International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 07, July 2026)

Satellite-Based Assessment of Long-Term Water Spread Dynamics in Kaddam Reservoir, Telangana, India.

Mood Naresh[1], Manjulavani Kunchepu[2]
[1]*Research Scholar in Department of Civil Engineering, JNTUH, India*
[2]*Professor in Department of Civil Engineering, JNTUH, India*

***Abstract*-- Monitoring long-term variations in reservoir water extent is essential for sustainable water resources management, irrigation planning, and climate change assessment. This study evaluates the spatio-temporal dynamics of the Kaddam Reservoir, Telangana, India, using multi-temporal Landsat satellite imagery acquired between 1990 and 2025. The Modified Normalized Difference Water Index (MNDWI) was employed to accurately delineate the reservoir water surface, and the extracted water bodies were processed in ArcGIS Pro to estimate water spread area. The results reveal considerable temporal variability in reservoir extent over the 35-year study period. The maximum water spread area was observed in 2015 (22.49 km²), followed by 2025 (22.37 km²) and 2020 (22.28 km²), indicating improved reservoir storage conditions during recent years. In contrast, the minimum water spread area occurred in 2005 (7.54 km²), while similarly reduced extents were recorded in 2000 (7.90 km²) and 2010 (7.60 km²), reflecting periods of lower water availability. Earlier observations in 1990 (18.38 km²) and 1995 (18.41 km²) showed moderate reservoir conditions. The MNDWI values successfully distinguished water bodies from surrounding land features, demonstrating the effectiveness of the method for long-term reservoir monitoring. The findings confirm that integrating Landsat imagery, MNDWI, and GIS techniques provides a reliable and cost-effective approach for assessing historical changes in reservoir water extent. The study offers valuable baseline information for reservoir operation, drought assessment, irrigation planning, and sustainable water resources management in the Godavari River basin.**

***Keywords*-- MNDWI; Landsat; Remote Sensing; GIS; Water Spread Area.**

I. INTRODUCTION

Freshwater resources are fundamental to agricultural productivity, domestic water supply, industrial development, ecosystem sustainability, and socio-economic growth. Reservoirs play a critical role in regulating streamflow, storing monsoon runoff, mitigating floods, supporting irrigation, and ensuring water security during dry periods. However, rapid population growth, increasing water demand, climate variability, irregular rainfall patterns, and sedimentation have significantly influenced reservoir storage and water availability worldwide.

Consequently, continuous monitoring of reservoir water dynamics has become an essential component of sustainable water resources management (Pekel et al., 2016; Wulder et al., 2019).

Traditional field-based methods for measuring reservoir water extent are often labour-intensive, expensive, and spatially limited. Recent advances in satellite remote sensing and Geographic Information Systems (GIS) have transformed the monitoring of inland water bodies by enabling rapid, consistent, and cost-effective observations over large spatial and temporal scales (Du et al., 2016). The long-term archive of the Landsat satellite programme provides an unparalleled opportunity to evaluate historical changes in surface water over several decades, making it one of the most valuable datasets for hydrological and environmental studies (Wulder et al., 2019).

Several spectral water indices have been developed to improve the extraction of water bodies from multispectral satellite imagery. The Normalized Difference Water Index (NDWI) proposed by McFeeters (1996) enhances open water features by utilizing the green and near-infrared (NIR) bands. However, NDWI frequently misclassifies built-up areas and moist soils as water, particularly in heterogeneous landscapes. To overcome these limitations, Xu (2006) introduced the Modified Normalized Difference Water Index (MNDWI), which replaces the NIR band with the short-wave infrared (SWIR) band. This modification significantly improves the discrimination of water bodies by suppressing built-up land, vegetation, and bare soil, thereby providing higher mapping accuracy for lakes, reservoirs, wetlands, and floodplains (Xu, 2006).

