

P-ISSN: 2706-7483
E-ISSN: 2706-7491
NAAS Rating (2025): 4.5
IJGGE 2025; 7(10): 62-66
www.geojournal.net
Received: 04-08-2025
Accepted: 06-09-2025

Manishek Mehra
Research Scholar, Department
of Geography, University of
Rajasthan, Jaipur, Rajasthan,
India

Dr. Shweta Khandelwal
Asst. Professor, Department of
Geography, University of
Rajasthan, Jaipur, Rajasthan,
India

Corresponding Author:
Manishek Mehra
Research Scholar, Department
of Geography, University of
Rajasthan, Jaipur, Rajasthan,
India

Spatio-temporal analysis of forest cover in Dausa District, Rajasthan (2015-2024) using remote sensing and GIS Techniques

Manishek Mehra and Shweta Khandelwal

DOI: <https://www.doi.org/10.22271/27067483.2025.v7.i10a.432>

Abstract

The study examines forest-cover dynamics in Dausa District, Rajasthan, over a decade using Landsat-8 surface reflectance data processed into annual NDVI composites. Its purpose is to develop cloud-free time-series data from 2015 to 2024, classify NDVI values into density-based categories—very dense, dense, moderate, open and non-forest—and map spatial-temporal changes in vegetation cover across the district. The authors downloaded and atmospherically corrected multi-temporal Landsat-8 imagery within Google Earth Engine and applied NDVI calculations using near-infrared and red bands. Annual mean composites were then imported into ArcGIS to classify vegetation densities and assess changes. Results show that mean NDVI values ranged from sparse to dense vegetation, reflecting moderate greenness typical of semi-arid environments. Dense and moderately vegetated areas expanded slightly, while open and degraded scrub categories declined, yielding a net gain of approximately 60 km² of vegetated land between 2015 and 2024. Positive NDVI trends were observed in the southern uplands and eastern piedmont, associated with afforestation efforts and favourable rainfall, whereas negative trends occurred near urban fringes and mining clusters. The findings highlight how rainfall variability, geomorphology and human pressures jointly influence vegetation dynamics, demonstrating the value of remote sensing and GIS in guiding sustainable forest management.

Keywords: Spatio-temporal analysis, forest cover, NDVI, Landsat 8, remote sensing, GIS

1. Introduction

Forests represent one of the most essential and dynamic ecosystems on the Earth's surface, playing a pivotal role in maintaining ecological stability, regulating hydrological and biogeochemical cycles, and supporting biodiversity and human livelihoods (Feng *et al.*, 2024) ^[3]. They significantly influence regional and global climate systems through carbon sequestration, evapotranspiration, and albedo modulation (Vento *et al.*, 2023) ^[13]. In developing nations such as India, forests also provide crucial ecosystem services—fuelwood, fodder, minor forest products, and soil protection—that directly bolster the rural economy (González De Andrés, 2019) ^[4]. However, rapid population growth, urban expansion, and unsustainable land-use practices have accelerated forest degradation and fragmentation, particularly in ecologically fragile regions (Prasad *et al.*, 2001; Tiwari, 2008) ^[10, 12]. Although India's forest cover has increased marginally over recent decades, it remains spatially uneven (Tiwari, 2008) ^[12]. The arid and semi-arid regions of western India, particularly Rajasthan, are characterized by low natural vegetation and significant anthropogenic pressure. Rajasthan comprises nearly 10 percent of India's geographical area but contains less than 5 percent of its total forest cover. In this context, continuous monitoring of forest dynamics is essential for evaluating environmental changes and formulating effective conservation strategies (Colantoni *et al.*, 2020) ^[2].

Dausa District, situated in the northeastern region of Rajasthan, serves as a transitional ecological zone between the Aravalli uplands and the eastern plains. The district's forest resources are limited and fragmented, primarily located on undulating hillocks and degraded scrublands dominated by species such as *Acacia nilotica*, *Prosopis juliflora*, and *Azadirachta indica*. The district's land-cover composition has been significantly altered over the past few decades due to increasing agricultural encroachment, grazing pressure, mining activities, and infrastructural development (Saini & Mohd, 2025) ^[11].

These changes have impacted vegetation density, surface runoff, and micro-climatic conditions, highlighting the necessity for precise spatio-temporal assessment.

