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Hot Spot analysis of vegetation cover in Uttar Pradesh during 2011 to 2021

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ABSTRACT

This study presents a hot spot analysis of vegetation cover in Uttar Pradesh from 2011 to 2021 using the Normalized Difference Vegetation Index (NDVI). The MODIS satellite data product "MOD13C2_006_CMG_0_05_Deg_Monthly_NDVI" was utilized for the analysis. The hot spot analysis technique employed was the Getis-Ord Gi*, which identifies clusters of high and low vegetation cover. The results revealed distinct patterns of hot and cold spots across different districts of Uttar Pradesh. Cold spots, indicating lower vegetation cover, were identified in districts such as Auraiya, Banda, Etawah, and Fatehpur. On the other hand, hot spots, indicating higher vegetation cover, were observed in districts including Bijnor, Meerut, Moradabad, and Muzaffarnagar. The findings contribute to our understanding of the dynamics of vegetation cover and its implications for ecosystem health and resilience in the region. These results can guide policymakers and land managers in making informed decisions to promote vegetation growth and improve ecological conditions in Uttar Pradesh.

Key words: Hot spots, NDVI, MODIS, Getis-Ord Gi*

1) INTRODUCTION

Vegetation cover plays a crucial role in environmental sustainability, biodiversity conservation, and regional climate patterns [1, 2, 3]. Monitoring and analyzing changes in vegetation cover over time can provide valuable insights into ecosystem health, land management practices, and the impacts of climate change [4, 5, 6]. In this research paper, we focus on conducting a hot spot analysis of vegetation cover in Uttar Pradesh, India, from 2011 to 2021. The aim of this study is to identify spatial patterns, trends, and areas of high vegetation cover concentration, also known as hot spots, within the region.

Uttar Pradesh, one of the most populous and agriculturally significant states in India, exhibits a diverse range of vegetation cover types, including forests, agricultural lands, and urban areas [7, 8]. Understanding the dynamics of vegetation cover in this region is crucial for sustainable land use planning, ecological conservation, and climate change mitigation efforts [9, 10, 11]. By conducting a hot spot analysis, we can identify areas where vegetation cover exhibits statistically significant clusters of high or low values, indicating areas of particular ecological importance or vulnerability.

To undertake this analysis, we utilize remote sensing data, specifically the Normalized Difference Vegetation Index (NDVI), which is widely used as an indicator of vegetation health and vigor [12, 13]. The NDVI values are derived from satellite imagery and provide a quantitative measure of vegetation cover density and vitality. By examining the spatiotemporal patterns of NDVI in Uttar Pradesh, we can gain insights into the changes in vegetation cover over the study period and identify regions that have experienced notable shifts in vegetation dynamics.

The methodology employed in this study includes statistical analyses such as the Getis-Ord Gi* statistic, which detects statistically significant hot spots and cold spots in the distribution of vegetation cover [14, 15]. This approach allows us to identify areas with consistently high or low NDVI values, highlighting regions of particular interest for further investigation and targeted conservation efforts.

The objectives of the work were first to identify hot spots and cold spots of vegetation cover across different districts in Uttar Pradesh. Second to provide insights into the patterns and trends of vegetation cover in Uttar Pradesh and their implications for land management and conservation.

2) MATERIALS AND METHODS

Study area: Uttar Pradesh, located in northern India (Figure 1), is the most populous state in the country, spanning an area of approximately 243,290 square kilometers [16]. It is bordered by several states, including Uttarakhand, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, and Bihar. The state is characterized by its diverse geographical features, including the Gangetic plains, the foothills of the Himalayas, and the Vindhya Mountain range [17].

With a population of over 200 million people, Uttar

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Pradesh is known for its cultural and historical significance, housing several iconic landmarks such as the Taj Mahal in Agra and the holy city of Varanasi along the banks of the River Ganges [18]. The state is also an agricultural powerhouse, with a significant portion of its land used for farming and cultivation [19].