Recent studies have demonstrated that the integration of Landsat imagery, MNDWI, and GIS techniques provides reliable estimates of long-term changes in reservoir water extent. Global assessments of surface water have shown considerable temporal variability resulting from climate change, land use modifications, and anthropogenic water management practices (Pekel et al., 2016). Similarly, cloud computing platforms such as Google Earth Engine have enabled efficient processing of multi-decadal satellite archives, facilitating large-scale hydrological analyses with improved computational efficiency (Gorelick et al., 2017).

The Kaddam Reservoir (Kaddam Narayana Reddy Project), situated in Nirmal District, Telangana, India, is one of the important irrigation reservoirs in the Godavari River basin. The reservoir supplies irrigation water to thousands of hectares of agricultural land and plays a significant role in regional water resource management. Although the reservoir has substantial socio-economic importance, comprehensive long-term investigations of its water spread dynamics using multi-temporal satellite imagery remain limited. Understanding historical changes in reservoir extent is therefore essential for evaluating hydrological variability, reservoir performance, and future water management strategies.

II. Study Area

The Kaddam Reservoir (Kaddam Narayana Reddy Project) is located on the Kaddam River, a major tributary of the Godavari River, in Nirmal District, Telangana, India (formerly Adilabad District). The reservoir is geographically situated between approximately 19°05′–19°15′ N latitude and 78°30′–78°40′ E longitude(Figure 1). It is one of the important medium irrigation projects in northern Telangana and plays a significant role in supporting agricultural production and regional water security.

The reservoir was constructed to provide irrigation water to the surrounding command area and to regulate seasonal runoff from the Kaddam River catchment. The project was commissioned during the post-independence irrigation development programme and was later renamed the Kaddam Narayana Reddy Project in honour of the former Deputy Chief Minister of Telangana. The reservoir has a Full Reservoir Level (FRL) of approximately 700 ft (213.36 m) and a gross storage capacity of about 7.60 TMC (approximately 215 million m³). Water stored in the reservoir is primarily utilized for irrigation, with additional benefits including groundwater recharge, fisheries, and flood moderation (Government of Telangana, 2024)

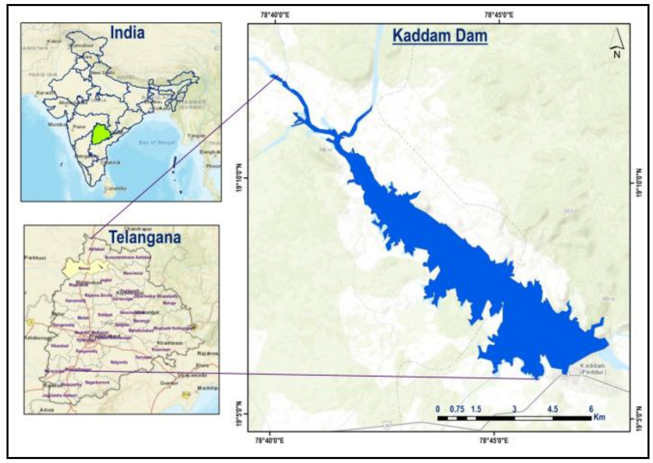

Figure 1. Location of the Kaddam Reservoir (Kaddam Narayana Reddy Project) in Nirmal District, Telangana, India, showing the reservoir boundary

The study area experiences a tropical semi-arid climate, characterized by hot summers, a southwest monsoon season from June to September, and relatively dry winters. The average annual rainfall ranges between 900 and 1,100 mm, with nearly 80% of the precipitation received during the southwest monsoon. Consequently, the reservoir exhibits significant seasonal and interannual fluctuations in water level and water spread area depending on monsoon intensity and inflow conditions.

The catchment is predominantly covered by agricultural land, deciduous forest, scrub vegetation, and scattered rural settlements. Paddy, cotton, maize, and pulses are the major crops cultivated within the command area. The hydrological behaviour of the reservoir is strongly influenced by monsoon rainfall, upstream runoff, irrigation withdrawals, and reservoir operation policies.