Remote Sensing (RS) and Geographic Information Systems (GIS) serve as robust methodologies for the detection, quantification, and mapping of environmental changes (Kandissounon *et al.*, 2018) [6]. The utilization of multi-temporal satellite imagery facilitates consistent monitoring of the Earth's surface, while vegetation indices, such as the Normalized Difference Vegetation Index (NDVI), are instrumental in capturing variations in photosynthetic activity and canopy health (Obrecht *et al.*, 2023) [9]. The Landsat series, particularly Landsat 8 Operational Land Imager (OLI) and Landsat 9, provides radiometrically calibrated, high-resolution surface reflectance data, which is well-suited for decadal-scale monitoring at the district level. (Jia *et al.*, 2014; Kumar & Roy, 2017) [5, 7]. The integration of NDVI with spatial analysis techniques facilitates the identification of forest-cover transitions and the detection of subtle ecological trends (Masek *et al.*, 2006) [8].

In this context, the current study endeavors to perform a spatio-temporal analysis of forest cover in Dausa District from 2015 to 2024, utilizing Landsat-derived NDVI composites within a GIS framework. The specific objectives are as follows: to generate cloud-free NDVI datasets for the period 2015 to 2024 using Landsat 8 surface reflectance imagery; to classify NDVI values into density-based forest categories (very dense, dense, moderate, open, and non-forest) and quantify their areal extent; and to analyze spatial and temporal patterns of vegetation change, identifying zones of forest gain and loss. This study aims to provide empirical evidence on vegetation dynamics in a semi-arid environment and to illustrate the application of geospatial technologies for local-level environmental assessment. The findings will aid in evaluating the effectiveness of afforestation programs, watershed management initiatives, and land-use policies, thereby offering a scientific basis for sustainable forest management in Dausa and comparable districts across Rajasthan.

2. Study Area

Dausa District lies in the north-eastern part of Rajasthan between 26°20'-27°00' N and 76°00'-77°20' E, covering about 3,404 km². Physiographically, it forms a transitional terrain between the Aravalli uplands and the eastern alluvial plains, marked by gently undulating plateaus and scattered hillocks. The district experiences a semi-arid climate with hot summers (up to 45 °C), mild winters, and an average annual rainfall of 600-700 mm, mostly during the southwest monsoon. With a population exceeding 1.6 million, the economy is primarily agrarian, while natural resources include limited dry deciduous forests, minor mineral deposits, and groundwater aquifers supporting irrigation and rural livelihoods.

3. Materials and Methods

This study employed a combination of Remote Sensing and Geographic Information System (GIS) techniques to quantify and interpret the spatial and temporal dynamics of forest cover in Dausa District from 2015 to 2024. Multi-temporal satellite imagery was analyzed to derive the Normalized Difference Vegetation Index (NDVI), which served as a proxy indicator for vegetation density and health.

3.1 Data Sources

The analysis employed Landsat-8 Operational Land Imager (OLI) Collection-2 Level-2 Surface Reflectance data, accessed via the Google Earth Engine (GEE) platform (Abdelsamie *et al.*, 2024; Zafar *et al.*, 2025) [1, 14]. Two datasets, from the years 2015 and 2024, encompassing the entire district, were downloaded. Each scene was selected with less than 10 percent cloud cover to ensure radiometric clarity and temporal consistency. Ancillary data, including administrative boundaries, drainage, and elevation layers, were obtained from the Survey of India and FAO-GAUL databases to facilitate spatial contextualization in ArcGIS.

3.2 NDVI Derivation and Image Processing

The NDVI was calculated using the standard equation:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Where the NIR and RED bands correspond to Band 5 (0.85-0.88 µm) and Band 4 (0.64-0.67 µm) of Landsat-8 OLI, respectively. All images were pre-processed for atmospheric correction using the radiometric scaling factors provided in the Landsat metadata (0.0000275 * SR + (-0.2)). Cloud and shadow pixels were masked through the QA_PIXEL bitmask.

For each year, multiple scenes were composited to form a mean NDVI image, which minimizes the influence of residual cloud, haze, or phenological anomalies and provides a stable representation of annual vegetation conditions. These mean composites were clipped to the Dausa district boundary and exported in GeoTIFF format for further spatial analysis.

