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RESEARCH ARTICLE

Spatial pattern and hot spots of vegetation change in Uttar Pradesh during 2001 to 2021

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ABSTRACT

This study focuses on analyzing the spatial pattern and hot spots of vegetation change in Uttar Pradesh from 2001 to 2021. The analysis was conducted using spatial autocorrelation and hot spot analysis techniques. The data source used for the study was the "MOD13C2_006_CMG_0_05_Deg_Monthly_NDVI" dataset. The spatial autocorrelation analysis employed Moran's Index to examine the spatial clustering of vegetation change. The results indicated a positive spatial autocorrelation, suggesting the presence of clustered patterns in the vegetation change across the study area. The hot spot analysis, utilizing the Getis-Ord Gi* statistic, identified districts as hot spots and cold spots of vegetation change. These areas exhibited significantly higher or lower rates of vegetation change compared to neighbouring regions.

The findings of this study provide valuable insights into the spatial dynamics of vegetation cover in Uttar Pradesh. The identification of hot spots and cold spots helps in understanding the areas with the highest rates of vegetation change and highlights the need for targeted conservation and management efforts. These results can inform policymakers, land managers, and conservationists in developing strategies for sustainable land use practices and ecosystem preservation.

Key words: NDVI, Getis-Ord Gi* statistic, Moran's Index

1) INTRODUCTION

Alternaria Vegetation plays a crucial role in maintaining ecological balance and providing various ecosystem services [1]. Monitoring and understanding the spatial patterns of vegetation change are essential for effective land management and conservation efforts [2]. Uttar Pradesh, one of the most populous states in India, has undergone significant land use changes over the past few decades [3]. Assessing the spatial patterns and identifying hot spots of vegetation change in Uttar Pradesh can provide valuable insights into the dynamics of its natural resources and help guide sustainable development practices [4]. This study aims to investigate the spatial pattern and hot spots of vegetation change in Uttar Pradesh during the period of 2001 to 2021.

Spatial pattern analysis is a fundamental tool for examining the distribution and arrangement of features across a landscape [5]. Moran's Index is a widely used spatial autocorrelation technique that measures the degree of spatial clustering or dispersion of a variable [6]. By applying Moran's Index to vegetation data, we can assess the spatial autocorrelation and identify areas with similar vegetation characteristics [7]. This analysis will enable us to determine whether vegetation change in Uttar Pradesh exhibits a spatial pattern during the study period.

The objectives of this study are as follows:

1. To assess the spatial pattern of vegetation change in Uttar Pradesh during the period of 2001 to 2021 using Spatial Autocorrelation Moran's Index.
2. To identify hot spots and cold spots of vegetation change in Uttar Pradesh using Getis-Ord Gi* statistics.

By achieving these objectives, this study aims to enhance our understanding of the spatial and temporal dynamics of vegetation change in Uttar Pradesh, identify areas with significant ecological transformations, and contribute to informed land management strategies and sustainable development in the region.

2) MATERIALS AND METHODS

Study area: Uttar Pradesh, located in northern India, serves as the study area for this research [8]. It is the most populous state in India [9] and is known for its rich cultural heritage and diverse landscapes [10].

Uttar Pradesh is characterized by a variety of landforms, including the Gangetic plains in the north, the Vindhya Range in the south, and the foothills of the Himalayas in the northwest [11]. The state encompasses a wide range of ecosystems, from fertile agricultural lands to dense forests and wetlands [12].

It exhibits a diverse climatic regime, with hot summers and cool winters [13]. The major rivers flowing through Uttar Pradesh, such as the Ganges and Yamuna, provide essential water resources for agriculture and support the ecological balance of the region [14].