Uttar Pradesh experiences a subtropical climate, with hot summers and cool winters. The region receives rainfall primarily during the monsoon season, which spans from June to September [20]. The combination of fertile soil, favorable climate, and abundant water resources contributes to the state's agricultural productivity.

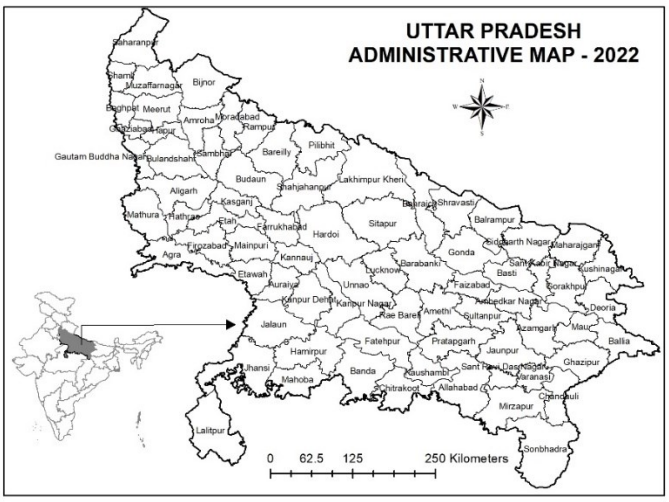


Figure 1: Study Area map

Data Source: The data source used in this study is the MODIS (Moderate Resolution Imaging Spectroradiometer) product, specifically the MOD13C2_006_CMG_0_05_Deg_Monthly_NDVI dataset. MODIS is a satellite-based sensor that captures data on land surface properties and vegetation dynamics. The MOD13C2_006_CMG_0_05_Deg_Monthly_NDVI dataset provides monthly vegetation indices derived from MODIS data at a spatial resolution of 0.05 degrees, covering the global land surface [21].

The Normalized Difference Vegetation Index (NDVI) is a widely used vegetation index calculated from satellite imagery. It measures the greenness and vigor of vegetation by quantifying the difference between the reflectance of near-infrared (NIR) and red-light bands. The MOD13C2_006_CMG_0_05_Deg_Monthly_NDVI dataset offers long-term time series data spanning from 2011 to 2021, allowing for the analysis of vegetation dynamics and changes over the study period.

The dataset is processed using rigorous quality control measures to ensure the accuracy and reliability of the NDVI values. It provides valuable information on vegetation cover, biomass production, and phenological patterns at a regional and global scale. The availability of monthly data enables the examination of seasonal variations and trends in vegetation dynamics, aiding in the understanding of ecosystem health, climate change impacts, and land management practices.

***Data Analysis*:** The data analysis in this study employs the Hot Spot Analysis technique, specifically the Getis-Ord Gi* statistic. This spatial statistical analysis method is widely used to identify hotspots and coldspots in geographic datasets, allowing for the identification of areas with high or low concentrations of a particular attribute. In the context of this study, the analysis focuses on vegetation cover in Uttar Pradesh from 2011 to 2021.

The Getis-Ord Gi* statistic calculates a z-score for each feature in the dataset, indicating the degree of clustering or dispersion of the attribute being analyzed. The formula for the Getis-Ord Gi* statistic is as follows:

Gi*(d) = (X_i - mean(X)) / (standard deviation(X)) * SUM (w_ij * X_j)

In the formula, Gi*(d) represents the Gi* statistic for a specific feature, X_i is the attribute value for the feature, mean(X) is the mean value of the attribute across all features, standard deviation(X) is the standard deviation of the attribute, w_ij is the spatial weight between the feature i and its neighbouring feature j, and X_j is the attribute value of the neighbouring feature j.

By calculating the Gi* statistic for each feature, a z-score is obtained that indicates whether the feature is part of a statistically significant hotspot (positive z-score) or a cold spot (negative z-score). The higher the absolute value of the z-score, the stronger the evidence of clustering or dispersion.