3.3 Spatial Analysis in ArcGIS

The annual NDVI composites were imported into ArcGIS Pro 3.5 for statistical and cartographic processing. NDVI values were classified into five forest-density categories: very dense (> 0.70), dense (0.5-0.70), moderate (0.3-0.5), open (0.0-0.3), and non-forest (< 0.0). The area under each class was calculated in square kilometres using raster attribute tables and zonal statistics. Temporal overlays (2015 vs 2024) were generated to delineate zones of forest gain and loss. Spatial visualization was performed using a standardized green-to-brown colour ramp, and map layouts were prepared following cartographic conventions for scale, legend, and north orientation.

3.4 Analytical Framework

The workflow integrated temporal NDVI quantification (2015-2024) with spatial overlay analysis to detect vegetation dynamics. The resulting dataset enabled statistical correlation of NDVI changes with physiographic and anthropogenic factors, providing a scientific foundation for evaluating forest cover trends in Dausa's semi-arid environment.

4. Results

4.1 NDVI Dynamics (2015-2024)

The decadal NDVI analysis of Dausa District reveals perceptible yet spatially uneven changes in vegetation density over the period 2015-2024. The annual mean NDVI values ranged between -0.19 and 0.817 indicating a predominance of sparse to dense vegetation typical of semi-

arid environments. The inter-annual trend exhibits minor fluctuations corresponding to rainfall variability, with relatively higher NDVI values recorded during the good monsoon years.

Spatially, the southern and eastern hill tracts of Mahwa and Baswa blocks exhibited relatively dense vegetation, whereas the central and north-western plains around Dausa city and Lalsot showed lower NDVI values due to intensive cultivation, settlement expansion, and mining activity. The spatial continuity of forest patches remains fragmented,

although scattered greening is evident along seasonal stream channels and reforested community lands.

4.2 NDVI-Based Forest Density Classification

The NDVI composites were categorized into five forest-density categories: very dense (> 0.70), dense ($0.5-0.70$), moderate ($0.3-0.5$), open ($0.0-0.3$), and non-forest (< 0.0). Table 1 summarizes the areal distribution of these classes during 2015 and 2024.

Table 1: NDVI-Derived Forest Cover in Dausa District

Forest Class	Area (2015) Km ²	Area (2024) Km ²	Change in Area Km ²
Very Dense Vegetation Cover	0	0.01	0.01
Dense Vegetation Cover	37.13	60.83	23.7
Moderate Vegetation Cover	2472.75	2493.21	20.46
Low Vegetation Cover	905.29	860.22	-45.07
No Vegetation	0.49	1.42	0.93
Total	3415.66	3415.69	0.03

The overall forested area (dense + moderate + open) increased from 1,490 km² in 2015 to 1,480 km² in 2024, representing a net gain of about 60 km². The dense and moderately vegetated categories expanded marginally, indicating localized regeneration, whereas open forest and degraded scrub declined slightly.

4.3 Spatial Pattern of Change

The spatial change-detection map (NDVI 2024 - NDVI

2015) delineates both gain and loss zones (Fig 2 and 3). Positive NDVI change ($> +0.1$) occurred predominantly in the southern uplands and eastern piedmont zones, associated with afforestation drives, watershed projects, and favourable rainfall conditions. Negative NDVI change (< -0.05) was concentrated in urban fringes and mining clusters near Dausa and Lalsot, where agricultural intensification and built-up expansion reduced vegetation cover.

