



Trend and growth rate analysis of forest area under Banda district of Uttar Pradesh

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ABSTRACT

The present study was undertaken to analyze the trend and growth rate performance of forest area as well as geographical area, dense forest, Open Forest, and Total Forest of the Banda district of Bundelkhand region of Uttar Pradesh. The time series data has been collected from the Forest Survey of India, which was published by Dehradun, Uttarakhand. It is under the Ministry of Environment, Forest, and Climate Change, Government of India, from 1991-91 to 2021-22 periods. It was found that the simple and compound growth rates were -4.74 and -4.31, respectively, of the geographical area. The simple and compound growth rates of -15.54 and -13.72, respectively, of the total forest area of the Banda district were negative but significant.

INTRODUCTION

A forest ecosystem is a very sophisticated and dynamic system made up of trees, plants, flies, and animals, as well as their interaction with the environment that surrounds them, which includes soil, water, air, and climate. It is crucial to the preservation of the ecological balance and to sustaining biodiversity. Forests are primary producers undertaking photosynthesis, whereby they absorb carbon dioxide, producing oxygen, which is key to life on Earth. It is crucial in balancing carbon cycles since they have the capability of storing carbon. Nonetheless, once these ecosystems are disturbed, the stored carbon escapes into the air in the form of carbon dioxide (CO₂) that goes on to cause global warming by trapping heat and hindering its transmission to space. They also serve to regulate the water cycle, prevent soil erosion, and offer a home to a wide range of flora and fauna.

Forest ecosystems would have various classes of forests with different characteristics and biotic diversity, rapidly named as tropical rain forests, temperate forests, boreal forests, and mangrove forests. Nevertheless, these ecosystems are threatened by many problems, such as deforestation, changes in weather patterns, wildfires, and incompatible land use activities. It is important to conserve forests by adopting a sustainable management approach, afforestation, and involvement of communities to ensure optimum health and productivity of these ecosystems critical to the well-being of nature and society. Forest degradation is an open issue that varies according to the definition of the terms of forest and forest degradation.

The forest ecosystem of the Banda district in the Bundelkhand region of Uttar Pradesh is known to have such characteristics as a semi-arid climate, striated land, and dry deciduous forest. The tree species found here are mostly of the dry

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condition-adapted species like Neem (*Azadirachta indica*), Babool (*Acacia nilotica*), Ber (*Ziziphus mauritiana*), Mahua (*Madhuca indica*), Khair (*Acacia catechu*), Palas (*Butea monosperma*), Tendu (*Diospyros melanoxylon*), Semal (*Salmalia malabarica*), and Kardhai (*Anogeissus pendula*). In the Bundelkhand Intermediate sub-region we also see salai (*Boswellia serrata*), seesham (*Dalbergia sissoo*), dhau (*Anogeissus latifolia*), jamun (*Syzizium*), seja, the karaundha (*Carissa spinarum*) shrub, and occasionally, teak. Such forests play crucial roles for the local rural folks by providing crucial ecosystem services such as soil conservation, fuel wood, fodder, and non-timber forest products. The water supply is irregular, bringing about low vegetation in the forest ecosystem of Banda as compared to that of dense forested areas. Nevertheless, many kinds of wildlife exist in these forests, such as jackals, foxes, hares, and a diversity of birds and reptiles. Parts of the region are drained by seasonal rivers that include Bagain and Ken, which aid the biodiversity of the ecosystem during monsoon seasons. Even though the Banda forests lie on the list of ecologically significant forests in the country, deforestation, overgrazing, illicit logging, and land degradation are a thorn in the flesh. Population pressure and unsustainable extraction of resources further serve to increase forest degradation. It is of the essence to integrate conservation activities, such as social forestry schemes, afforestation campaigns, and social involvement of people, to save and reclaim the forest ecosystems within the locality. To guarantee the long-term ecosystem health and resilience of the forest in Banda, local awareness would need to be enhanced, and sustainable use of the forest industries should be encouraged.

METHODOLOGY

The study was carried out in the Banda district of Uttar Pradesh, which is situated in the southern belt of Uttar Pradesh in the region of Bundelkhand. It is located between the latitude of 24° 53' N and 25° 55' N and the longitude of 80° 07' E to 81° 34' E, occupying a size of about 4413 square kilometers. The time series data of geographical area, dense forest, open forest, and total forest of Banda district have been collected during the period of 1991-91 to 2021-22 from the website of Forest Survey of India, Dehradun (Uttarakhand).