The Hot Spot Analysis using the Getis-Ord Gi* statistic helps to identify areas in Uttar Pradesh with significant concentrations of high or low vegetation cover. This analysis provides insights into the spatial patterns and distribution of vegetation across the study area, enabling the identification of regions that exhibit consistent hotspots or coldspots of vegetation cover over the 2011-2021 period.

Negative values in the dataset were treated by converting them to null or missing values. The rationale behind this conversion is to exclude negative values from the analysis, as they may not be meaningful or relevant to the research objective.

3) RESULTS AND DISCUSSION

Clusters of Hot and Cold Spots: The analysis of clusters of hot and cold spots in Uttar Pradesh reveals interesting patterns in the distribution of vegetation cover. The results indicate areas with statistically significant concentrations of high vegetation cover (hot spots) and low vegetation cover (cold spots) based on the Getis-Ord Gi* statistic (Figure 2).

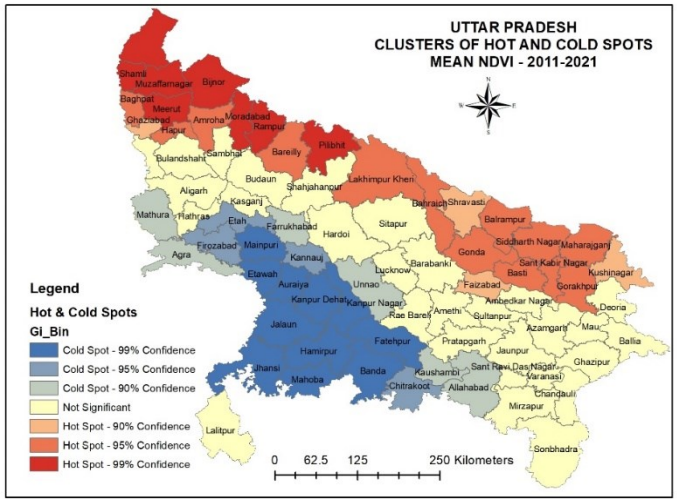
Cold spots: Several districts in Uttar Pradesh, including Auraiya, Banda, Etawah, Fatehpur, Hamirpur, Jalaun, Jhansi, Kanpur Dehat, Kanpur Nagar, Mahoba, and Mainpuri, exhibit significant cold spots of vegetation cover. These districts have consistently lower vegetation cover compared to their neighbouring areas over the 2011-2021 period. The negative values (-3) indicate a strong concentration of low vegetation cover in these districts.

Moderate cold spots: Some districts, such as Chitrakoot, Etah, Firozabad, Kannauj, Agra, Allahabad, Farrukhabad, Kaushambi, Mathura, and Unnao, demonstrate moderate cold spots with a value of -2 or -1. These districts have relatively lower vegetation cover, although not as

pronounced as the districts in the strong cold spot category.

Neutral areas: Several districts, including Aligarh, Ambedkar Nagar, Azamgarh, Ballia, Barabanki, Budaun, Bulandshahr, Chandauli, Deoria, Gautam Buddha Nagar, Ghazipur, Hardoi, Hathras, Jaunpur, Kasganj, Lalitpur, Lucknow, Mau, Mirzapur, Pratapgarh, Rae Bareli, Sant Ravi Das Nagar, Shahjahanpur, Sitapur, Sonbhadra, Sultanpur, Varanasi, Amethi, Sambhal, and Faizabad, exhibit neutral values (0) for vegetation cover. These districts do not show significant deviations from the average vegetation cover in the study area.