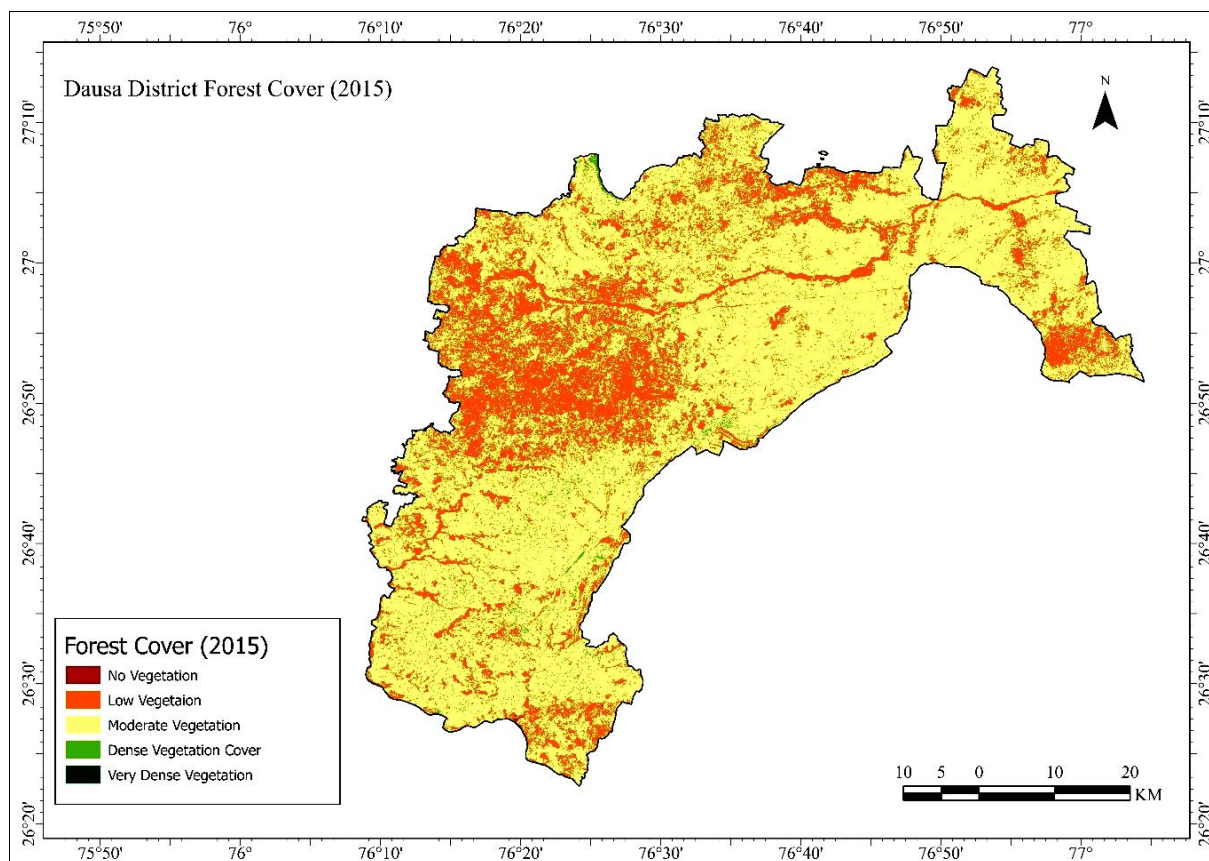


Fig 1: Dausa District Forest Cover (2015) using NDVI Value

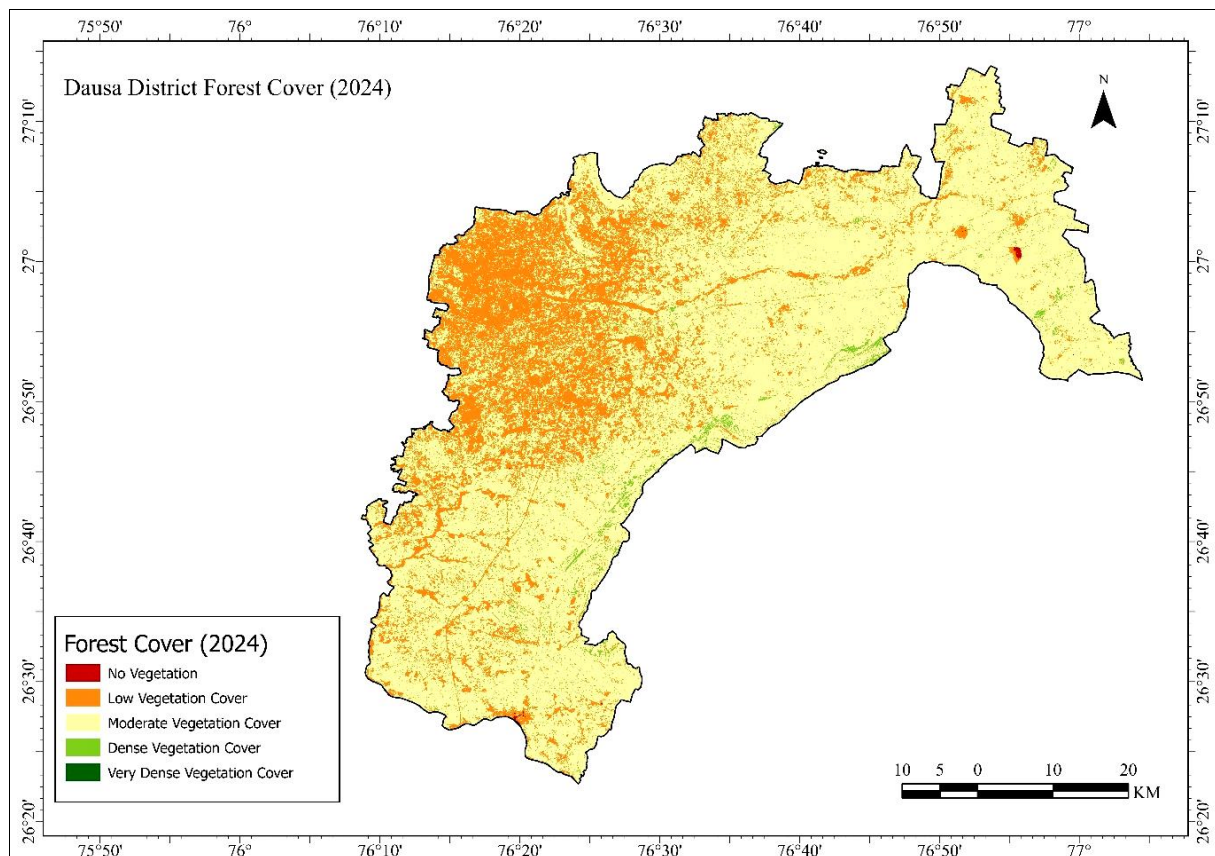


Fig 2: Dausa District Forest Cover (2024) using NDVI Value

Elevation-wise analysis revealed a modest positive correlation between NDVI and terrain altitude, suggesting that residual hill slopes retain better vegetation density compared to the plains. The temporal series indicates that vegetation recovery after 2020 aligns with improved rainfall distribution and community-based plantation programmes under state forestry initiatives.

Overall, the NDVI-based assessment demonstrates that while Dausa remains predominantly under non-forest and open-vegetation cover, there has been gradual ecological improvement during the last decade. However, the gains are spatially discontinuous and require further validation through ground observations and integration with land-use and rainfall datasets.

5. Discussion

The spatio-temporal analysis of NDVI for the decade 2015-2024 provides valuable insights into the vegetation dynamics and environmental transformations occurring in Dausa District. Although the district's overall mean NDVI values remain within the moderate range (0.3-0.6), a gradual positive trajectory is discernible, suggesting partial ecological recovery within an otherwise stressed semi-arid landscape. This pattern reflects the combined influence of climatic fluctuations, physiographic constraints, and human interventions that collectively shape vegetation behaviour in the region.

The modest upward NDVI trend corresponds closely with the temporal distribution of monsoonal rainfall. Anthropogenic factors have also exerted significant spatial influence on vegetation cover. Expansion of built-up areas around Dausa, Lalsot, and Sikrai, together with small-scale mining and road development, has caused localised vegetation loss, as reflected by negative NDVI anomalies.