Moving Average Method

Moving average of extent (or period) m is a series of successive averages of m terms at a time, starting with 1st, 2nd and 3rd term etc. Thus, the first average is the mean of the 1st, m terms, the 2nd is the mean of the m terms from 2nd to $(m+1)$ th term, the third is the mean of the m terms from 3rd

to $(m+2)$ th term, and so on.

If m is odd $= (2k+1)$ say, moving average is placed against the mid-value of the time interval it covers, i.e. against $t=k+1$ and if m is even $= 2k$ (say), it is placed between the two middle value of the time interval it covers; i.e., between $t=k$ and $t=k+1$.

In the latter case, the moving average does not coincide with an original time period, and an attempt is made to synchronize the moving average and the original data by centering the moving average, which consists in taking a moving average extent two of these moving average and putting the first of these values against $t=k+1$. the graph obtained on plotting the moving average values against the corresponding time value gives a trend curve.

Growth rate

Growth rate in area has been worked out by fitting the following two different functions:

Simple linear function

$$Y_t = a + b \quad \dots (1)$$

Compound growth rate function

$$Y_t = a \left(1 + \frac{r}{100} \right)^t \quad \dots (2)$$

Where,

Y_t = Time series data on area at time t ,

a and b = parameters of the function to be estimated.

t = Time index ($t=1,2,3,\dots,n$)

r = Average compound growth rate per annum.

However, before the fitting of above function, the series data on area was smoothed by moving-average method. After fitting the first linear trend function by least-square method,

we get the estimate of b denoted by \hat{b} (say). Then, annual linear growth rate is computed as follows

$$r = \frac{\hat{b}}{\bar{Y}} \times 100 \quad \dots (3)$$

Where,

\bar{Y} is arithmetic mean of Y_t .

To obtain annual compound growth rate, second function was first linearized

By taking log on both side, i.e.

$$Y_t = a \left(1 + \frac{r}{100} \right)^t \quad \dots (4)$$

$$\log Y_t = \log a + t \log \left(1 + \frac{r}{100}\right) \quad \dots (5)$$

$$Y_t^* = a + bt \quad \dots (6)$$

Where,

$$b = \log \left(1 + \frac{r}{100}\right) \quad \dots (7)$$

The above linearized function was fitted by least square method and estimate of b as \hat{b} was obtained. The annual compound growth rate is then computed as

$$r = (\text{Antilog } \hat{b} - 1) \times 100 \quad \dots (8)$$

Both growth rates are expressed in percentage. The best fitted function was judged on the basis of R².

RESULTS

Geographical area, Dense, open and Total Forest area of district Banda

The analysis of forest cover in Banda district from 1991 to 2022 reveals significant trends and transitions in forest ecosystem dynamics. Initially, the geographical area of the district was recorded at **7,624 km²** until 1999-2000, after which it was revised to approximately **4,532 km²** 2001-02, and further to **4,408 km²** in recent years. This change likely reflects administrative boundary revisions rather than actual land loss. By using the method of moving average, it also showed a decline in geographical area of district Banda. The trend of geographical area through 3 years moving average

along with the linear trend line and the values of R² are shown in Fig.-1.

During the early 1990s, Banda had a stable and comparatively higher forest cover, with dense forests consistently recorded at 331 km² and open forests around 268–272 km². The total forest area during this period exceeded 600 km², indicating a relatively healthy forest ecosystem. However, a dramatic decline in forest cover is observed starting from 2001-02, where dense forest area dropped sharply to 165 km², and open forest to just 18 km². This decline coincides with the reduction in geographical area, but also suggests widespread deforestation or forest degradation. The three-year moving average for dense forest during this phase fell significantly from 331.00 km² in 1997-98 to 174.33 km² in 2001-02, and further down to 73.00 km² in 2003-04. The open forest area followed a similar trend, reaching a low of 46.67 km² in 2009-10. Such impairment may be associated with the loss of forests, alteration of land uses and the growth in human activities on forest resources. In spite of mild improvement in open forest nibbling in the later years, dense forests were kept down and the aggregate timber cover did not soar significantly to challenge about 100-103 km² by 2011-12 and onwards. Although the earlier decline in dense forest was not reversed, open forest areas showed signs of recovery, likely due to reforestation, afforestation programs, or natural regeneration. Even without taking into consideration any possible reforestation that might have kept the open forest levels steady, the long-term trend in forest density is downwards according to the 3-year moving averages. This information proves the necessity of taking some immediate actions to encourage the forest preservation, as well as the process of reforestation, in Banda district to achieve the ecological balance. The trend of dense, open and total forest area through 3 years moving average along with their linear trend line and the values of R² are shown in Fig.-2, 3 and 4 respectively.

