J. Mountain Res. P-ISSN: 0974-3030, E-ISSN: 2582-5011 DOI: https://doi.org/10.51220/jmr.v21-i1.5
Vol. 21(1), (2026) 41-48

# Urban Green Spaces for Sustainable Development: A Spatio-Temporal NDVI Analysis of Dehradun City (2004-2024)

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**Received: 26.03.2026; Revised: 15.05.2026; Accepted: 22.05.2026**


**Abstract:** Ever-increasing rate of urbanization across the globe has apparently transformed land use patterns, often resulting in the Urban Green Spaces (UGS) reduction and increased ecological stress within cities. Urban Green Spaces (UGS) play a crucial role in promoting environmental sustainability by mitigating urban heat island effects, improving air quality, enhancing biodiversity and contributing to human well-being. In rapidly developing countries like India, accelerated urban expansion has intensified pressure on vegetated land, particularly in medium sized and emerging cities experiencing unplanned growth. Dehradun, the capital city of Uttarakhand, has undergone extensive urban expansion over the past two decades, with increase in built-up area and major decline in vegetation and agricultural area, especially following its recognition as the state capital in 2000. This study evaluates the spatial and temporal changes in urban green cover between 2004 and 2024 using NDVI derived from multi-temporal satellite imagery. By analyzing NDVI values over two decades, the study quantifies vegetation trends and examines their relationship with expanding built-up areas. The findings seek to provide empirical evidence emphasizing the urgency of strengthening urban green space planning to support sustainable urban development in Dehradun.

**Keywords:** Urban Expansion • NDVI • Sustainable Development • Urban Greenspaces

## Introduction

Urbanization results in an increasing proportion of the population living in cities. The urban population of the world has grown rapidly from 751 million in 1950 to 4.2 billion in 2018. Together, India, China and Nigeria will account for 35% of the projected growth of the world's urban population between 2018 and 2050. By 2050, it is projected that India will add 416 million urban dwellers by 2050 (United Nations Department of Economic and Social Affairs, 2018. Due to increasing urban population, cities in India have experienced rapid spatial expansion. Large towns and cities are experiencing a constant high rate of growth in their population, and as a result unplanned and uncontrolled expansion of settlements at the densely populated sites occurs. These rapidly expanding centers affect the natural environment of an area, creating more ecological stress (Sangwan et al 2023).

Dehradun, capital of Uttarakhand, has undergone rapid changes in its land use patterns following its designation as the state capital in 2000. As per census 2011 the urban population of state of Uttarakhand is 30.5 Lakh including cantonments & census towns. The overall urbanization rate, which is around 30.2%, of Uttarakhand is comparable with the national average of 31.2%. The population growth rate varies across districts and urban areas. However, it is noteworthy that average annual urban growth rate of 4.0% is much high compared to rural growth rate 1.2% of the state (Urban Development directorate, Government of Uttarakhand). Ever since Dehradun has been recognized as the capital of the state of Uttarakhand, there has been boom in its population Increasing demand for housing and infrastructure has led to large scale conversion of vegetated land into built-up surfaces which has led to the conversion of vegetated land to build up surfaces. Even

though the efforts for sustainable development, Dehradun city is facing substantial loss of trees (Bist 2022).

Urban living limits access to nature and can increase exposure to certain environmental hazards, such as air and noise pollution. Many urban areas face increasing pressure from expanding populations, limited resources and growing impacts of climate change. These challenges must be addressed in order for cities to provide healthy and sustainable living environments. Substantial impact of urbanization is seen on the green spaces where large scale encroachment on the agricultural and vegetated land leads to ecological deterioration (Jana et al 2020). Urban Green spaces (UGS) and other nature-based solutions offer innovative approaches to increase the quality of urban settings, enhance local resilience and promote sustainable lifestyles, improving both the health and the well-being of urban residents. Urban Green Spaces (UGS) provide health, societal, ecological, economic and planning related advantages to human society (Sangwan et al 2023). Urban Green Spaces constitute a part of the SDG 11 (Make cities and human settlements inclusive, safe, resilient and sustainable); target 11.7 (provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities). The significance of Urban Green Spaces (UGS) and the standards for the provision of healthy and sustainable environment needs immediate attention in the urban area (Kamble et al 2022).

