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Spatio-temporal variability of NDVI over Indian continents

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Abstract

The significance of the Normalized Difference Vegetation Index (NDVI) variations in India lies in its implications for ecosystem health, agricultural productivity, and climate change monitoring.This study aims to assess the NDVI patterns across India with different spatial/temporal scales. The spatial and temporal NDVI variations were examined through geospatial methods using satellite data from Moderate Resolution Imaging Spectroradiometer (MODIS) from 2000 to 2010 across India. It was discovered that the time series of India's annual averaged NDVI from 2001 to 2010 shows a positive trend with a slope of 0.003/yr. It also suggests that NDVI values were lower in arid regions like Rajasthan and Gujarat, while they were greater in the western Himalayas, north-eastern states, and coastal areas. The study also found that, as a result of increased vegetation growth, NDVI values increased during the monsoon months (June to September) and declined during the dry winter months. It has also been discovered that changes in land use and cover, along with variations in temperature and rainfall, have a major influence on NDVI patterns. The understanding of the spatial and temporal variation of NDVI over the Indian climate region is crucial for ecosystem management, agricultural planning, and climate change mitigation. The findings of this study can serve as a valuable reference for policymakers, land managers, and researchers working towards sustainable land use practices, conservation efforts, and climate adaptation strategies in India.

1. Introduction

The Indian subcontinent, encompassing India, Pakistan, Bangladesh, and Nepal, is a region of immense ecological and environmental significance. With a diverse range of ecosystems, including tropical forests, grasslands, and arid deserts, the region supports a vast array of plant and animal species (Champion and Seth, 1968). Vegetation, a critical component of these ecosystems, plays a vital role in regulating the climate, maintaining soil health, and supporting biodiversity (IPCC, 2013).

The Normalized Difference Vegetation Index (NDVI), a widely used remote sensing-based indicator, provides a valuable tool for monitoring vegetation health and dynamics (Tucker, 1979). NDVI is a measure of the difference between the reflectance of near-infrared and red light, which is sensitive to the presence and condition of vegetation (Huete et al., 2002). By analyzing the NDVI data, researchers can gain insights into the spatio-temporal patterns of vegetation growth, phenology, and productivity (Myneni et al., 1997).

The Indian subcontinent is characterized by a complex and dynamic climate, with significant seasonal and inter-annual variations in temperature, precipitation, and other environmental factors. These variations can profoundly impact vegetation growth and productivity, leading to changes in ecosystem function and services. Understanding the spatio-temporal variability of NDVI over the Indian subcontinent is essential for assessing the impacts of climate change, land use change, and other environmental factors on vegetation and ecosystems (Rosenzweig et al., 2007).

Several studies have investigated the spatio-temporal variability of NDVI over specific regions of the Indian subcontinent, such as the Indo-Gangetic Plain (Singh et al., 2017) and the Western Ghats (Ramesh et al., 2017). However, a comprehensive analysis of the spatio-temporal variability of NDVI over the entire Indian subcontinent is still lacking.

This study aims to investigate the spatio-temporal variability of MODIS NDVI over the Indian subcontinent, from 2000 to 2010 using a combination of remote sensing and statistical techniques. By analyzing NDVI data from multiple satellite sensors this study seeks to provide new insights into vegetation dynamics and ecosystems in this critical region.

2. Data and Methodology

The study analyzed NDVI data from February 2000 to December 2010, using the MODIS satellite, which has been in orbit since February 2000, to provide NDVI datasets at various temporal and spatial scales. Specifically, the study utilized the monthly average NDVI data product

(MOD13C2) with a spatial resolution of 0.05 degrees (Didan 2015). The MODIS NDVI product is recognized for its reliability and suitability in illustrating long-term vegetation changes across large regional scales due to its geographical-temporal resolution, time duration, and consistent on-orbit status (Sun et al. 2015).

In remote sensing, the linear regression approach is a common statistical technique for assessing temporal fluctuations in NDVI data. NDVI, a widely-used vegetation index, measures the "greenness" or health of vegetation by evaluating the reflectance of red and near-infrared (NIR) light bands. In studies of temporal variation, linear regression fits a straight line (linear model) to the NDVI values over time, revealing the trend of NDVI changes during the period of interest. The slope of the line indicates the rate of NDVI change and whether the trend is increasing or decreasing, while the intercept represents the baseline NDVI value at a specific time point.