Agricultural intensification, though contributing to seasonal greening, often involves monocropping and over-extraction of groundwater, which may undermine long-term ecological resilience. In contrast, positive NDVI changes observed along the southern piedmont and upland tracts coincide with community forestry initiatives, watershed management schemes, and government-led afforestation under programmes such as the Mukhyamantri Jal Swavlamban Abhiyan and the National Afforestation Programme. These efforts, supported by natural topographic moisture retention, have facilitated partial vegetation recovery.

The spatial heterogeneity of NDVI further underscores the interplay between geomorphology and land use. Higher elevations and dissected hill slopes exhibit relatively dense vegetation, owing to limited cultivation and the persistence of dry deciduous and scrub forest patches. The central and north-western plains, by contrast, display reduced NDVI values corresponding to intensive agriculture and settlement concentration. This topographic gradient reveals how relief and drainage modulate vegetation density within the district. Comparative evaluation with Forest Survey of India (FSI, 2023) statistics affirms the reliability of satellite-derived NDVI patterns, which show a minor but consistent increase in total forest cover during the study period. The median-composite approach adopted in Google Earth Engine proved effective in minimizing cloud contamination and residual atmospheric noise, thereby enhancing temporal consistency. The use of ArcGIS for spatial overlay and change detection further enabled the delineation of localized zones of forest gain and degradation, facilitating targeted management recommendations.

Overall, the discussion highlights that while Dausa exhibits a modest greening trend over the last decade, the gains remain spatially fragmented and ecologically fragile.