**Study Area**

Dehradun is the capital city of the State of Uttarakhand, India. It extends from 30°01' N and 30°28'N Latitude to 77°34' E and 78°18'E Longitude. Dehradun is situated between the middle Himalayas and the Shiwalik hills to the north and south respectively (Fig 1).

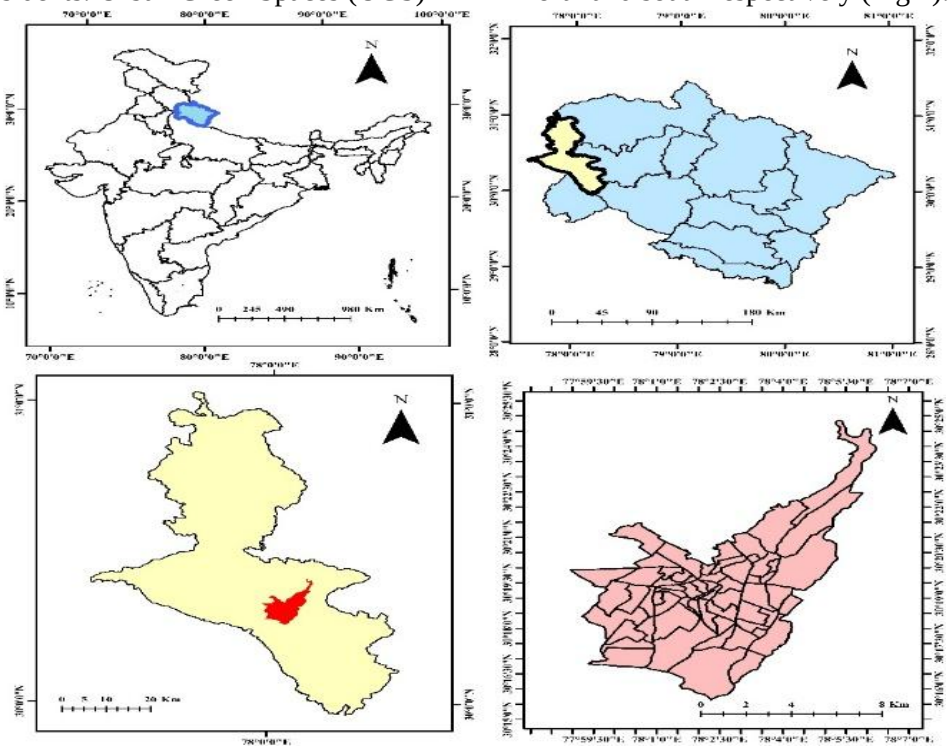

**Fig1: Location Map of Dehradun City**

**Data & Methodology**

Remote sensing and Geographic Information System (GIS) are important tools to study the landscape change detection over spatial as well as temporal scale. It is very useful for the extraction of information such as built-up area, open green spaces, urban land use mapping (Gupta & Goyal 2014). Satellite imagery was obtained from USGS Earth Explorer (earthexplorer.usgs.gov). For 2004, Satellite

image is collected from Landsat 7 ETM+ (2004/11/04) with spatial resolution of 30m. For 2024, Satellite image is collected from Landsat 8 OLI (2024/12/05) with spatial resolution of 30m. Projection Details of the satellite images used are UTM Zone 44N, WGS 84 (Table 1).