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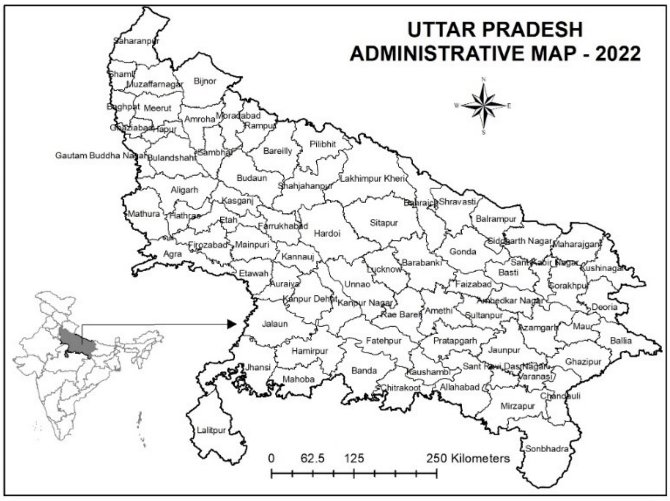

Figure 1: Study Area

Data Source: The data source used in this study is the MOD13C2_006_CMG_0_05_Deg_Monthly_NDVI dataset [15]. This dataset, derived from the MODIS Terra and Aqua satellites, provides monthly Normalized Difference Vegetation Index (NDVI) measurements at a spatial resolution of 0.05 degrees. The MOD13C2 dataset is widely utilized in remote sensing and ecological studies to monitor vegetation dynamics over time [16].

The MOD13C2_006_CMG_0_05_Deg_Monthly_NDVI dataset offers valuable information on vegetation greenness and vigor, with NDVI values ranging from -1 to 1. These values enable the assessment of vegetation cover and health, with higher values indicating denser and healthier vegetation. By analyzing the monthly NDVI values, researchers can study changes in vegetation cover, identify hotspots of vegetation activity, and monitor the health and productivity of ecosystems.

***Data Analysis*:** The data analysis in this study involved the application of two methods: spatial autocorrelation using Moran's Index and Hot Spot Analysis (Getis-Ord Gi*). These methods provided insights into the spatial patterns and clustering of vegetation cover in Uttar Pradesh.

Spatial Autocorrelation using Moran's Index: Spatial autocorrelation is a statistical technique used to measure the degree of similarity or dissimilarity between spatially adjacent features. In this study, Moran's Index was employed to assess the spatial autocorrelation of vegetation cover in Uttar Pradesh. Moran's Index formula is as follows:

$$I = (n * \sum(i=1 \text{ to } n) \sum(j=1 \text{ to } n)\ wij(xi - \bar{x})(xj - \bar{x})) / (\sum(i=1 \text{ to } n)(xi - \bar{x})^2 * \sum(i=1 \text{ to } n) \sum(j=1 \text{ to } n)\ wij)$$

Please note that in these formulas, "n" represents the number of observations, "xi" and "xj" represent the values of the variable at locations "i" and "j" respectively, "wij" represents the spatial weights between locations "i" and "j", "x̄" represents the mean of the variable, and "s" represents the standard deviation of the variable.

Moran's Index ranges from -1 to 1, where positive values indicate positive spatial autocorrelation (similar values clustered together), negative values indicate negative spatial autocorrelation (dissimilar values clustered together), and values close to 0 indicate no spatial autocorrelation (random distribution) [17].

Hot Spot Analysis (Getis-Ord Gi):* Hot Spot Analysis, also known as spatial clustering analysis, helps identify statistically significant clusters of high or low values in a spatial dataset. In this study, the Getis-Ord Gi* statistic was used to identify hot spots and cold spots of vegetation cover in Uttar Pradesh. The formula for the Getis-Ord Gi* statistic is as follows:

$$Gi^* = (\sum(j=1 \text{ to } n)\ wij*xj - \bar{x} * \sum(j=1 \text{ to } n)\ wij) / (s * \sqrt{((\sum(j=1 \text{ to } n)\ wij^2)/n - ((\sum(j=1 \text{ to } n)\ wij)/n)^2)})$$

The Getis-Ord Gi* statistic produces a z-score for each spatial unit, indicating whether it is a statistically significant hot spot (positive z-score) or a cold spot (negative z-score) of vegetation cover. The magnitude of the z-score reflects the strength of the clustering pattern [18]

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

Vegetation Change: The vegetation change analysis reveals the extent of change in vegetation cover across different districts in Uttar Pradesh. The values represent the magnitude of vegetation change, with positive values indicating an increase in vegetation cover and negative values indicating a decrease.