Table 1: Moving average trend of Geographical areas, Dense, open and Total forest area of district Banda

Year	Geographical area (km ²)	3 Year Moving Average	Dense forest km ²	3 Year Moving Average	Open forest km ²	3 Year Moving Average	Total Forest	3 Year Moving Average
1991-92	7624	-	331.00	-	268.00	-	599.00	-
1993-94	7624	7624.00	331.00	331.00	268.00	269.33	599.00	600.33
1995-96	7624	7624.00	331.00	331.00	272.00	270.67	603.00	601.67
1997-98	7624	7624.00	331.00	331.00	272.00	271.00	603.00	602.00
1999-20	7624	6593.33	331.00	275.67	269.00	186.33	600.00	462.00
2001-02	4532	5562.67	165.00	174.33	18.00	121.00	183.00	295.33
2003-04	4532	4532.00	27.00	73.00	76.00	56.67	103.00	129.67
2005-06	4532	4490.67	27.00	36.64	76.00	66.00	103.00	102.64
2007-08	4408	4490.67	55.91	36.30	46.00	46.33	101.91	102.64

2009-10	4532	4490.67	26.00	35.97	17.00	46.67	103.00	102.64
2011-12	4532	4532.00	26.00	26.00	77.00	57.00	103.00	103.00
2013-14	4532	4490.67	26.00	36.00	77.00	66.67	103.00	102.67
2015-16	4408	4449.33	56.00	46.00	46.00	56.33	102.00	102.33
2017-18	4408	4408.00	56.00	55.97	46.00	46.00	102.00	101.97
2019-20	4408	4408.33	55.91	55.94	46.00	46.00	101.91	101.94
2021-22	4409	-	55.92	-	46.00	-	101.92	-