**Table 1: Details of the Satellite Data used for LULC and NDVI change detection**

| Year | Satellite | Sensor | Path/Row | Acquisition Date |
|---|---|---|---|---|
| 2004 | Landsat 7 | ETM+ | 146/039 | 04/11/2004 |
| 2024 | Landsat 8 | OLI/TIRS | 146/039 | 05/12/2024 |

The Land Use/Land Cover (LULC) classification was carried out using Supervised Classification Technique based on Maximum Likelihood method. Land use categories taken are Built-up area, Vegetation, Agricultural land and Barren Land. Accuracy assessment was done using confusion matrix and Kappa coefficient. The overall classification accuracy achieved was 88% with a Kappa Coefficient of 0.82 indicating satisfactory classification performance.

**NDVI (Normalized Difference Vegetation Index):**

NDVI is one of the most widely used spectral indices for assessing vegetation cover and health using remotely sensed satellite imagery. It is computed as the ratio of near-infrared band (NIR) to the red (R) band of the Landsat image (Jana et al 2020).In urban environments, NDVI serves as an effective indicator for identifying variations in green cover and monitoring the impact of land use changes on vegetation distribution. (Kamble et al 2022) studied the temporal changes in the green cover of Ranchi city using NDVI for 2010 and 2020. (Ahmad et al., 2024) assessed the NDVI of Delhi city, using the Landsat-9 data. (Albawwab & Ansari 2024) studied the NDVI of Nagpur city, and emphasized on the reduction of green cover, and need for incorporating UGS in the urban planning frameworks. In the present study, NDVI was employed to evaluate the spatio-temporal changes in vegetation cover in Dehradun city between 2004 and 2024 in response to expanding built-up areas. Landsat 7 ETM+ (2004) and Landsat 8 OLI (2024) satellite imageries were used for the present study. Landsat Level-2 Surface Reflectance products were utilized for NDVI computation in order to ensure radiometric consistency across the temporal dataset. NDVI was calculated using standard formula:

$$NDVI = \frac{NIR-Red}{NIR+Red}$$

NDVI values ranges from +1 to -1, where higher positive values indicate denser and healthier vegetation cover, while lower values represent sparse or non-vegetated surfaces.

**Results & Discussion**

Land use Land cover (LULC) analysis disseminate significant insights into the spatial transformation of urban landscapes over time. Rapid Urbanization often leads to major transformation in land cover characteristics, particularly through the conversion of vegetated surfaces into built-up areas, resulting into the increased temperatures of urban areas, biodiversity loss as well as environmental degradation. To accommodate the escalating urban population, the barren and the vegetated lands are converting into built-up areas and concrete jungle is seen everywhere(Agarwal et al 2018). In the case of Dehradun city, accelerated urban growth over the past two decades has resulted in major changes in land use patterns, especially in terms of expansion of built-up areas at the cost of vegetation and open land. The comparative assessment of LULC categories between 2004 and 2024 (Fig 2) indicates a substantial increase in built-up area, accompanied by a corresponding decline in vegetated and agricultural land. The results show the intensifying pressure of built-up area on the declining green cover including agricultural

fields and dense vegetation. Due to unplanned urban expansion, the city of Dehradun has undergone environmental deterioration especially in terms of vegetative area (Gupta & Goyal, 2014).