Hot spots: Several districts in Uttar Pradesh, including Ghaziabad, Kushinagar, Shravasti, Amroha, Baghpat, Bahraich, Balrampur, Bareilly, Basti, Gonda, Gorakhpur, Lakhimpur Kheri, Maharajganj, Sant Kabir Nagar, Siddharth Nagar, Hapur, Bijnor, Meerut, Moradabad, Muzaffarnagar, Pilibhit, Rampur, Saharanpur, and Shamli, demonstrate hot spots of vegetation cover. These districts have consistently higher vegetation cover compared to their neighboring areas over the study period. The positive values (1, 2, or 3) indicate a strong concentration of high vegetation cover in these districts.



These findings provide valuable insights into the spatial distribution of vegetation cover in Uttar Pradesh from 2011 to 2021. The identification of hot spots and cold spots helps in understanding the underlying factors influencing vegetation dynamics, such as land use practices, climate conditions, and ecological processes. This information can support targeted conservation and land management strategies in areas with low vegetation cover and highlight regions of high vegetation cover that may require protection or sustainable management to maintain ecosystem health and services.

4) CONCLUSION

In conclusion, this study conducted a hot spot analysis of vegetation cover in Uttar Pradesh from 2011 to 2021 using the Getis-Ord Gi* statistic. The analysis revealed distinct patterns of hot spots and cold spots, indicating areas with statistically significant concentrations of high and low vegetation cover, respectively.

The results identified several districts as cold spots, characterized by consistently lower vegetation cover compared to their neighbouring areas. These districts may require targeted interventions and management strategies to improve vegetation cover and promote ecological health. On the other hand, the presence of hot spots in certain districts indicated a strong concentration of high vegetation cover. These areas can serve as potential conservation priorities, as they exhibit favorable conditions for vegetation growth. Preserving and managing these hot spots can contribute to sustaining biodiversity, ecosystem services, and overall environmental well-being.

The findings of this study provide valuable insights into the spatial distribution of vegetation cover in Uttar Pradesh over the study period. Understanding the patterns and dynamics of vegetation cover is crucial for informed decision-making in land management, conservation planning, and sustainable development initiatives.

It is important to acknowledge the limitations of this study, such as the reliance on remote sensing data and the chosen analysis method. Further research and integration of ground-based data can enhance the accuracy and reliability of the findings. Nonetheless, the hot spot analysis approach applied in this study contributes to our understanding of the spatial patterns and trends of vegetation cover in Uttar Pradesh, offering valuable information for policymakers, researchers, and land managers.

By identifying areas of concern and highlighting regions of ecological significance, this study can support targeted interventions and informed decision-making to promote sustainable land management practices, conserve biodiversity, and enhance ecosystem services in Uttar Pradesh.

Conflict of Interest

The authors declare no conflict of interest in relation to this research study. The research was conducted with the sole objective of contributing to the scientific understanding of geostatistical analysis of the Normalized Difference Vegetation Index (NDVI) in Uttar Pradesh. The analysis, interpretation, and conclusions presented in this paper are based on objective scientific principles and rigorous data analysis methods. The authors have no financial, personal, or professional relationships that could influence the research findings or introduce bias in the study. Furthermore, no external funding or sponsorship was received that could potentially influence the outcome or interpretation of the research. The authors have followed ethical guidelines and scientific integrity throughout the research process to ensure transparency, accuracy, and impartiality in the findings and conclusions presented.

Data Declaration

The data used in this research study is obtained from reliable and publicly available sources. The primary dataset utilized for the analysis is the ".MOD13C2_006_CMG_0_05_Deg_Monthly_NDVI" dataset, which provides monthly Normalized Difference Vegetation Index (NDVI) values at a spatial resolution of 0.05 degrees. This dataset is widely recognized and accepted in the scientific community for vegetation monitoring and analysis.