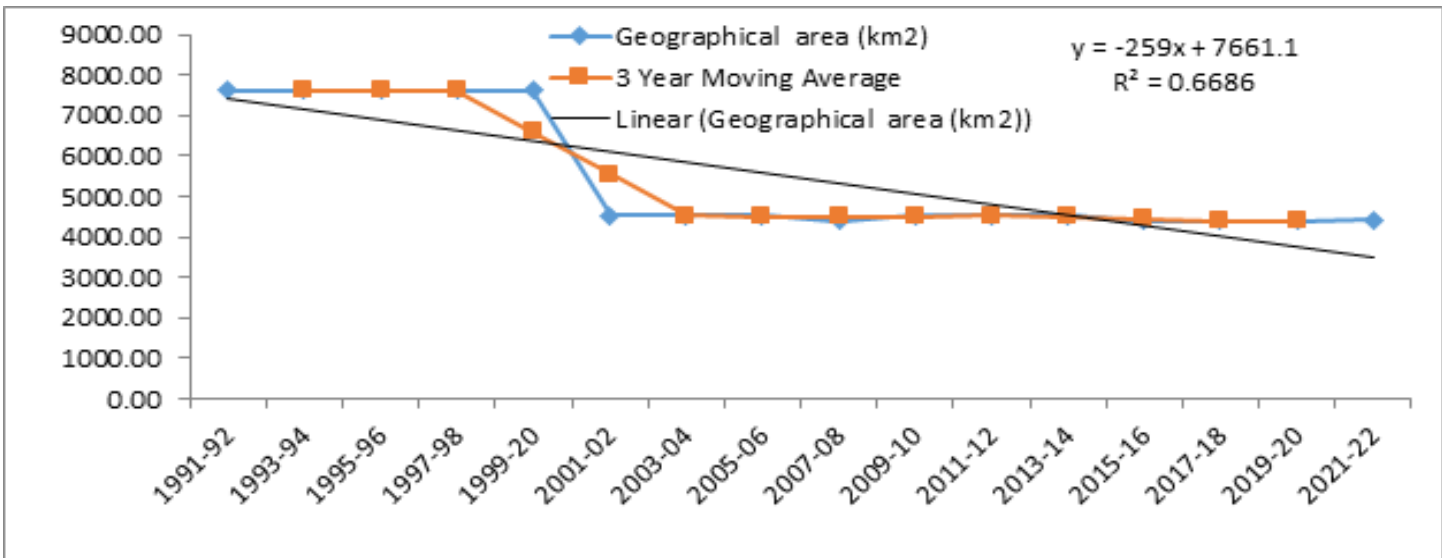


Fig.-1: Trend line of geographical area of district Banda

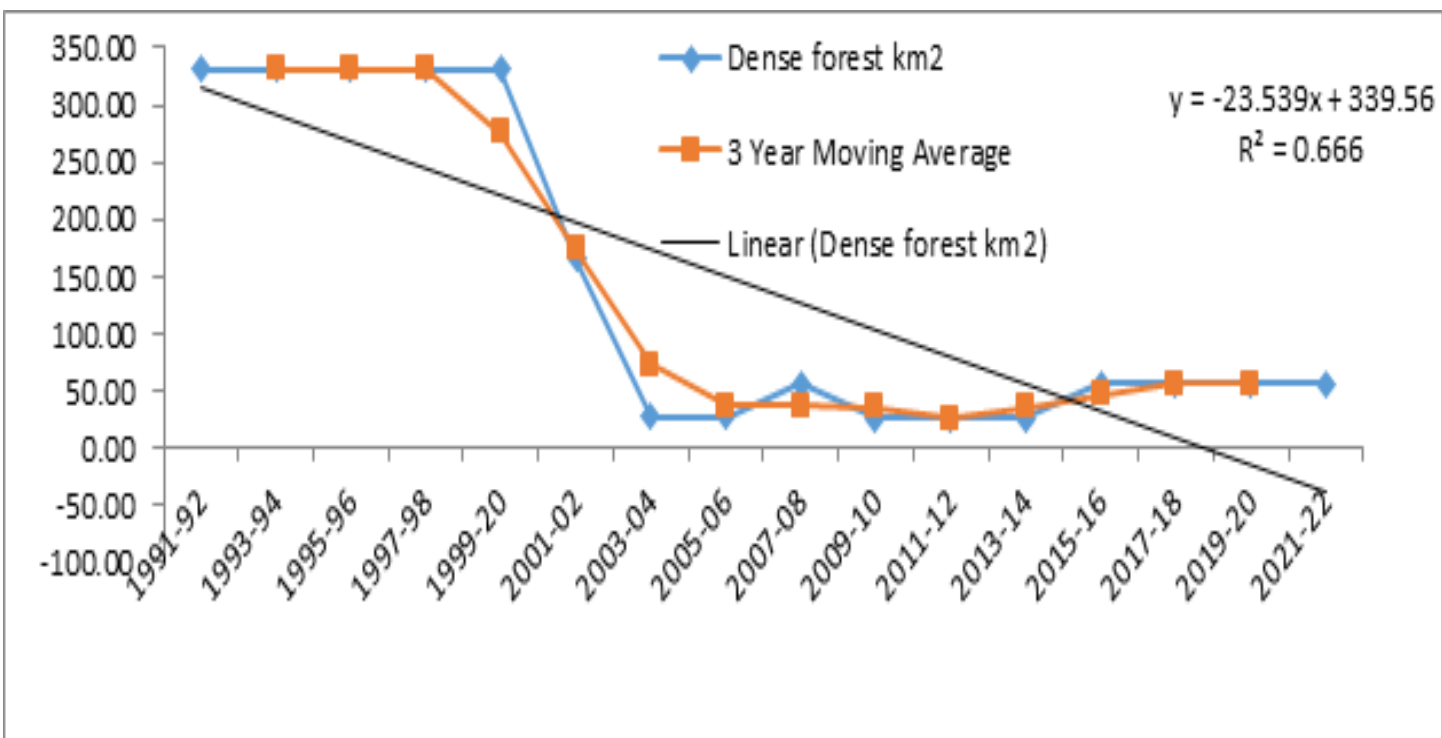


Fig.-2: Trend line of dense forest area of district Banda

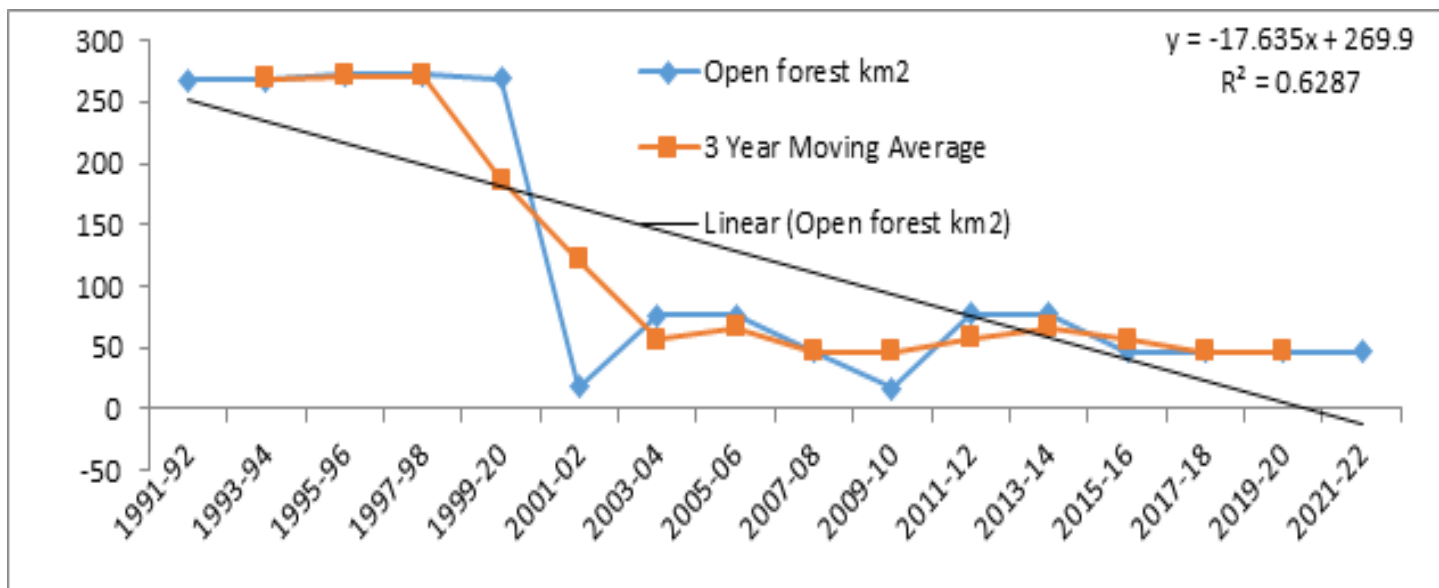


Fig.-3: Trend line of Open forest area of district Banda

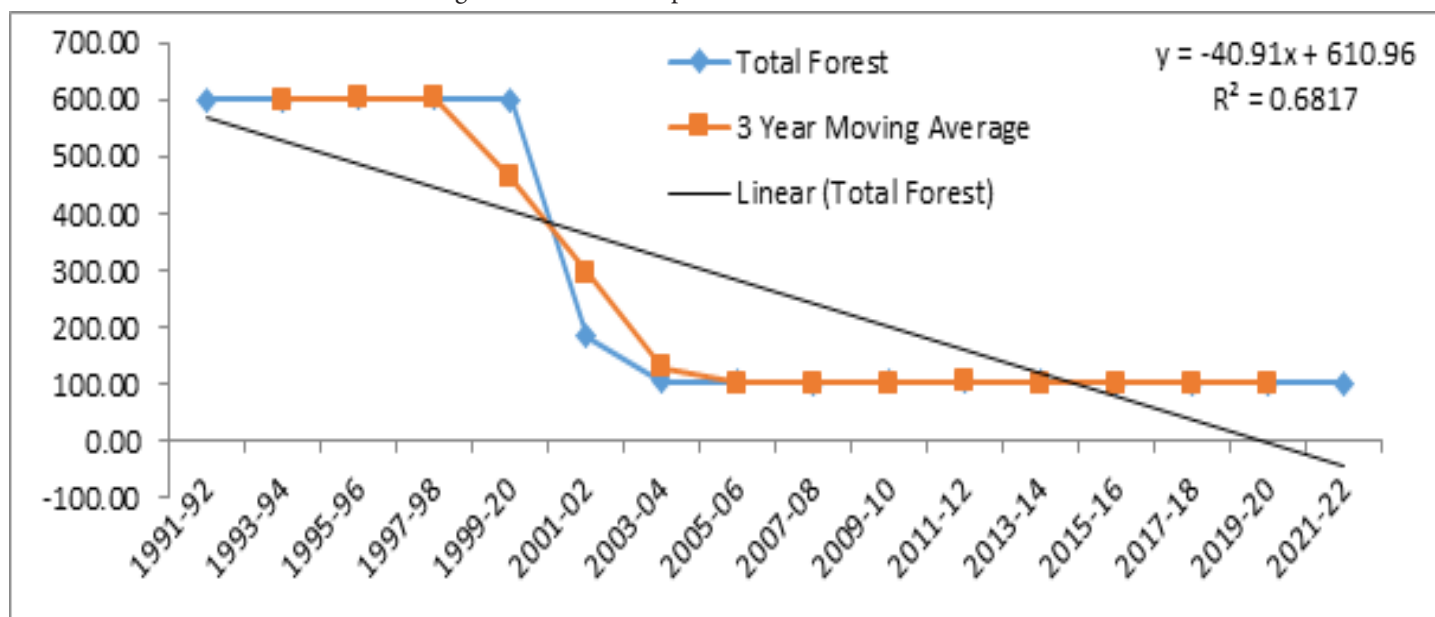


Fig.-4: Trend line of total forest area of district Banda

Growth rate of forest area of Banda district of Uttar Pradesh

The analysis of growth rates in forest cover and geographical area of Banda district provides strong evidence of long-term ecological degradation. The **Simple Growth Rate (SGR)** reveals a **negative trend across all categories**, with the **geographical area declining by -4.74%**, and a highly significant reduction observed in **dense forest (-16.87%)**, **open forest (-14.96%)**, and **total forest area (-15.54%)**. These reductions are statistically significant, indicating a consistent pattern of forest depletion over the study period. When the **3-year moving average** is applied to smooth