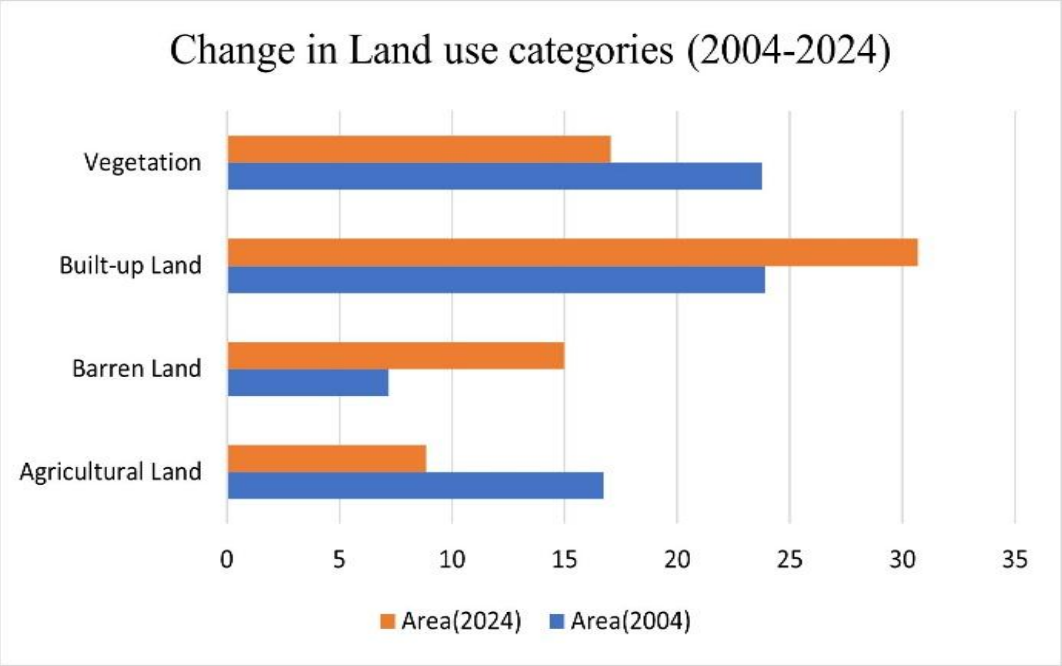


**Fig 2: Comparative LULC change analysis over two decades (2004-2024)**

While LULC analysis highlights the quantitative transformation of land categories, it does not capture the variations in vegetation density and health within these classes. Therefore, NDVI analysis was carried out to evaluate the spatio-temporal changes in vegetation cover in Dehradun city between 2004 and 2024 and to understand the implications of increasing built-up area on urban green spaces.

For the year 2004, NDVI was derived from Landsat-7 ETM+ imagery using band 4 (Near Infrared) and band 3 (Red). For 2024, Landsat-8 OLI imagery was used for NDVI computations, taking band 5 (Near Infrared) and band 4 (Red). The NDVI measures the vegetation greenness, and is calculated as the ratio between the near- infrared (NIR) band and red (R) band(Jana et al., 2020). The NDVI classes were categorized as very sparse vegetation (including areas having built-up areas or bare soil), sparse vegetation (including areas with agricultural fallow land, open scrub or fragmented green patches), moderate vegetation (including areas having mixed vegetation patches, agricultural field or plantation area) and dense vegetation (including area having dense tree cover, forest patches).

For 2004, the NDVI values ranged from 0.06 to 0.80 indicating the presence of vegetation cover ranging from sparse grasslands and open scrubs to moderately dense vegetation and forest patches within Dehradun city. For 2024, the NDVI values ranged from -0.02 to 0.40, indicating a shift towards predominantly non-vegetated and sparsely vegetated surfaces across Dehradun city, with limited presence of moderately vegetated regions, and almost nonexistent forest patches (Fig 3).

