

Spatio-Temporal Analysis of Land Use Land Cover Change and Climate Variability in the Kaddam Dam Watershed and Command Area (1985–2025), Telangana, India.

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Abstract:

Dams play a critical role in water storage for drinking, irrigation, and groundwater recharge; however, inadequate periodic assessment can increase the risk of structural failure and severe socio-economic impacts due to flooding. This study presents a spatio-temporal analysis of land use and land cover (LULC) change and climate variability in the Kaddam Dam watershed, located in Nirmal district, Telangana, India. The watershed forms a tributary of the Godavari River and supports extensive irrigation through its command area.

Multi-temporal Landsat multispectral datasets (Landsat-5, Landsat-8, and Landsat-9) from 1985 to 2025 at five-year intervals were used to analyze LULC dynamics using supervised classification techniques in a GIS environment. The results reveal a substantial expansion of built-up land, increasing nearly fivefold across the watershed during the study period, indicating rapid urbanization and land conversion. Water bodies exhibited an approximately 2.5-fold increase, with a pronounced rise after 2020. An expansion of Bare land was also observed, leading to the reduction of cropland, dense vegetation, and wetland areas.

Within the dam command area, built-up land increased nearly four times between 1985 and 2025, while water bodies expanded by approximately 6.5 times, significantly impacting other land-use classes. The increase in water bodies along watershed boundaries is attributed to the influence of the Godavari River and the presence of additional hydraulic structures within the basin. Climate analysis using historical and projected World Clim datasets indicates a declining rainfall trend of approximately 70 mm and a projected increase in mean temperature of about 1°C over the study period.

The overall classification accuracy achieved was 84%, with a Kappa coefficient of 0.88, demonstrating reliable LULC classification. The findings highlight the combined influence of anthropogenic activities and climate variability on watershed dynamics and emphasize the need for sustainable land-use planning and integrated watershed management to ensure long-term dam safety and water resource sustainability.

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1. Introduction

Systematic land use and land cover (LULC) classification has been undertaken since the mid-1970s, following standardized classification frameworks developed through coordinated efforts of scientific agencies, including the National Aeronautics and Space Administration (Anderson et al., 1971). In India, the National Remote Sensing Centre (NRSC), under the Department of Space, established a LULC classification scheme consisting of 24 categories up to Level-II, which is suitable for mapping at a scale of 1:250,000 and was adapted from earlier classification systems (NRSA, 2004). Time-series LULC mapping has become a crucial tool for understanding land surface dynamics and is widely used for assessing and predicting environmental changes and climate-related impacts (Yaqian He et al., 2017). Over the last five decades, the Earth's surface has undergone substantial transformation, largely driven by rapid population growth. This growth has intensified human activities, leading to widespread conversion of arable and open lands into built-up areas. The rapid expansion of urbanization has therefore emerged as a major factor influencing changes in land use and land cover (LULC) patterns (Digra et al., 2022).

The Kaddam Dam watershed has undergone substantial land use and land cover (LULC) transformations, as revealed by NDVI and time-series analysis. Previous studies indicate that nearly 265.65 km² (26,565 ha) of forest land has been converted into agricultural land, highlighting intensified human activities and agricultural expansion within the watershed (K. Ramya et al., 2018). Further analysis of LULC changes between 1988 and 2022 shows an almost fourfold increase in cropland area,

which has occurred primarily at the expense of forest and barren land. In contrast, water bodies and built-up areas exhibit only a marginal increase over the study period, indicating selective land conversion influenced by irrigation development and dam-related activities (Sridhar et al., 2015).

2. Materials and Methods

2.1 Study Area

The Kaddam Dam watershed is located in the northern part of Telangana, India, and forms an important sub-basin of the Godavari River system. The dam is constructed across the Kaddam River, which originates in the Dedra Reserved Forest of Adilabad District. The river flows eastward and joins the Godavari River near Dasturabad village in Kaddam Mandal, approximately 80 km downstream from its origin. The confluence point lies about 6.5 km downstream of the Kaddam Dam and nearly 48 km east of Nirmal town along the Basar–Mancherial road.

The watershed study area was delineated using the SRTM DEM dataset, resulting in a macro-watershed covering an area of approximately 12,560 km². The delineated watershed represents a major macro-watershed system, incorporating multiple significant water bodies, including major reservoirs, and spanning five districts of Telangana State, India. The derived watershed boundary was validated through comparison with the Hydro SHEDS Atlas (Lehner, B., Grill G et al 2015), confirming that the basin falls within the Godavari River Basin. The watershed exhibits significant topographic variability, with elevations ranging from approximately +457 m in the upper reaches to +183 m in the downstream regions. This altitudinal gradient plays a critical role in controlling hydrological processes, including surface runoff generation, drainage density, and flow accumulation dynamics across the basin.

Kaddam Dam was originally constructed between 1949 and 1958 to serve irrigation and water storage purposes. However, the dam experienced a breach in 1958 due to extreme flood inflows of nearly 5.19 lakh cusecs, which exceeded its original design capacity of about 2.5 lakh cusecs (Irrigation department et al., Telangana). Following this event, the dam was reconstructed and upgraded by 1969 to enhance its flood-handling capacity and structural safety. The reconstruction included the installation of nine additional flood gates, increasing the total number of spillway gates to eighteen. Consequently, the design outflow capacity was increased to approximately 6 lakh cusecs, and the gross storage capacity was enhanced to about 7.603 TMC (127 million cubic meters). The Full Reservoir Level (FRL) was raised from +212.10 m to +213.30 m. At present, the dam plays a significant role in regional water storage and irrigation management. Figure 1 illustrates the political boundaries of the districts encompassed within the watershed, namely Adilabad, Nirmal, Nizamabad, and Jagtial, while the downstream portion extends into Mancherial district.