3. Result and discussion

3.1 Temporal variation of NDVI from 2000 to 2010

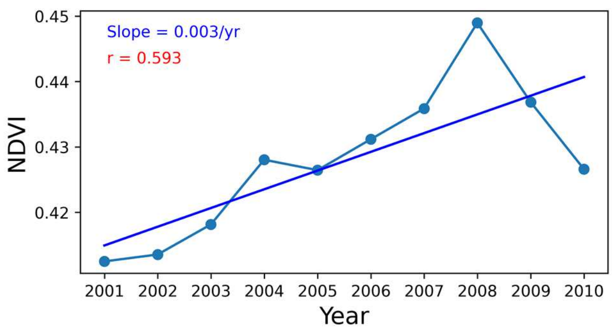

Figure 1. Time series of annual averaged NDVI over India. The line illustrates the NDVI's linear fit across the time series from 2000 to 2010. The text on the upper left labels the inter-annual growth rate and correlation coefficients.

Figure 1 shows the time series of India's annual average NDVI from 2001 to 2010. The trend line shows a positive linear relationship between NDVI and year, with a slope of 0.003/yr and a correlation coefficient of 0.593. This indicates that NDVI has been increasing over time, suggesting a general greening trend in India's vegetation over this period. The NDVI values show fluctuations from year to year, reflecting inter-annual variability. These changes could be due to various factors such as climatic conditions, land use changes, agricultural practices, and natural disasters. The peak NDVI observed around 2009 suggests a particularly favorable year for vegetation growth, possibly due to favorable climatic conditions or successful agricultural practices during that period. The positive trend in NDVI could be attributed to several factors, including increased rainfall, improved agricultural methods, and reforestation and afforestation efforts. Figure 2. shows that the NDVI has been increasing in all four seasons, with the strongest increase during the monsoon season (slope = 0.0040/yr, r = 0.632). It has also been rising in the post-monsoon season (slope = 0.0044/yr, r = 0.669), summer season (slope = 0.0024/yr, r = 0.426), and winter season (slope = 0.0038/yr, r = 0.631). Each season displays inter-annual variability, with year-to-year fluctuations in NDVI values. This variability can be attributed to changes in climatic conditions, agricultural practices, and natural events like droughts or floods. The post-monsoon season Figure 2 (c) shows the highest correlation coefficient, indicating the most consistent positive trend, while the summer season Figure 2 (a) shows the least consistent trend.

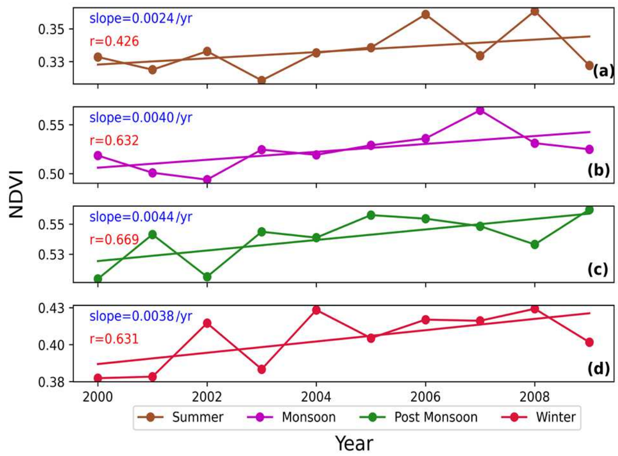

Figure 2. Time series of seasonal averaged NDVI over India during the (a) summer, (b) monsoon, (c) post-monsoon, and (d) winter seasons. The line illustrates the NDVI's linear fit across the time series from 2000 to 2010. The text on the upper left labels the inter-annual growth rate and correlation coefficients.

3.2. Spatial distribution of NDVI trend

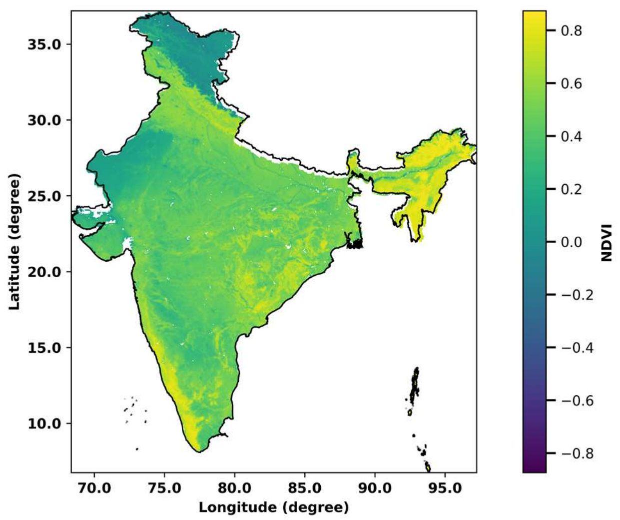

Figure 3. Spatial distribution of the average NDVI over India from 2000-2010.