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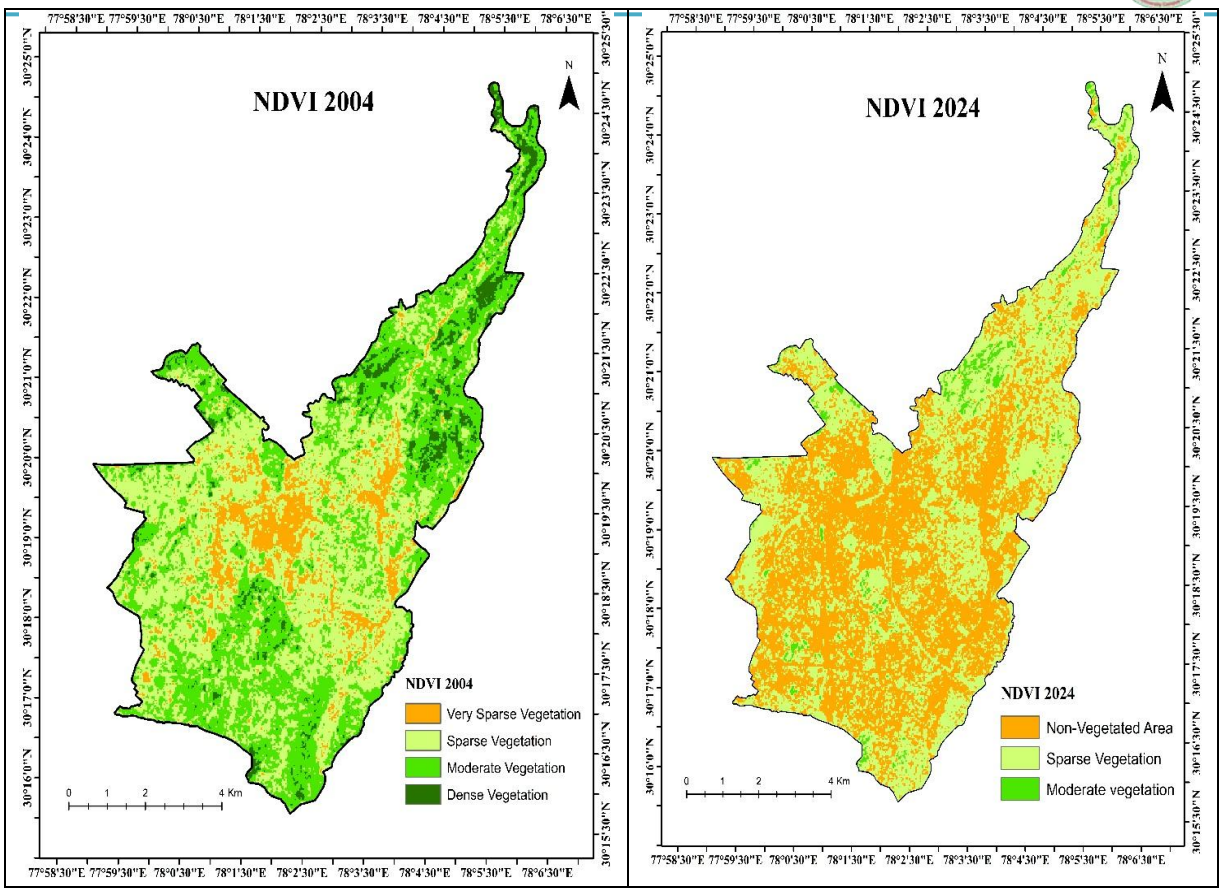


**Fig 3: Change in the NDVI of Dehradun City over two decades (2004-2024)**

Furthermore, the dense vegetation class (NDVI: 0.60-0.80), which was present in 2004, exhibits negligible spatial coverage in 2024, reflecting a substantial decline in high-intensity green cover in Dehradun city over two decades. The observed decline in moderate to dense vegetation cover over two decades highlights the growing impact of urban expansion on the city's green infrastructure and underscores the need for enhanced planning and conservation of Urban Green Spaces to ensure sustainable urban development. This decline in vegetation intensity corresponds with the observed expansion of built-up areas as indicated by LULC analysis. The reducing vegetation cover in the Dehradun city emphasizes on the need to incorporate the Urban Green Spaces in the Urban Planning Policies and Frameworks (Table 2).