Command Area:

The Kaddam Dam ayacut (command area) was delineated using official maps provided by the Irrigation Department, Government of Telangana, which were subsequently georeferenced to generate accurate spatial datasets. This command area represents the reservoir irrigation command zone supporting agricultural activities within the Godavari River Basin, underscoring its critical importance for regional crop production and food security. The spatial boundary of the command area is integrated and represented in the satellite imagery, LULC maps, and corresponding classified outputs, enabling detailed spatial analysis of land use patterns within the irrigation command.

The command area consists of 1191 sq.km also constitutes a highly sensitive flood-prone zone, particularly during extreme rainfall events and high inflow conditions, when the reservoir reaches the Full Reservoir Level (FRL) and experiences overflow. Such events pose significant flood hazards, resulting in substantial impacts on agricultural lands, human settlements, and downstream infrastructure, thereby creating major management challenges and conflicts between irrigation benefits and flood risk mitigation

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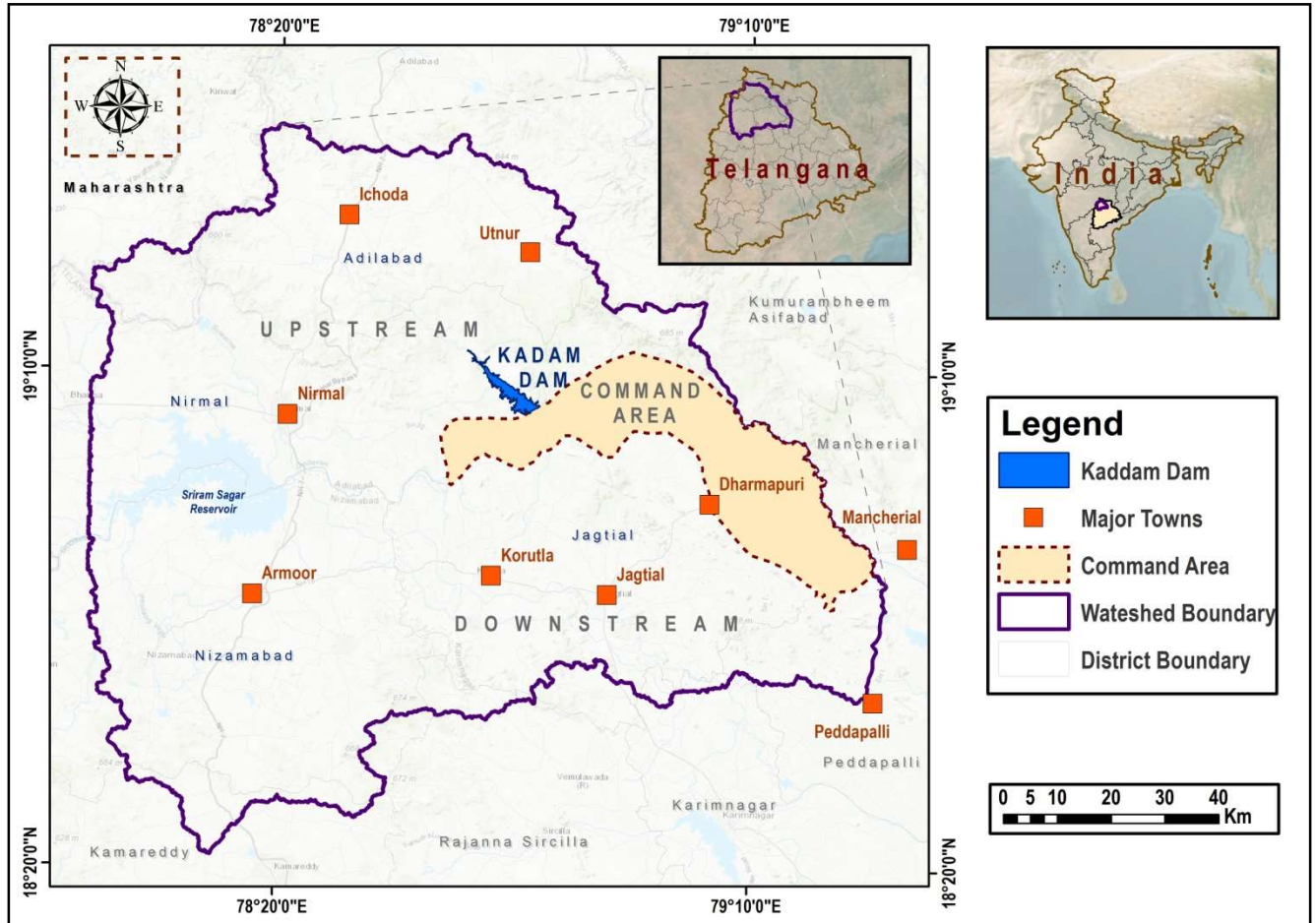


Figure .1. Political boundaries of the Kaddam Dam watershed and its command area.

2.2 Dataset Used

Satellite datasets were acquired from the USGS Earth Explorer platform(USGS, 2023), consisting of radiometrically corrected, cloud-free multispectral imagery. All scenes were spatially subset using the watershed boundary shapefile, and multispectral band composites were generated for further analysis. The processed datasets were utilized for supervised classification to derive land use/land cover (LULC) classes and to assess temporal changes in individual thematic classes. Climate datasets, including historical and projected rainfall and temperature variables, were downloaded from the WorldClim database. These datasets were employed to analyze climate variability and to assess projected climate change scenarios within the watershed.