Among the districts, Auraiya shows the highest vegetation change with a value of 0.057326, followed by Etawah with 0.064854 and Mainpuri with 0.055286. These districts have experienced significant positive changes in vegetation cover during the study period.

On the other hand, districts like Baghpat, Bulandshahr, and Gautam Buddha Nagar have relatively negative vegetation change values.

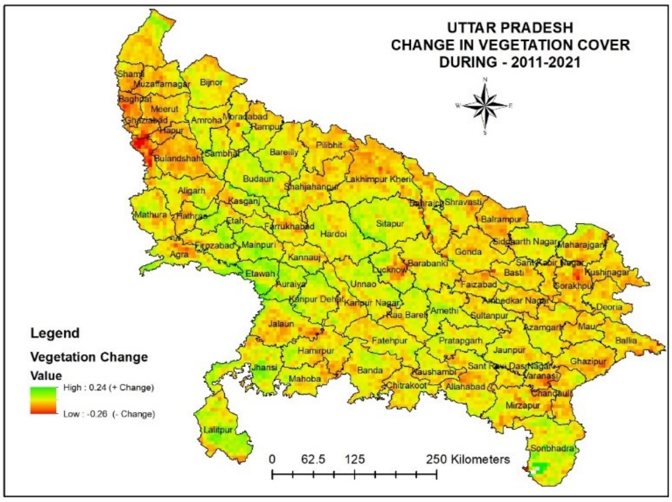

Figure 2: Vegetation Change

Spatial Pattern of Vegetation Change: The spatial pattern analysis of vegetation change in Uttar Pradesh reveals a highly significant and clustered pattern. The z-score of 9.89 indicates that the observed pattern is extremely unlikely to occur by random chance, with a p-value of less than 1%.

Moran's Index is a measure of spatial autocorrelation that quantifies the degree of similarity or dissimilarity between neighboring areas. In this case, the Moran's Index is calculated to be 0.56. This positive value suggests a strong positive spatial autocorrelation, indicating that areas with similar vegetation change values are clustered together in space.
The Expected Index of -0.013514 represents the average value expected under the assumption of spatial randomness. The positive difference between the observed Moran's Index and the Expected Index suggests that there is a spatial clustering of similar vegetation change values beyond what would be expected by chance.
The Variance of 0.003320 provides information about the variability of vegetation change values among neighbouring areas. A lower variance indicates that neighbouring areas have more similar vegetation change values, contributing to the observed spatial pattern.
Overall, the results indicate a significant and clustered spatial pattern of vegetation change in Uttar Pradesh. This suggests that there are localized areas where vegetation is undergoing similar changes, which could be influenced by common environmental factors or human activities. The findings provide valuable insights into the spatial dynamics of vegetation change and can inform targeted conservation and land management strategies in the region.

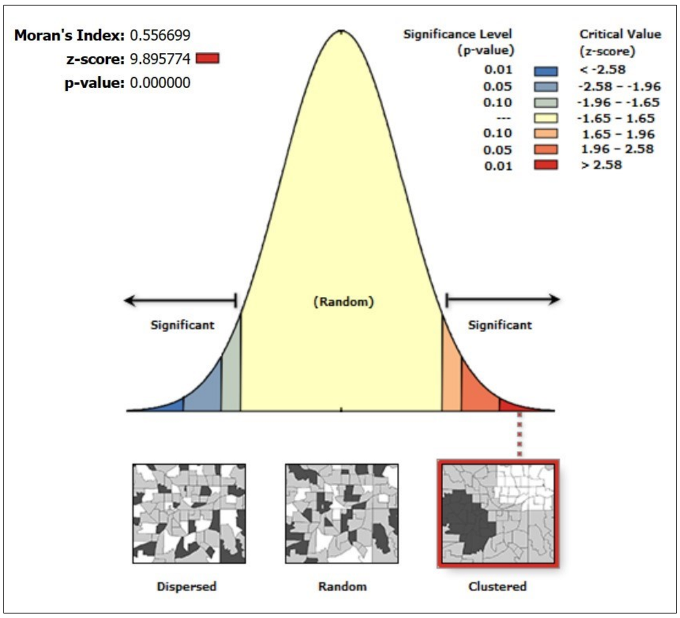

Figure 3 Spatial Autocorrelation

Hot spots of Vegetation Change: The analysis of hot spots of vegetation change in Uttar Pradesh reveals spatial clusters of significant changes. In this analysis, negative values indicate hot spots of negative change, representing areas with higher rates of vegetation decrease, while positive values indicate cold spots, representing areas with vegetation increase.
Among the districts analyzed, several hot spots were identified, where negative vegetation change rates were significantly higher. These hot spots include Auraiya, Amroha, Baghpat, Bulandshahr, Gautam Buddha Nagar, Ghaziabad, Meerut, Muzaffarnagar, Sambhal, and Shamli.