out short-term fluctuations, the SGR values show even more alarming declines, with **dense forest cover falling by -19.50%**, **open forest by -16.50%**, and **total forest by -17.55%**, all of which are highly significant ($R^2 > 70\%$). This suggests that the underlying trend is not just due to temporary variation, but rather a sustained loss of forest resources over time. The **Compound Growth Rate (CGR)**, which accounts for exponential changes over time, also shows a **consistent negative growth**. The geographical area declined at a CGR of **-4.31%**, while **dense forest cover reduced by -15.15%**, **open forest by -12.57%**, and **total forest area by -13.72%**. These patterns are reinforced by the 3-year moving average CGR values, which again show steeper declines, particularly in **dense forest (-17.28%)** and **total forest cover (-15.20%)**.

Table 2: Growth rate of forest area of Banda district of Bundelkhand region of Uttar Pradesh

Growth Rate	Geographical Area	Dense forest	Open forest	Total Forest
Simple Growth Rate	-4.74 (0.6685**)	-16.87 (0.6654**)	-14.96 (0.6287**)	-15.54 (0.6817)
SGR-3-Year Moving Average	-5.14 (0.7249**)	-19.50 (0.7105**)	-16.50 (0.7152**)	-17.55 (0.7277**)
Compound Growth Rate	-4.31 (0.6752)	-15.15 (0.5283**)	-12.57 (0.4530**)	-13.72 (0.7100)
CGR-3-Year Moving Average	-4.66 (0.7394)	-17.28 (0.6548**)	-13.97 (0.7539)	-15.20 (0.7595)

Note: Figures in bracket denote R^2 and ** Significant at $p \leq 0.0$

The high R^2 values across all growth rate calculations indicate a **strong and statistically reliable trend of forest decline**. The sharp reduction in **dense forest cover**, which plays a critical role in maintaining biodiversity and ecological stability, is particularly concerning. These findings reflect the cumulative impact of **deforestation, land-use changes, over-exploitation of resources, and lack of effective forest management** in Banda district.