Table 1 Data sets used for the study

Sensor /Product	Dataset Used	Date of Acquisition	No of Bands	Data Characteristics
Landsat-5	Supervised Classification -LULC	02 nd March 1985	04	Radiometrically corrected, cloud-free, multispectral data
Landsat-7		01 st January 1990	04	
		22 nd January 1995	07	
Landsat-5		17 th January 2005	07	
		31 st January 2010	11	
Landsat-8 OLI-TIRS	29 th January 2015			
		11 th January 2020		

2.3 Image Preprocessing:

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Landsat-9 OLI-2		18 th December 2025	11	
World Clim-Bioclimate variables	Rainfall & Temperature	2000 to 2025		Gridded climatic surfaces
World Clim CMIP6	Projected Rainfall & Temperature	2026 to 2040		Downscaled climate projections

The downloaded satellite images were spatially extracted by masking with the watershed boundary shapefile. Subsequently, the individual spectral bands were layer-stacked using QGIS software to generate multispectral composite images for the period 1985 to 2025. The multispectral datasets were composed using the Near-Infrared (NIR), Red, and Green bands, and the resulting composites were visualized and interpreted as shown in Figure 2.

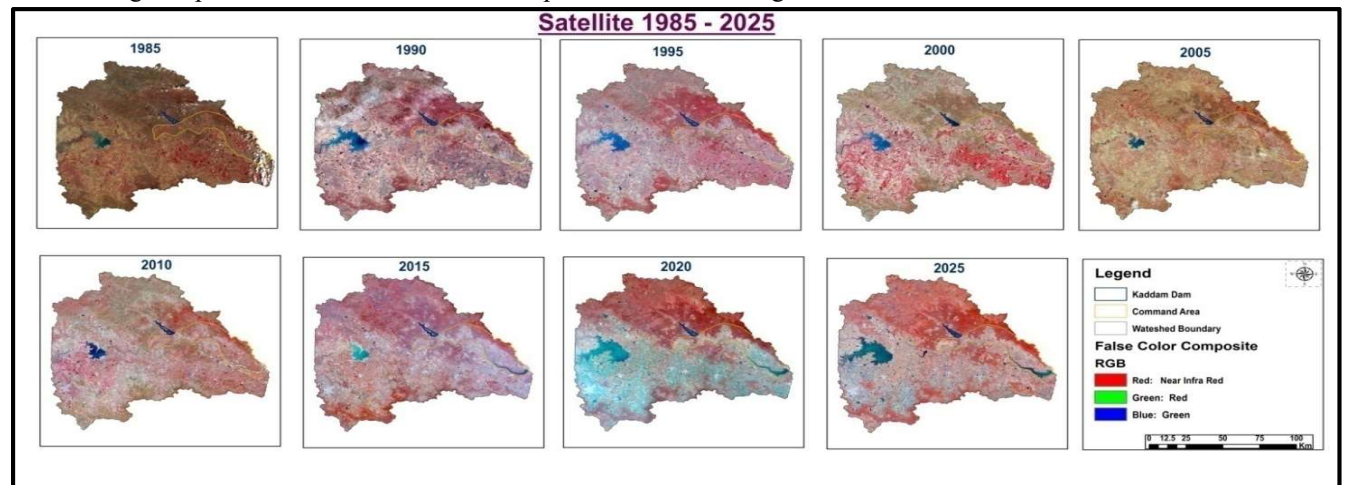


Figure 2. Satellite Data used for LULC

2.4 Supervised Classification and Signature File

The layer-stacked and clipped multispectral images were utilized to perform supervised classification using class-specific spectral signature files. The signature files were generated by selecting homogeneous, representative reflectance pixels for each land use/land cover (LULC) class, namely: Barren Land (open land, rocky and hill areas), Built-up (urban areas, residential structures), Cropland (various crop types), Dense Vegetation (forest cover and dense green biomass), Sparse Vegetation (scattered vegetation patches), Water Bodies (surface water reflectance pixels), and Wetlands (areas surrounding water bodies with high moisture reflectance).

For classification accuracy and class reliability, training samples were derived using Google Earth high-resolution imagery and real-time ground truth data. A minimum of twenty-five (25) training samples per class were collected to generate robust spectral signature files, which were subsequently used to produce the classified LULC maps.

2.5 Climate Datasets : High-resolution gridded climate datasets were obtained from the WorldClim version 2.1(Fick, SE et al 2017) database at a spatial resolution of 2.5 arc-minutes (~5 km). Historical precipitation and temperature datasets covering the period 2000–2025 were used to assess observed climatic variability within the watershed and command area. Future climate projections were derived from the MPI-ESM1-2-HR Global Climate Model (GCM) under the CMIP6 framework(Eyring V et al 2016), using the SSP1-2.6 (SSP126) emission scenario. The projected datasets include precipitation (wc2.1_2.5m_prec_MPI-ESM1-2-HR_ssp126) and maximum temperature (wc2.1_2.5m_tmax_MPI-ESM1-2-HR_ssp126) for the period 2026–2040. These datasets were spatially subset to the watershed and command area boundaries and integrated with the LULC and hydrological datasets for analyzing climate variability, future climate change scenarios, and their interactions with land use dynamics, hydrology, and flood risk.

3. Results

3.1 LULC Classification

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Multispectral satellite images were classified for the period 1985 to 2025 at five-year temporal intervals into seven land use/land cover (LULC) classes, as illustrated in Figure 3. The classified maps follow a standardized color scheme for visualization: Barren Land (light gray), Built-up (red), Cropland (light yellow), Dense Vegetation (dark green), Sparse Vegetation (light green), Water Bodies (blue), and Wetlands (light blue).