In this study, the spatial extent of the Kaddam Reservoir was extracted from multi-temporal Landsat satellite imagery acquired between 1990 and 2025. Reservoir water boundaries were delineated using the Modified Normalized Difference Water Index (MNDWI)and analysed in QGIS to quantify long-term changes in water spread area.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 07, July 2026)

The study provides a comprehensive assessment of historical reservoir dynamics and contributes valuable information for sustainable water resources management, irrigation planning, and climate adaptation in the Godavari River basin.

III. 3. MATERIALS AND METHODOLOGY

3.1 Satellite Data

Multi-temporal Landsat satellite imagery was used to investigate the long-term dynamics of the Kaddam Reservoir water spread area. Cloud-free images representing similar seasonal conditions were selected to minimize seasonal variability and ensure consistency in temporal analysis. Landsat imagery was obtained from the United States Geological Survey (USGS) Earth Explorer** archive. The study utilized images from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), and Landsat 9 Operational Land Imager-2 (OLI-2), covering the period from 1990 to 2025..

All satellite images were geometrically corrected, radiometrically calibrated, and atmospherically corrected (Collection 2 Level-2 Surface Reflectance products) before analysis. The Landsat archive provides a spatial resolution of 30 m, which is appropriate for monitoring medium-sized reservoirs and evaluating long-term changes in water spread area (Wulder et al., 2019).

3.2 Water Body Extraction Using MNDWI

The Modified Normalized Difference Water Index (MNDWI) proposed by Xu (2006) was employed to delineate the reservoir water surface. Compared with the Normalized Difference Water Index (NDWI), MNDWI replaces the Near Infrared (NIR) band with the Shortwave Infrared (SWIR) band, significantly improving the discrimination of open water from built-up areas, vegetation, and exposed soil.

The MNDWI was calculated as:

MNDWI}=Green-SWIR/ Green+SWIR

For Landsat imagery, the following band combinations were used:

Landsat 5 TM: Green (Band 2) and SWIR1 (Band 5)

Landsat 7 ETM: Green (Band 2) and SWIR1 (Band 5)

Landsat 8 OLI:Green (Band 3) and SWIR1 (Band 6)

Landsat 9 OLI-2:Green (Band 3) and SWIR1 (Band 6)

Raster calculations were performed in QGIS to generate MNDWI images. Pixels with positive

Table 1 Landsat satellite data used in the study

Sensor /Product	Dataset Used	Date of Acquisition	No of Bands	Data Characteristics
Landsat-5	Supervised Classification -LULC	02nd March 1985 01st January 1990 22nd January 1995	04 04 07	Radiometrically corrected, cloud-free, multispectral data
Landsat-7		29th February 2000	08	
Landsat-5		17th January 2005 31st January 2010	07	
Landsat-8 OLI-TIRS		29th January 2015 11th January 2020	11	
Landsat-9 OLI-2		18th December 2025	11	
World Clim-Bioclimatic variables	Rainfall & Temperature	2000 to 2025		Gridded climatic surfaces
World Clim CMIP6	Projected Rainfall & Temperature	2026 to 2040		Downscaled climate projections

MNDWI values were classified as water, while non-water pixels were excluded using an appropriate threshold determined through visual comparison with true-colour satellite imagery.

3.3 GIS Processing

The extracted water masks were converted into polygon features using QGIS. Small isolated pixels and classification noise were removed through post-processing to improve the delineation of the reservoir boundary. The resulting polygons were clipped using the reservoir boundary shapefile, and the water spread area was calculated in square kilometres (km²) using the Calculate Geometry tool.

The spatial analysis workflow consisted of:

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 07, July 2026)

1. Downloading Landsat Surface Reflectance images.
2. Image pre-processing.
3. Calculation of MNDWI.
4. Water body extraction using thresholding.
5. Raster-to-polygon conversion.
6. Clipping with the reservoir boundary.
7. Calculation of annual water spread area.
8. Temporal comparison of reservoir extent from 1990–2025.