Among the districts analyzed, several cold spots were identified. These districts experienced significant positive changes in vegetation. They include Auraiya, Etah, Etawah, Farrukhabad, Jalaun, Kannauj, Kanpur Dehat, Lalitpur, Mainpuri, and parts of Agra, Kanpur Nagar, Kasganj, and Lucknow.
These hot spots and cold spots provide valuable insights into the spatial distribution of vegetation change in Uttar Pradesh. They highlight areas where targeted conservation efforts or land management strategies may be required to address the significant changes in vegetation cover.

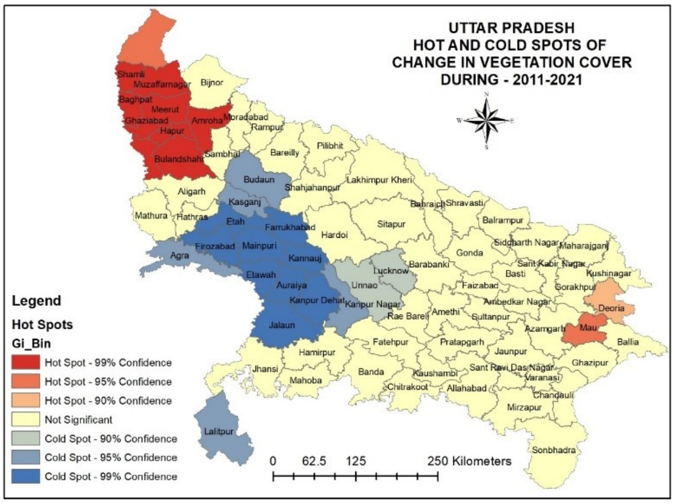

Figure 4: Hot spots of Vegetation Change

4) CONCLUSION

In conclusion, the analysis of vegetation change in Uttar Pradesh from the year 2001 to 2021 using spatial autocorrelation and hot spot analysis techniques has provided valuable insights into the spatial patterns and hot spots of vegetation change in the region. The results indicate significant spatial clustering of vegetation change, with distinct hot spots and cold spots identified.
The spatial autocorrelation analysis using Moran's Index revealed a significant positive spatial autocorrelation of vegetation change, indicating the presence of clustered patterns across the study area. This suggests that areas with similar vegetation change rates tend to be located near each other, indicating the influence of underlying spatial processes on vegetation dynamics.
Furthermore, the hot spot analysis using the Getis-Ord Gi* statistic identified specific districts as hot spots and cold spots of vegetation change. These areas exhibited significantly higher or lower rates of vegetation change compared to the surrounding regions. This information is crucial for understanding the spatial distribution of vegetation change and can aid in identifying priority areas for conservation efforts, resource allocation, and land management strategies.
The findings of this study contribute to our understanding of the spatial dynamics of vegetation cover in Uttar Pradesh and provide valuable information for policymakers, land managers, and conservationists. By identifying areas with high rates of vegetation change, conservation efforts can be targeted towards these regions to preserve and restore ecosystems, mitigate the impacts

of land degradation, and promote sustainable land use practices.

However, it is important to note that the analysis is based on remote sensing data and spatial statistical techniques, and additional field validation and on-the-ground studies are recommended to further validate and refine the findings. Nonetheless, the results obtained from this study provide a solid foundation for future research and decision-making processes aimed at preserving and managing the vegetation resources in Uttar Pradesh.

Conflict of Interest: The author declares 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 author has 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 author has followed ethical guidelines and scientific integrity throughout the research process to ensure transparency, accuracy, and impartiality in the findings and conclusions presented.

Data Dealation: 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.

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