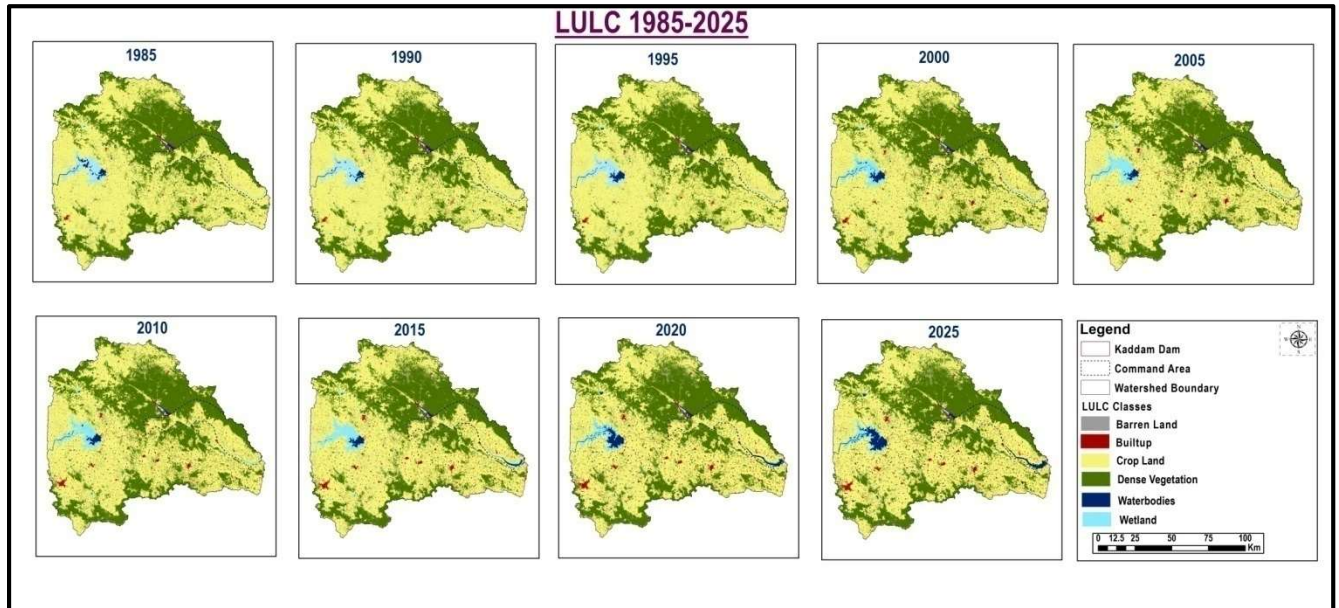


Figure 3 LULC classified images from 1985 to 2025

3.2 LULC Table

LULC Changes in the Watershed (1985–2025)

The land use/land cover (LULC) classification of the watershed for the period 1985–2025 shows measurable changes across all seven classes. The built-up area increased from 62.70 km² in 1985 to 324.53 km² in 2025. Cropland showed a gradual decrease from 7407.03 km² to 7275.67 km² during the same period. The dense vegetation class declined from 4475.52 km² in 1985 to 4231.09 km² in 2025, while shrub vegetation increased from 167.23 km² to 211.77 km². The water bodies category expanded from 116.98 km² in 1985 to 307.53 km² in 2025. In contrast, wetlands reduced from 330.53 km² to 209.40 km² over the study period.

These quantitative variations across temporal intervals are presented in Table no 2

Table 2 LULC Changes in the Watershed Area (Sq.Kms)

Classes	1985	1990	1995	2000	2005	2010	2015	2020	2025
Barren Land	167.23	171.91	157.23	147.51	158.94	167.55	236.29	211.62	211.77
Builtup	62.70	62.65	72.06	201.84	253.32	247.75	290.11	320.23	324.53
Crop Land	7407.03	7402.92	7386.20	7296.06	7278.1	7221.2	7299.4	7211.7	7275.6
Dense Vegetation	4475.52	4475.98	4497.58	4454.55	4422.5	4477.6	4244.0	4315.3	4231.0
Waterbodies	116.98	97.76	88.86	103.44	65.72	90.21	83.56	227.55	307.53
Wetland	330.53	348.76	357.83	356.61	381.34	355.58	406.48	273.47	209.40

LULC Changes in the Command Area (1985–2025)

The land use/land cover (LULC) classification of the Kaddam Dam command area for the period 1985–2025 shows significant temporal variations across all classes. Cropland decreased from 676.16 km² in 1985 to 648.11 km² in

2025. Dense vegetation reduced from 466.41 km² in 1985 to 431.06 km² in 2025, while sparse vegetation declined from 12.42 km² to 9.12 km² during the same period. The built-up area increased from 8.22 km² in 1985 to 35.15 km² in 2025. The water bodies class expanded from 8.80 km² in 1985 to 57.17 km² in 2025. Wetlands showed a net decline from 19.52 km² in 1985 to 10.93 km² in 2025. The temporal distribution and spatial patterns of these classes are presented in Table no 3.

Table 3 LULC Changes in the Command Area (Sq.Kms)

Classes	1985	1990	1995	2000	2005	2010	2015	2020	2025
Barren Land	12.42	17.06	16.77	13.58	20.14	13.19	11.22	9.33	9.12
Builtup	8.22	8.18	8.39	24.27	28.28	26.02	32.44	32.51	35.15
Crop Land	676.16	671.69	668.50	653.48	652.35	646.49	630.15	646.28	648.11
Dense Vegetation	466.41	466.35	468.57	465.98	464.60	473.57	452.66	437.08	431.06
WaterBodies	8.80	9.26	3.82	4.51	2.38	3.44	19.89	41.57	57.17
Wetland	19.52	18.99	25.48	29.72	23.79	28.82	45.18	24.75	10.93

3.3 Accuracy Assessment

Classification accuracy was evaluated through systematic comparison of the classified outputs with real-time ground truth observations, high-resolution satellite imagery, and Google Earth imagery, using both pixel-to-pixel and object-based validation approaches.

Approximately 30 Ground Control Points (GCPs) per class were collected and incorporated into the automatic classifier to strengthen training data quality and improve class separability. The accuracy assessment was performed using ERDAS Imagine Version 2015, employing standard confusion matrix (error matrix) analysis. Producer's accuracy, User's accuracy, and Overall accuracy metrics were computed to quantify classification performance.