3.4 Accuracy Assessment

The extracted water boundaries were visually validated using false-colour composite images and high-resolution imagery available in Google Earth. Reservoir boundaries derived from MNDWI were compared with the corresponding satellite images to ensure accurate delineation of the water surface. The consistency of extracted water spread areas across different years indicates that the adopted methodology is suitable for long-term reservoir monitoring.

IV. Results And Discussion

4.1 Spatio-Temporal Variation of Water Spread Area

The Modified Normalized Difference Water Index (MNDWI) successfully delineated the Kaddam Reservoir water surface for all selected years between 1990 and 2025. The extracted water boundaries corresponded well with the true-colour Landsat imagery, demonstrating the capability of MNDWI to distinguish water from surrounding vegetation, bare land, and built-up areas. The generated water masks were converted into polygons in QGIS, and the water spread area was calculated for each observation year.

The results indicate considerable temporal variability in the reservoir water spread area throughout the study period (Table 2 and Figure 2). The reservoir covered 18.38 km² in 1990 and remained relatively stable at 18.41 km² in 1995, suggesting favourable hydrological conditions during the early part of the study period. A substantial decline was observed in 2000, when the water spread area decreased to 7.90 km², representing a reduction of approximately 57% compared with 1995. A similar condition persisted in 2005, when the reservoir reached its minimum recorded water spread area of 7.54 km². In 2010, the water spread area remained low at 7.60 km², indicating prolonged periods of reduced inflow and limited reservoir storage.

A significant recovery in reservoir extent was observed after 2010. The water spread area increased markedly to 22.49 km² in 2015, representing the maximum value recorded during the study period.

The reservoir maintained a high water extent in 2020 (22.28 km²) and 2025 (22.37 km²), suggesting improved storage conditions during the recent decade. These results indicate a clear transition from relatively dry reservoir conditions during 2000–2010 to substantially wetter conditions after 2015.

The temporal pattern demonstrates that reservoir water spread is highly responsive to interannual climatic variability, particularly fluctuations in monsoon rainfall and upstream runoff. Since the Kaddam Reservoir depends primarily on monsoon inflows from its catchment, variations in rainfall directly influence reservoir storage and surface water extent. The considerable increase in water spread area after 2015 is consistent with periods of improved monsoon rainfall reported across Telangana and highlights the importance of seasonal precipitation in regulating reservoir behaviour.

4.2 Performance of MNDWI for Water Extraction

The MNDWI approach provided reliable delineation of the reservoir boundary for all analysed Landsat images. The index effectively enhanced open water while suppressing surrounding vegetation, exposed soil, and built-up features. Compared with conventional NDWI, MNDWI produced cleaner reservoir boundaries with fewer classification errors, particularly along shallow shoreline regions. The consistency of extracted water boundaries across multiple Landsat sensors demonstrates that MNDWI is an effective technique for long-term reservoir monitoring using multi-temporal satellite imagery.

The use of Landsat Surface Reflectance products further improved classification accuracy by minimizing atmospheric effects and ensuring consistency among different satellite missions. The integration of remote sensing and GIS enabled rapid estimation of reservoir water spread area without the need for extensive field measurements.

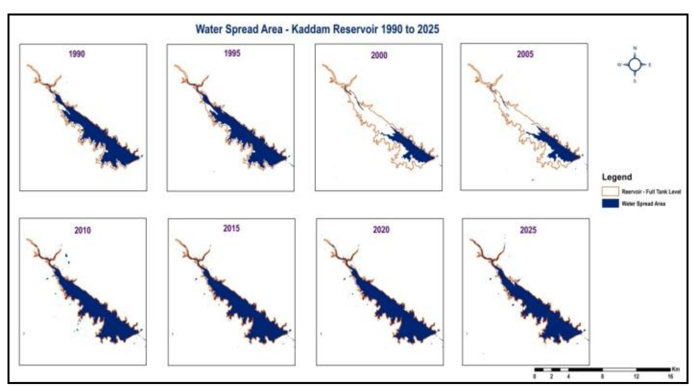

Figure 2: Spatio-Temporal Variation of the Kaddam Reservoir Water Spread Area Derived from MNDWI (1990–2025)