DISCUSSION

The findings of the present study indicate a significant and continuous decline in forest cover from 1991-91 to 2021-22. Similar observations were reported by Koren and Mipun (2020) also observed a reduction in forest cover in the Senapati district of Manipur, where the forested area accounted for 75.91 percent of the district geographical area in 2005 and 66.55 percent of the total district's geographical area (3,271 km²). Specifically, in 2005, the district contained 296 km² under Very Dense Forest (VDF), 936 km² under Moderately Dense Forest (MDF) and 1,251 km² under Open Forest. Over the following decades, a marked reduction occur across these forest categories, resulting in an overall loss of 9.34 percent (306 km²) of its forest cover in the period between 2005 and 2015. Similar results were reported by SFR (2015). Mahato et al. (2021) also demonstrated a substantial decline of 7.47% forest cover from 1990 to 2000, followed by a further reduction of 7.11% during 2000 to 2010. However, a marginal recovery of 2.34% in forest cover from 2010 to 2020. Overall, net conversion of forest to non-forest area was 195.17 km² in the last forty years. There was a considerable decline in the forest to non-forest (11.94% to 3.50%) from 2000–2010 to 2010–2020. These findings are consistent with the observation of the present study. Differing results reported by Nithin and Mahajanashetti (2017), who reported that Tripura ranked highest among Indian states in terms of growth rate area (9.27%) as well as production (11.55%). At

the national level, their study showed a statistically significant annual growth rate of 3.36 percent in the area under rubber cultivation. Puyravaud et.al. (2010) affirm the findings of the present study and indicated that the early 1990s, tree plantations expanded in India at an estimated rate of roughly 15,400 km²/year. Subtracting plantations from total forest cover shows that native forests in India have declined by 1.5%–2.7% per year. Bhushan (2017) also highlighted the similar findings which revealed that mostly degradation of forest has been detected in eastern part of Indian districts because of mass population pressure, development activities, agricultural expansion and mining activities, where western and south-west part of India's districts recorded positive growth of the forest during 1991-99, caused by reforestation activities, participation of local people in management process with the help of local institution. The SGR of the present study has a **negative trend across all categories**, with the **geographical area declining by -4.74%**, and a highly significant reduction observed in **dense forest (-16.87%)**, **open forest (-14.96%)**, and **total forest area (-15.54%)**. These reductions are statistically significant, indicating a consistent pattern of forest depletion over the study period. The findings of the study corroborate with (Lall et. al.2025; Tripathi et. al. 2023; Kumar et. al. 2022; Almamun, 2021; Kalia et. al. 2021; Annu and Tanwar, 2018 & Rijal et. al. 2021) the other similar study conducted in a different context. Differing findings reported by Wang and Pu (2018) that forest landscape pattern had stability in the reservoir area, in all directions, was not significant, but the southern region was slightly more stable; and the stability of the forest landscape pattern in the reservoir area increased from 1990 to 2012. Xiaobang et al. (2024) made contrary observation that the Fractional Forest Cover (FFC) has an increasing trend with average rates of 0.022/10a in the last 25 years, and 0.03/10a after 2010 largely corresponding to the fourth and fifth phases of the Three-North Shelter Forest Program (TNSFP) and increasing trend after 2010 was stronger than that before 2010.

CONCLUSION

The analysis of forest cover trends in Banda district over the past three decades reveals a **significant and consistent decline** in both dense and open forest areas. The results, supported by negative simple and compound growth rates with high statistical significance, indicate that **forest degradation in the region is both severe and sustained**. The steep reduction in **dense forest cover**, in particular, suggests a loss of biodiversity, ecological balance, and critical ecosystem services. Although the open forest area has shown minor stabilization in recent years, the overall forest area has not recovered to its earlier levels. The observed decline is likely driven by factors such as **deforestation, agricultural expansion, population pressure, and inadequate forest management**. This calls for **urgent and integrated conservation measures**, including **afforestation, sustainable land use planning, and community-based forest governance**, to restore ecological integrity and ensure long-term environmental sustainability in the Banda district.