**Table 2: Change in the % area under different NDVI ranges from 2004-2024**

| NDVI Range | % Area in 2004 | % Area in 2024 |
|---|---|---|
| **<2** (Very Sparse/ Non-Vegetated area) | 9.9 | 48.75 |
| **0.2-0.4** (Sparse Vegetation) | 46.02 | 48.36 |
| **0.4-0.6** (Moderate Vegetation) | 38.45 | 2.89 |
| **0.6-0.8** (Dense Vegetation) | 5.53 | - |

**Need for Strengthening Urban Green Spaces (UGS)**

Urban Green Spaces is a crucial component of an urban ecosystem due to its ecosystem dynamics and since is a significant contribution in the well-being of the human race (Rao & Puntambekar 2014). Urban Green Spaces belong to Sustainable Development Goal 11, target 11.7 implying universal access to safe and public green spaces in urban areas making them resilient and sustainable. Deforestation mainly due the increasing demand of other land use categories, derelict the green spaces and put urban areas in a

deprived state of "green services"(Gupta & Goyal 2014). Urban development is happening apparently at the cost of green spaces and as a result the green spaces are diminishing (Jana et al 2020).Green spaces provide opportunities to increase the quality of urban settings, enhance local resilience and promote sustainable lifestyles, improving both the health and the well-being of urban residents (WHO Regional office for Europe,2017). Urban Green Spaces help in maintaining the urban biodiversity and mitigate the air as well as noise pollution. It enhances the quality of urban living. Urban Green Spaces embodies peace and cleaner environment which is considered as an important factor for making cities sustainable (Rao & Puntambekar 2014). To overcome the ecological stress that has been increasing due to the rapidly growing urban population, green spaces provision within the city limits with set standards emerge as the crucial part of the urban planning(Sangwan et al 2023). Urban green space is a part of "green infrastructure" and is an important part of public open spaces which serve as a health-promoting setting for all members of the urban community. Hence, it is important that public green spaces are easily accessible to all population groups and distributed equitably within the city (WHO Regional office for Europe). To ensure that the benefits of Urbanization are fully shared and inclusive, policies to manage urban growth need to ensure access to infrastructure and social services for all, focusing on the needs of the urban poor and other vulnerable groups for housing, education, healthcare, decent work and safe environment. (United Nations Department of Economics and Social Affairs, Population Division, 2018). Urban Green Spaces (UGS) have been widely recognized as an essential component of sustainable urban development by several international and national planning agencies. A sustained decline in vegetation intensity as reflected by NDVI values implies a functional reduction in the ecological infrastructure of the city. Urban Green Spaces (UGS) can help to mitigate the ill effects of Urbanization in the high-density cities (Kamble et al 2022). Planning UGS needs special consideration in the master plans of the cities (Sangwan et al 2023). For planning future policies, quantifying the per capita deficit of UGS can help frame constructive strategies (Kamble et al 2022). The World Health Organization recommends a minimum provision of 9 $m^2$ of green space per capita, with an ideal standard of up to 50 $m^2$ per person, to support the physical and psychological well-being of urban populations. Likewise, UN-Habitat suggests that 15-20% of total urban land area should be allocated to open and green spaces in order enhance environmental sustainability and urban resilience. In the Indian context, the Ministry of Housing and Urban Affairs, through the Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines, recommends the provision of approximately 10-12 $m^2$ of recreational open space per capita in urban areas. These standards serve as critical benchmarks for evaluating the adequacy of urban green infrastructure in rapidly expanding cities such as Dehradun. In light of these recommended standards, the observed decline in vegetation cover in Dehradun raises concerns regarding the adequacy of existing green infrastructure within the urban landscape.

**Conclusion:**

The present study examined the impact of urban expansion on vegetation cover in Dehradun city by analyzing Land Use Land Cover (LULC) changes and NDVI-based vegetation intensity between 2004 and 2024. The findings reveal a substantial increase in built-up area over the two decades, accompanied by a corresponding decline in vegetation cover across the urban landscape. NDVI analysis further indicated a marked reduction in moderate to dense vegetation classes in 2024 as compared to 2004, reflecting growing anthropogenic pressure on the city's green infrastructure. The diminishing extent of high-intensity vegetation highlights

the adverse implications of unregulated urban growth on ecological balance and environmental sustainability. In this context, the integration of UGS into urban planning frameworks emerges as a necessary strategy to mitigate the environmental impacts of rapid urbanization and to promote sustainable urban development in Dehradun.

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