Figure 3. illustrates the average spatial distribution of NDVI over India from 2000 to 2010, using a color gradient where yellow denotes denser vegetation and purple denotes sparse vegetation or bare terrain. Higher NDVI values,

shown in yellow to green, are primarily found in the northeastern states, parts of the Western Ghats, and northern India, including the Himalayan foothills with extensive forest cover. Central and southern India exhibit moderate NDVI values, indicated by green shades, representing mixed vegetation and agricultural land. Lower NDVI values, shown in darker green to purple, are present in parts of Gujarat, Rajasthan, and the Deccan Plateau in northwest India, characterized by semi-arid and arid conditions, sparse vegetation, and desert landscapes. The NDVI spatial distribution is influenced by climate and geography, with higher values in regions of high rainfall and favorable climates and lower values in drier, harsher climatic areas.

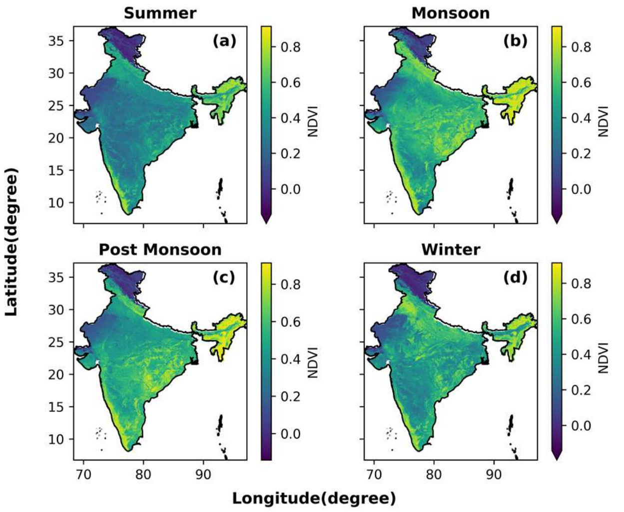

Figure 4. Spatial distribution of the seasonal NDVI trend over India during (a) Summer, (b) Monsoon, (c) post-monsoon, and (d) Winter seasons over the period 2000-2010.

Figure 4 shows the spatial distribution of seasonal NDVI, which was found highest during the monsoon season and lowest during winter. The heavy rainfall during the monsoon season promotes plant growth, while the dry and cold winter inhibits it. NDVI peaks in northern India during the monsoon due to the highest rainfall in this region. It is also relatively high in southern India, attributed to the dense evergreen forests. Conversely, NDVI is lowest in western India during the monsoon, as it is a desert region with minimal rainfall. During winter, the lowest NDVI is in northern India due to the harsh cold and dry conditions, while it is relatively low in southern India because of the high density of deciduous forests.

4. Conclusion

The NDVI time series from 2000 to 2010 shows a positive trend in vegetation health across India. This trend has a moderate correlation, indicating a consistent increase over the observed period. Inter-annual variability highlights the influence of environmental and anthropogenic factors on vegetation. Similarly, seasonal NDVI data from 2000 to 2010 reveal positive trends in vegetation health across all seasons. The most significant improvements are observed during the monsoon and post-monsoon periods. Moderate to strong correlation coefficients indicate that these trends are consistent and significant, emphasizing the importance of seasonal climatic factors in driving vegetation health.

The spatial distribution of average NDVI in India from 2000 to 2010 shows significant regional variations due to climatic conditions, geography, and human activities. High NDVI values are present in regions with dense forest cover and favorable climates, while low values are found in arid and semi-arid areas. Seasonal NDVI trends highlight the monsoon's strong influence on vegetation, significantly boosting coverage in the northern, eastern, and central regions. Vegetation markedly declines during the summer and winter, showing seasonal variability. The northern and north-eastern areas consistently maintain higher vegetation cover across all seasons.

6. Acknowledgements

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