REFERENCES

- Almamun, M.A., Nihad, S., Sarkar, M.A.R., Aziz, M.A., Qayum, M.A. & Ahmed, R. (2021). Growth and trend analysis of area, production and yield of rice: A scenario of rice security in Bangladesh. *PLoS ONE*, 16(12): e0261128. <https://doi.org/10.1371/journal.pone.0261128>
- Annu & Tanwar, N. (2018). Scenario of fertilizer consumption in different agro-climatic zones of eastern Uttar Pradesh, *Journal of Pharmacognosy and Phytochemistry* 7(3): 2741-2742
- Annu & Tanwar, N. (2018). Trend in fertilizer consumption in different agro-climatic zones of Eastern Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry*, 7(3): 2600-2605.
- Bhushan, S. (2017). Trend of Deforestation in India: A comparative Approach to identify the qualitative and quantitative change of natural vegetation cover. *International Journal of Scientific Research and Management (IJSRM)*, 5(07):6538-6547. <https://doi.org/10.18535/ijsrm/v5i7.94>
- Koren, T.S. & Mipun, B.S. (2020). Assessment of Forest Cover and Forest Loss in the Senapati District of Manipur, India. *Applied Ecology and Environmental Sciences*, 8(6):367-372. <https://doi.org/10.12691/aees-8-6-6>.
- Kalia, A., Shukla, G., Mishra, D., Mishra, B.P. & Patel, R.R. (2021). Comparative trend analysis of mustard in Bundelkhand region, Uttar Pradesh and India. *Indian Journal of Extension Education*, 57(1), 15-19.
- Kumar, A., Kalia, A., Gupta, B.K., Mishra, D., Shukla, G., Mishra, B.P. & Ojha, P.K. (2022). An Economic Analysis of Mustard Production in Bundelkhand region of U.P., *AMM*, 53(1):5039-5048.
- Kumar, N., Singh, S.K., Ahamad, R., Yadav, A., Sangwan, A., Wagh, T. & Singh, Y.P. (2022). Statistical analysis and growth performance of rice in Bundelkhand region. *The Pharma Innovation Journal*, SP-11(6): 771-77.
- Lall, A.J., Singh, C.B. & Mishra, S. (2025). Sorghum Production in Bundelkhand Region of Uttar Pradesh: A Comprehensive District Level Data Analysis from 2001 to 2022. In: Singh, C.B., Mishra, S., Jasmine Lall, A. (eds) *Global Millets Production for a Sustainable Future*. Springer, Cham. https://doi.org/10.1007/978-3-031-88157-2_14
- Mahato, R., Nimasow, G., Nimasow, O.D. & Bushi, D. (2021). Assessing the tropical forest cover change in northern parts of Sonitpur and Udalguri district of Assam, India. *Scientific Reports*, 11:11170. <https://doi.org/10.1038/s41598-021-90595-8>
- Nithin, K.N. & Mahajanashetti, S.B. (2017). Trend and Growth Rate Analysis of Area, Production and Productivity of Natural Rubber in India. *Research Journal of Agricultural Sciences*, 8(3): 731-734.
- Puyravaud, J.P., Davidar, P. & Laurance, W.F. (2010). Cryptic destruction of India's native forests. *Conservation Letters* 3:390-394.
- Rijal, M., Thapa, R., Srivastava, A. & Lamsal, G. (2021). Trend, Growth Rate and Instability Analysis of Production, Productivity, Area and Supply of Potato in Kavrepalanchok District, Nepal. *Food and Agri Economics Review*, 1(2): 80-87.
- SFR (2015). Indian State of Forest Report. Forest Survey of India, Dehradun, Government of India.
- Tripathi, S. M., Kalia, A., Mishra, B. P., Mishra, S., Mishra, D., & Shukla, G. (2023). Trends in Area Production and Productivity of Sesame: Analysis of Bundelkhand Region of Uttar Pradesh. *Indian Journal of Extension Education*, 59(4), 40-43.
- Wang, W. & Pu, Y. (2018). Analysis of Landscape Patterns and the Trend of Forest Resources in the Three Gorges Reservoir Area. *Journal of Geoscience and Environment Protection*, 6, 181-192. <https://doi.org/10.4236/gep.2018.65015>
- Xiaobang, L., Shunlin, L., Han, M., Bing, L., Yufang, Z., Yingying, L., Tao H., Guodong, Z., Jianglei, X., Changhao, X., Rui, M., Wenfu, Wu. & Jiahua, T. (2024). Landsat-observed changes in forest cover and attribution analysis over Northern China from 1996-2020, *GIScience & Remote Sensing*, 61:1, 2300214, <https://doi.org/10.1080/15481603.2023.2300214>