The overall classification accuracy achieved for the study years was 68.3% (1985), 71.51% (1990), 70.46% (2000), 74.21% (2005), 80.64% (2010), 82.19% (2015), 80.41% (2020), and 82.81% (2025). Overall accuracy was calculated by summing the diagonal elements of the confusion matrix (representing correctly classified pixels) and dividing by the total number of validation samples, following standard remote sensing accuracy assessment procedures.

3.4 LULC Change Detection

Land Use/Land Cover (LULC) change detection was carried out for three representative years—1985, 2005, and 2025 to comprehensively assess long-term landscape dynamics over two time intervals: 1985–2005 and 2005–2025. Change detection analysis was performed using the Intersect tool, which enabled class-wise comparison between vector LULC datasets of different years. The spatial distribution of LULC transitions is illustrated in Figure 4, showing LULC changes from 1985 to 2025, while the corresponding quantitative statistics are presented in Table 4, summarizing the class-wise

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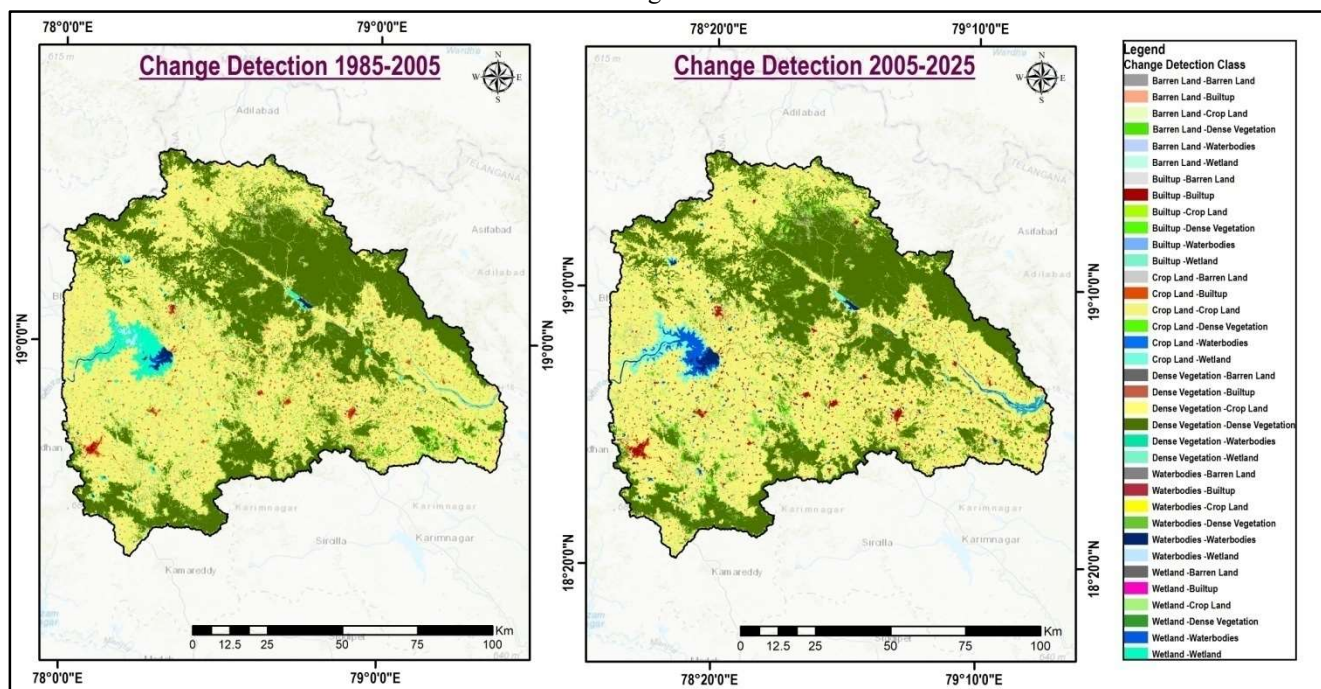


Figure 4:LULC Change detection Map

The LULC change matrix reveals substantial spatial transitions between 1985–2005 and 2005–2025, highlighting dominant persistence as well as notable inter-class conversions. Cropland remained the most stable land-use category in both periods, retaining an area of 6912.28 sq. km during 1985–2005 and 6731.88 sq. km during 2005–2025, although a gradual decline is evident due to conversions to built-up areas and dense vegetation. Built-up land shows a pronounced expansion, with built-up-to-built-up area increasing sharply from 59.10 sq. km to 226.43 sq. km, indicating accelerated urban growth in the recent two decades

Table 4: LULC Change detection classes of Watershed in Sq.Km

S.No	Change Detection	Area 1985-2005 (Sq.Km)	Area 2005-2025 (Sq.Km)
1	Barren Land -Barren Land	91.59	98.37
2	Barren Land -Builtup	18.30	3.67
3	Barren Land -Crop Land	37.26	28.39
4	Barren Land -Dense Vegetation	19.44	15.06
5	Barren Land -Waterbodies	0.01	13.19
6	Barren Land -Wetland	0.64	0.27
7	Builtup -Barren Land	0.12	1.70
8	Builtup -Builtup	59.10	226.43
9	Builtup -Crop Land	3.37	24.58
10	Builtup -Dense Vegetation	0.10	0.46
11	Builtup -Waterbodies	0.00	0.10
12	Builtup -Wetland	0.00	0.03
13	Crop Land -Barren Land	46.59	65.81
14	Crop Land -Builtup	146.28	86.91
15	Crop Land -Crop Land	6912.28	6731.88

