = .001, for the main impact of state. The mean forest cover for Madhya Pradesh (*M* = 24.95, SD = 0.22) was substantially higher than for total India (*M* = 20.96, SD = 0.45), *p* = .001, for the main effect of state. The mean forest cover for Uttarakhand (*M* = 45.51, SD = 0.33) was substantially higher than for Uttar Pradesh (*M* = 5.93, SD = 0.14), *p* = .001, for the main impact of state. The mean forest cover for Uttarakhand (*M* = 45.51, SD = 0.33) was considerably higher than for total India (M = 20.96, SD = 0.45), *p* = .001, for the main impact of state. The mean forest cover for Uttar Pradesh (*M* = 5.93, SD = 0.14) was substantially lower than for total India (*M* = 20.96, SD = 0.45), *p* = .001, for the main impact of state. There were no additional major consequences discovered.

Policy Implications

The creation of the new states has sparked concerns that there would be an upsurge in calls for the establishment of new states in other regions of the nation. Therefore, it becomes essential for leaders to have a clear vision and then make a choice based on well-researched facts, taking into account the effects on the environment, economy, and society. The forestry programs of the Government of India, such as the Greening India Mission, National Forest Action Plan 1999, National Afforestation Program, Protected Areas Management, and Compensatory Afforestation, aim to contribute to conservation and at the same time lead to building resilience in the communities dependent on them or the forest ecosystem itself by conserving biodiversity, which is one of the key factors determining the resilience of forest ecosystems. In India's Nationally Determined Contributions, agroforestry is mentioned as one of the methods for coping with and adapting to climate change (Murthy & Kumar, 2019). Thus, it is clear that forest cover is crucial and has a significant impact on climate change adaptation. Therefore, a clear strategy is required to ensure that forest ecosystems and the ecosystem services provided by the sector are not jeopardized. Thus, a forest policy or road map that focuses on planning, prioritizing, and implementing adaptation actions in particular projects and forestry programs is desired.

In the economic development activities, the new states including Uttarakhand, and, in particular Chhattisgarh, must not lose out in realizing the importance of environment development and forest conservation activities. The parent states of Bihar and Uttar Pradesh need to act on this on priority basis. Plantation and protection activities should be promoted for enhancing the forest cover in all these states. Awareness and active participation of stakeholders' state citizens coupled with JFM can play a vital role in achieving this. At the same time a stringent monitoring, check, and control is required on encroachments on forest land, degradation of forests, mining fellings, rotational fellings, submergence of forest cover, and diversion of forest lands for irrigation and development activities. This should enable fostering holistic development through environment development in tandem with economic development and social development of the states.

Future Scope

Environment and climate change-related impact, vulnerability, and adaptation evaluations have a wide range of applications, including analyses of financial requirements and the costs and advantages of various adaption strategies from an economic, social, and environmental perspective. This requires a systematic study. Another area of research involves the economic valuation of forest ecosystem services. A thorough study of the cost–benefit ratios in these three states should result from monitoring and evaluating the effects on the economy, society, and the environment.

Limitations of Remote-Sensing Data

The forest cover mapping accuracy is hampered by the inherent constraints of remote-sensing data. The following are some of these limitations:

- Because the LISS-III sensor data has a resolution of 23.5 m, land cover with dimensions less than those listed above is not collected.
- Due to weak LAI and transmittance, young plantations and tree species with less chlorophyll or inferior foliage are frequently undetectable on satellite photos.

- Because of clouds and shadows, important ground information might sometimes be obscured. Without the use of ancillary data or ground truthing, such areas are difficult to classify.
- The extensive occurrence of weeds like lantana in forest areas, as well as agricultural crops like cotton, sugarcane, and other crops growing close to forest areas, mix spectral signatures and make identifying forest cover challenging.
- Where crop composition heterogeneity is high, broad classification may have an impact on accuracy.
- In some cases, the lack of suitable season data leads to a misinterpretation of the features.

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