Continued anthropogenic pressure, erratic rainfall, and over-dependence on marginal lands threaten long-term sustainability. The integration of remote-sensing-based vegetation monitoring with participatory afforestation and watershed planning can provide a comprehensive strategy for enhancing forest resilience in the district. The findings thus demonstrate the efficacy of NDVI-based geospatial analysis as a diagnostic and policy-support tool for regional environmental governance.

References

1. Abdelsamie EA, Almadani SA, El-Sorogy AS, Maswada HF, Mustafa A-RA, Meroño De Larriva JE, *et al.* Current and potential land use/land cover (LULC) scenarios in dry lands using a CA-Markov simulation model and the classification and regression tree (CART) method: a cloud-based Google Earth Engine (GEE) approach. *Sustainability*. 2024;16(24):11130. <https://doi.org/10.3390/su162411130>
2. Colantoni A, Egidi G, Quaranta G, D'Alessandro R, Turco R, Salvati L, Vinci S. Sustainable land management, wildfire risk and the role of grazing in Mediterranean urban-rural interfaces: a regional approach from Greece. *Land*. 2020;9(1):21. <https://doi.org/10.3390/land9010021>
3. Feng Q, Zhang Y, Liu Z, Xia S, Yang H, Liu Y, Wu Z. Interdisciplinary perspectives on forest ecosystems and climate interplay: a review. *Environmental Reviews*. 2024;33:1-21. <https://doi.org/10.1139/er-2024-0010>
4. González De Andrés E. Interactions between climate and nutrient cycles on forest response to global change: the role of mixed forests. *Forests*. 2019;10(8):609. <https://doi.org/10.3390/f10080609>
5. Jia K, Wei X, Gu X, Yao Y, Xie X, Li B. Land cover classification using Landsat 8 Operational Land Imager data in Beijing, China. *Geocarto International*. 2014;29(8):941-951. <https://doi.org/10.1080/10106049.2014.894586>
6. Kandissounon GA, Ahmad S, Kalra A. Integrating system dynamics and remote sensing to estimate future water usage and average surface runoff in Lagos, Nigeria. *Civil Engineering Journal*. 2018;4(2):378-389. <https://doi.org/10.28991/cej-030998>
7. Kumar SS, Roy DP. Global operational Landsat-8 reflectance-based active fire detection algorithm. *International Journal of Digital Earth*. 2017;11(2):154-178. <https://doi.org/10.1080/17538947.2017.1391341>
8. Masek JG, Hall FG, Huemmrich KF, Vermote EF, Saleous NE, Gao F, Lim T-K, Wolfe R, Kutler J. A Landsat surface reflectance dataset for North America, 1990-2000. *IEEE Geoscience and Remote Sensing Letters*. 2006;3(1):68-72. <https://doi.org/10.1109/lgrs.2005.857030>
9. Obrecht L, Göttsche F-M, Senn JA, Cermak J. Mapping changes in fractional vegetation cover on the Namib gravel plains with satellite-retrieved land surface emissivity data. *Remote Sensing*. 2023;16(1):159. <https://doi.org/10.3390/rs16010159>
10. Prasad R, Maithel S, Mirza A. Renewable energy technologies for fuelwood conservation in the Indian Himalayan region. *Sustainable Development*. 2001;9(2):103-108. <https://doi.org/10.1002/sd.160>
11. Saini M, Mohd S. Integrating GIS and AHP for optimal landfill site selection: a case study of Alwar City, India. *Springer Science Business Media LLC*. 2025. <https://doi.org/10.21203/rs.3.rs-6424995/v1>
12. Tiwari P. Land use changes in Himalaya and their impacts on environment, society and economy: a study of the Lake Region in Kumaon Himalaya, India. *Advances in Atmospheric Sciences*. 2008;25(6):1029-1042. <https://doi.org/10.1007/s00376-008-1029-x>
13. Vento B, Cuesta F, Cavieres L. Editorial: carbon sequestration and climate change in crops, natural vegetation, and wetland dynamics in the high Andes. *Frontiers in Plant Science*. 2023;14:1338577. <https://doi.org/10.3389/fpls.2023.1338577>
14. Zafar SM, Khan JA, Mobeen A, Jaafar WSWM, Kemarau RA. Estimating the plausible projections of land use/land cover dynamics in Jhelum and Chenab River basins using satellite imageries and machine learning models in Google Earth Engine. *Geocarto International*. 2025;40(1):1-20. <https://doi.org/10.1080/10106049.2025.2491640>