16	Crop Land -Dense Vegetation	278.87	332.28
17	Crop Land -Waterbodies	1.21	44.84
18	Crop Land -Wetland	21.52	16.07
19	Dense Vegetation -Barren Land	17.11	45.71
20	Dense Vegetation -Builtup	29.53	7.44
21	Dense Vegetation -Crop Land	303.58	483.40
22	Dense Vegetation -Dense Vegetation	4123.56	3882.93
23	Dense Vegetation -Waterbodies	0.30	2.29
24	Dense Vegetation -Wetland	1.23	0.54
25	Waterbodies -Barren Land	0.34	0.01
26	Waterbodies -Builtup	0.03	0.02
27	Waterbodies -Crop Land	8.90	0.25
28	Waterbodies -Dense Vegetation	0.27	0.02
29	Waterbodies -Waterbodies	50.49	64.06
30	Waterbodies -Wetland	56.95	1.36
31	Wetland -Barren Land	3.19	0.15
32	Wetland -Builtup	0.04	0.03
33	Wetland -Crop Land	12.45	6.88
34	Wetland -Dense Vegetation	0.13	0.09
35	Wetland -Waterbodies	13.71	183.05
36	Wetland -Wetland	301.00	191.14

Dense vegetation also exhibited relative stability, though a marginal reduction was observed from 4123.56 sq. km to 3882.93 sq. km, accompanied by increased conversion to cropland, particularly during 2005–2025. Transitions from cropland to dense vegetation increased in the later period, suggesting localized vegetation regeneration or plantation activities. Waterbodies displayed mixed behavior, with stable waterbody area increasing from 50.49 sq. km to 64.06 sq. km, while significant wetland-to-waterbody conversion (183.05 sq. km) during 2005–2025 indicates hydrological alterations.

Barren land showed moderate persistence, with limited but notable conversions to cropland and built-up areas. Wetlands experienced a net decline in stable wetland area from 301.00 sq. km to 191.14 sq. km, reflecting increasing anthropogenic pressure and hydrological changes. Overall, the results indicate intensified urbanization, redistribution of cropland and vegetation, and dynamic wetland–waterbody transformations over the four-decade study period.

3.5 Climate Change

Rainfall:

The rainfall maps for the entire watershed and the command area were generated using historical rainfall data along with projected rainfall scenarios. The spatial distribution of rainfall patterns is illustrated in Figure 5, providing a visual representation of both past and projected rainfall over the study area.

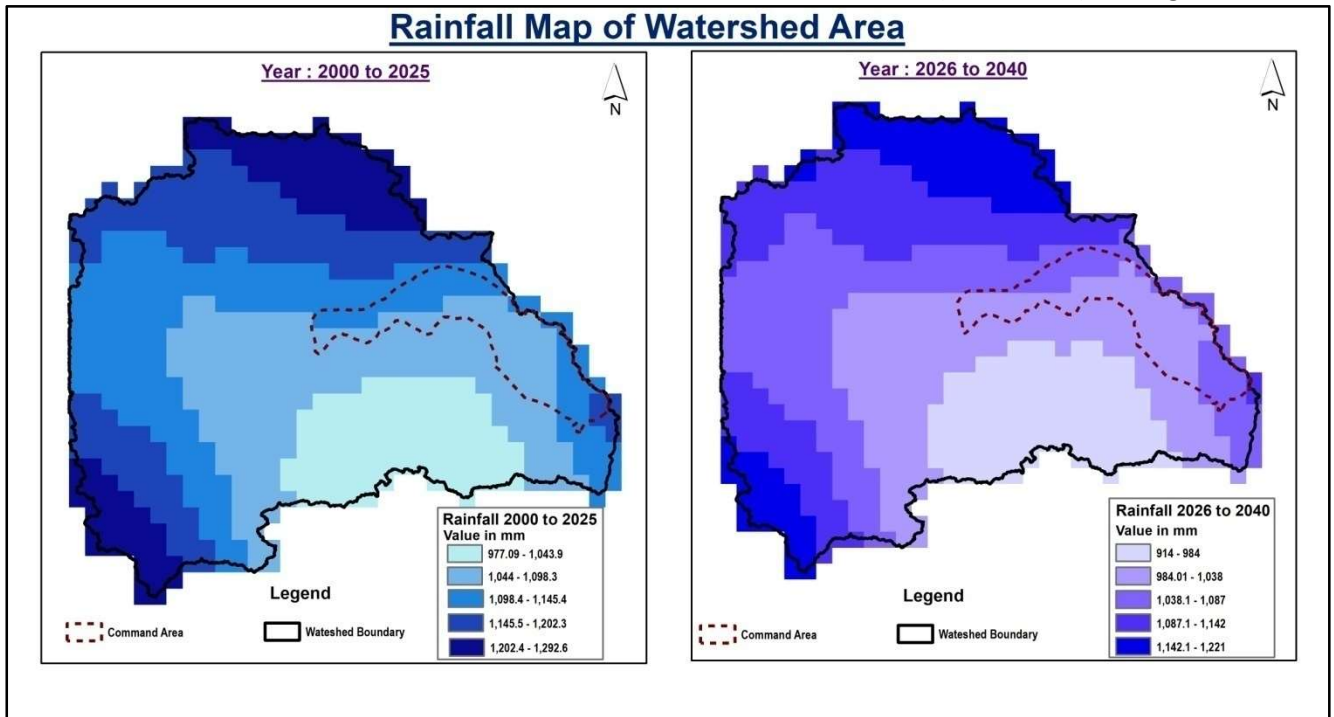


Figure 5. Historical and Projected Rainfall map

The average rainfall during the period 2000–2025 varies from 977 mm to 1292 mm across the watershed, with higher rainfall predominantly observed in the upstream regions and comparatively lower rainfall in the downstream areas. Rainfall over the command area ranges between 1044 mm and 1145 mm. The projected rainfall pattern shows a similar spatial distribution, varying from 914 mm to 1221 mm, with maximum rainfall concentrated in the upstream portions of the watershed and minimum rainfall occurring downstream. The projected rainfall within the command area falls within the range of 1038 mm to 1142 mm.