IJRDET
International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 07, July 2026)

Table 2 : MNDWI Values and Corresponding Water Spread Area of Kaddam Reservoir (1990–2025)

	MNDWI Values		
Year	Low	High	Spread Area in Sq .Km
1990	-0.58	0.85	18.38
1995	-0.58	0.93	18.41
2000	-0.59	0.76	7.9
2005	-0.87	0.94	7.54
2010	-0.76	0.75	7.6
2015	-0.37	0.25	22.49
2020	-0.33	0.23	22.28
2025	-0.35	0.22	22.37

4.3 Implications for Reservoir Management

Long-term monitoring of reservoir water spread area provides valuable information for irrigation planning, drought preparedness, and sustainable water resources management. The observed decline in reservoir extent during 2000–2010 indicates periods when water availability may have been constrained for agricultural and domestic use. Conversely, the substantial increase in water spread area after 2015 reflects improved reservoir storage conditions, which are beneficial for irrigation supply and regional water security.

The findings demonstrate that satellite-based monitoring offers a practical and cost-effective approach for assessing reservoir dynamics over extended periods. Such information can support government agencies in evaluating reservoir performance, optimizing water allocation, and developing adaptive management strategies under changing climatic conditions.

Overall, the integration of Landsat imagery, MNDWI, and GIS techniques proved to be an effective framework for monitoring historical changes in the Kaddam Reservoir.

The methodology is readily transferable to other reservoirs within the Godavari River basin and can contribute to regional water resource planning and climate resilience initiatives.

REFERENCES

[1] Central Water Commission. (2023). Water Resources Information System (WRIS), Reservoir Information, Ministry of Jal Shakti.

[2] Central Water Commission. (2023). National Register of Large Dams, Government of India.

[3] Du, Y., Zhang, Y., Ling, F., Wang, Q., Li, W., & Li, X. (2016). Water bodies' mapping from Sentinel-2 imagery with Modified Normalized Difference Water Index at 10-m spatial resolution. Remote Sensing, 8(4), 354. https://doi.org/10.3390/rs8040354

[4] Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment, 202, 18–27. https://doi.org/10.1016/j.rse.2017.06.031.

[5] Government of Telangana. (2024). Handbook of Irrigation Projects, Irrigation & CAD Department, Government of Telangana.

[6] Government of Telangana. (2024). Integrated Seasonal Monitoring System (ISMS): Major Reservoir Status Reports.

[7] India-WRIS. (2023). Water Resources Information System (WRIS), Ministry of Jal Shakti, Government of India.

[8] McFeeters, S. K. (1996). The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. International Journal of Remote Sensing, 17(7), 1425–1432.

[9] Pekel, J. F., Cottam, A., Gorelick, N., & Belward, A. S. (2016). High-resolution mapping of global surface water and its long-term changes. Nature, 540(7633), 418–422. https://doi.org/10.1038/nature20584

[10] Wulder, M. A., Loveland, T. R., Roy, D. P., Crawford, C. J., Masek, J. G., Woodcock, C. E., ... & Zhu, Z. (2019). Current status of Landsat program, science, and applications. Remote Sensing of Environment, 225, 127–147. https://doi.org/10.1016/j.rse.2019.02.015

[11] Xu, H. (2006). Modification of Normalized Difference Water Index (MNDWI) to enhance open water features in remotely sensed imagery. International Journal of Remote Sensing, 27(14), 3025–3033. https://doi.org/10.1080/01431160600589179.