REFERENCES

1) Bala, G., Caldeira, K., Wickett, M., et al. 2010. Combined climate and carbon-cycle effects of large-scale deforestation. Proceedings of the National Academy of Sciences, 107(16), 7242-7247.
2) Chave, J., Andalo, C., Brown, S., et al. 2014. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 145(1), 87-99.
3) Foley, J.A., DeFries, R., Asner, G.P., et al. 2005. Global consequences of land use. Science, 309(5734), 570-574.
4) Hansen, M.C., Potapov, P.V., Moore, R., et al. 2013. High-resolution global maps of 21st-century forest cover change. Science, 342(6160), 850-853.
5) Liu, J., Hull, V., Batistella, M., et al. 2018. Framing sustainability in a telecoupled world. Ecology and Society, 23(1), 36.
6) Tucker, C.J., Pinzon, J.E., Brown, M.E., et al. 2005. An extended AVHRR 8-km NDVI dataset compatible with MODIS and SPOT vegetation NDVI data. International Journal of Remote Sensing, 26(20), 4485-4498.
7) Mishra, A.K., Mohanty, S., Mishra, A., et al. 2019. Vegetation mapping and analysis of temporal dynamics in Uttar Pradesh using remote sensing and GIS techniques. International Journal of Environmental Science and Technology, 16(10), 6327-6342.
8) Roy, A., Roy, D.P., & Joshi, P.K. 2017. Remote sensing of vegetation and land-cover change in India during 1981–2014: A systematic review. International Journal of Remote Sensing, 38(8-10), 2630-2653.
9) Agarwal, A., Nagendra, H., & Ghate, R. 2018. Understanding the relationship between urbanization and land surface temperature in rapidly urbanizing regions using remote sensing. Sustainable Cities and Society, 40, 283-295.
10) Bandyopadhyay, S., Bhattacharya, A., & Mukhopadhyay, A. 2016. Spatio-temporal analysis of urbanization using remote sensing and GIS techniques: A case study of Kolkata, India. The Egyptian Journal of Remote Sensing and Space Science, 19(1), 77-88.
11) Singh, S.K., Khan, M.L., & Tripathi, R.S. 2016. Assessing the land use/land cover changes and urban sprawl in Lucknow city using remote sensing and GIS techniques. Journal of the Indian Society of Remote Sensing, 44(1), 131-141.
12) Huete, A.R. 1988. A soil-adjusted vegetation index (SAVI). Remote Sensing of Environment, 25(3), 295-309.
13) Pettorelli, N., Vik, J.O., Mysterud, A., et al. 2005. Using the satellite-derived NDVI to assess ecological responses to environmental change. Trends in Ecology & Evolution, 20(9), 503-510.
14) Getis, A., & Ord, J.K. 1992. The analysis of spatial association by use of distance statistics. Geographical Analysis, 24(3), 189-206.
15) Ord, J.K., & Getis, A. 2010. Local spatial autocorrelation statistics: Distributional issues and an application. Geographical Analysis, 27(4), 286-306.
16) Census of India. 2011. Population Enumeration Data (Final Population). Retrieved from http://www.censusindia.gov.in/2011census/population_enumeration.html
17) Gupta, S. 2018. Physical Geography of Uttar Pradesh. In M. R. Islam, A. Zakaria, & D. R. De (Eds.), Land Resources and Agriculture in India (pp. 73-86). Springer.
18) Uttar Pradesh Tourism. (n.d.). Destinations. Retrieved from https://www.up-tourism.com/destinations/index.html
19) Singh, R. K., & Kumar, P. 2017. Role of Agriculture in Economic Development: A Study of Uttar Pradesh. International Journal of Economic Research, 14(11), 327-339.
20) Directorate of Economics and Statistics, Uttar Pradesh. 2015. Agro Climatic Zone Wise Rainfall Distribution. Retrieved from http://des.up.nic.in/index1_files/Page1879.htm
21) MODIS Land Team. 2015. MOD13C2 MODIS/Terra Vegetation Indices Monthly L3 Global 0.05Deg CMG V006. NASA EOSDIS Land Processes DAAC. https://doi.org/10.5067/MODIS/MOD13C2.006