Temperature:

The temperature maps for the entire watershed and the command area were generated using historical temperature data along with projected temperature scenarios. The spatial distribution of temperature patterns is illustrated in Figure 6, providing a visual representation of both past and projected rainfall over the study area.

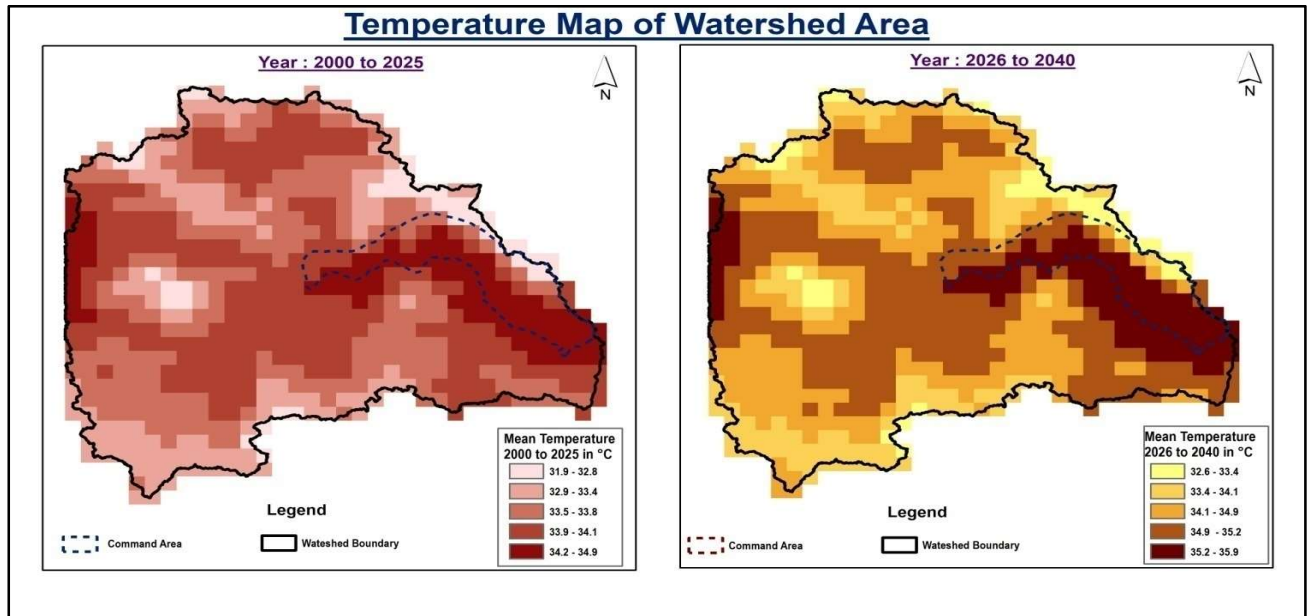


Figure 6. Historical and Projected Temperature map

The average temperature across the watershed during the period 2000–2025 ranges from 31.9 °C to 34.9 °C, with the highest temperatures observed within the command area, varying between 33.0 °C and 34.9 °C. The projected temperature pattern exhibits a similar spatial trend for the period 2025–2040, with temperatures ranging from 32.6 °C to 35.9 °C across the watershed. The command area continues to record the highest temperatures in the projected scenario, falling within the range of 34.9 °C to 35.9 °C.

4. Discussion

The results of the present study clearly indicate significant spatio-temporal changes in land use/land cover (LULC) and surface temperature patterns within the watershed and command areas. The observed changes reflect increasing anthropogenic activities, agricultural expansion, and infrastructural development over the study period.

The LULC analysis shows a noticeable conversion of natural land cover classes such as vegetation and water bodies into agricultural land, built-up areas, and barren land. This transformation is more pronounced in the command area compared to the watershed region, which can be attributed to intensified irrigation practices, population pressure, and associated developmental activities. Similar trends have been reported in earlier watershed-based studies, where command areas experience accelerated land cover modification due to improved water availability and human intervention. The LULC graph for both watershed and command area is shown in the figure 7 LULC graph of watershed and command area.

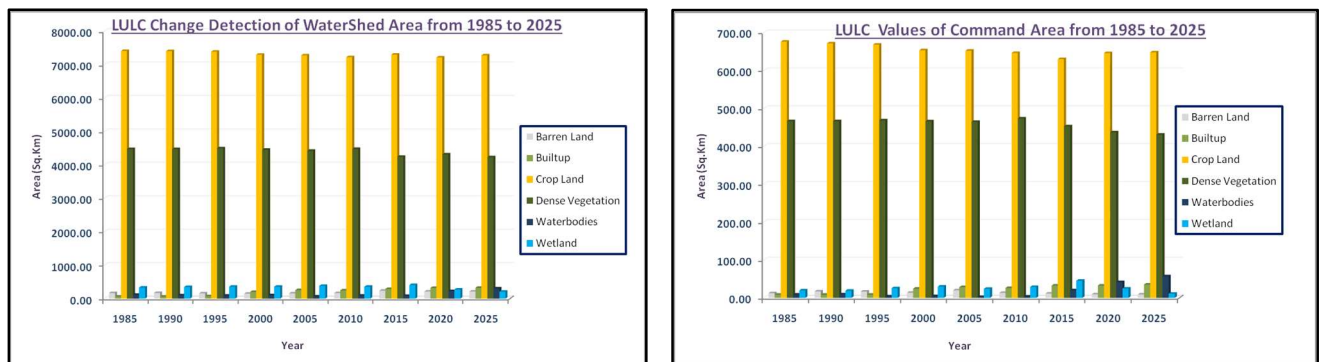


Figure 7 : LULC Graph from 1985 to 2025 for Watershed and Command Area

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The temperature analysis reveals an increasing trend in average surface temperature from earlier years to 2025, ranging approximately from 31.9 °C to 34.9 °C across the watershed. Higher temperatures were consistently observed in the command area, with values reaching up to 34.9 °C. This spatial variation in temperature can be linked to the reduction in vegetative cover and the expansion of built-up and barren land, which enhances heat absorption and reduces evapotranspiration. Vegetated areas, on the other hand, exhibited relatively lower temperatures due to shading and moisture retention.

The projected temperature trends from 2025 to 2040 indicate a continuation of the warming pattern, suggesting potential climate stress on water resources, agriculture, and ecosystem sustainability. The similarity between recent observed temperatures and projected values highlights the urgency of adopting sustainable land management practices. If the current trend of land cover conversion persists, it may further intensify the urban heat island effect and reduce the resilience of the watershed system.

Overall, the results emphasize a strong relationship between LULC changes and temperature variations in the study area. The findings underscore the need for integrated watershed management strategies, including afforestation, protection of water bodies, and controlled urban expansion, to mitigate rising temperatures and maintain ecological balance. These measures are essential for ensuring long-term sustainability of both the watershed and command areas.

5. Conclusion

The present study assessed the spatio-temporal changes in land use/land cover (LULC) and surface temperature patterns in the Kaddam Dam watershed and its command area to understand the impact of dam construction and climatic variations on the regional environment. The results clearly demonstrate that the Kaddam Dam has played a significant role in altering both land cover dynamics and micro-climatic conditions within the study area.

The watershed area exhibits relatively moderate land use changes when compared to the command area. Natural land cover classes such as forest and vegetation have shown gradual reduction, while agricultural and barren lands have moderately increased. These changes are primarily driven by population growth, upstream land conversion, and increasing anthropogenic pressure. However, the presence of the reservoir has helped in maintaining localized moisture conditions and partial stabilization of surrounding land cover in the immediate vicinity of the dam.

In contrast, the command area shows pronounced land use transformation following the commissioning of the Kaddam Dam. Improved irrigation facilities have led to a substantial expansion of agricultural land, particularly irrigated cropland, at the expense of sparse vegetation and fallow land. The increase in built-up areas within the command region further indicates enhanced socio-economic development supported by assured water availability from the dam. These changes highlight the effectiveness of the dam in promoting agricultural productivity and regional development.

Climate data analysis reveals a clear increasing trend in surface temperature across both watershed and command areas, with temperatures ranging from approximately 31.9 °C to 34.9 °C in recent years. Higher temperatures were consistently observed in the command area, which can be attributed to intensive land use practices, reduced vegetative cover, and expansion of built-up surfaces. Although the reservoir contributes to localized cooling effects near the dam through evaporation, its influence is limited spatially and does not fully offset the broader warming trend driven by land cover change and climate variability.

Projected temperature scenarios indicate continued warming in the coming decades, which may pose challenges to water availability, crop productivity, and overall dam performance. Increased temperatures can enhance evapotranspiration losses from the reservoir and irrigated fields, potentially reducing the effective water storage and irrigation efficiency of the Kaddam Dam system.

Overall, the study concludes that while the Kaddam Dam has been effective in transforming the command area through improved irrigation and agricultural expansion, these benefits are accompanied by environmental and climatic challenges. Sustainable watershed management practices, including afforestation, soil conservation, protection of upstream catchments, and efficient water use strategies, are essential to enhance the long-term effectiveness of the dam under changing climatic conditions. Integrating land use planning with climate-resilient water management will be crucial for maintaining ecological balance and ensuring the continued functionality of the Kaddam Dam system.

References

1. Anderson, James R., Hardy, Ernest E., and Roach, John T.,1972. A land-use classification system for use with remote-sensor data: U.S. Geol. Survey Circ. 671, 16 p.
2. Digra, M. – Dhir, R. – Sharma, N. (2022): Land use land cover classification of remote sensing images based on the deep learning approaches: a statistical analysis and review. *Arabian Journal of Geosciences*, 15(10):1003.
3. Eyring, V., et al. (2016). Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. *Geoscientific Model Development*, 9, 1937–1958. <https://doi.org/10.5194/gmd-9-1937-2016>
4. Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, 37(12), 4302–4315. <https://doi.org/10.1002/joc.5086>.
5. <https://irrigation.telangana.gov.in/img/projectspdf/kadam.pdf>
6. K.ramya, P.Sridhar,Assessment Of Land Use / Land Cover (LU/LC) Changes In Kaddam Watershed.al of Engineering Research and Application,ISSN : 2248-9622 Vol. 8, Issue 11 (Part -I) Nov 2018, pp 22-26
7. Lehner, B., Grill G. (2013). Global river hydrography and network routing: baseline data and new approaches to study the world’s large river systems. *Hydrological Processes*, 27(15): 2171–2186. <https://doi.org/10.1002/hyp.9740>.
8. National Remote Sensing Agency., 2004,,Manual on National Land use /land Cover mapping on 1:250,000 scale using multi-temporal IRS P6-AWiFS data, NRSA, Dept. of Space, Govt. of India, Balanagar, Hyderabad.
9. Sridhar, Psridhar & Anil, K. & Raju, J.N.S.S. & Ramana, K.V.. (2025). Land Use and Land Cover Classification using Support Vector Machine Technique: A Case Study of Kaddam Watershed. *Disaster Advances*. 18. 1-6. 10.25303/186da0106.
10. U.S. Geological Survey (USGS). (2023). *EarthExplorer: A web-based data discovery and access system*. U.S. Department of the Interior
11. Yaqian He ., Eungul Lee., Timothy A. Warner., 2017. A time series of annual land use and land cover maps of China from1982 to 2013 generated using AVHRR GIMMS NDVI data, *Remote Sensing of Environment* 199,201-2