



RESEARCH ARTICLE

Monitoring surface water dynamics of Chembarambakkam tank during major crop seasons using Sentinel-1 SAR data

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Abstract

Water availability in irrigation reservoirs plays an important role in agriculture productivity all over the world, especially in monsoon dependent regions like Tamil Nadu, India. Chembarambakkam tank is a prominent water reservoir situated in Kancheepuram district that serves as an important source of irrigation and drinking water for the areas surrounding it, including the Chennai city. Temporal variation in the tank's surface area affects cropping patterns and irrigation directly. Estimation and exploration of the spatiotemporal pattern of water spread area of Chembarambakkam tank during the 3 major crop seasons of kharif (June–September), rabi (October–January) and summer (February–May) using multi-temporal Sentinel-1 Synthetic Aperture Radar (SAR) images is the focus of this study. Sentinel-1 SAR data were processed to obtain waterbodies using backscatter thresholding technique for VV polarisation. Monthly and seasonal comparisons were conducted to evaluate the fluctuations by computing water spread areas. It was noted that there was a substantial reduction in water spread area by 1752.24 ha from June to September, which indicates a substantial reduction during the kharif season. Minimum water extent was realised in October at the onset of the rabi season (1740.08 ha) and maximum spread was released in January, which indicates recovery of water due to the northeast monsoon. In the summer season, additional reduction in water spread was realised, with the estimated reduction being 1915.68 ha by May. The findings highlight significant variations in surface water availability, which has direct influence on irrigation planning, crop selection and agricultural sustainability in the region. The study demonstrates the potential of Sentinel-1 SAR imagery for near real-time tracking of surface water bodies under evolving climatic conditions and indicates the importance of including remote sensing-based water estimation in regional water resource and agricultural planning.

Keywords: crop seasons; SAR; Sentinel 1A; water resource monitoring; water spread area

Introduction

Tank irrigation is one of the most important and ancient forms of irrigation method to collect and store the water from the rainfall, streams or rivers in many semiarid regions of south and Southeast Asia. In India especially in south Indian states like Tamil Nadu, Karnataka, Telangana and Andhra Pradesh have more than one-third of the total irrigated area (1). This stored water then utilised in Agricultural field, livestock maintenance and household management. However, over the past few decades, their significance has decreased rapidly. Along with the other issues, the green revolution and its increased productivity have put pressure on farmers and government organisations to use more dependable water sources, such as deep bore irrigation, lake and canals for agriculture. Understanding the annual variability of water spread in relation to crop seasons is essential for sustainable water allocation, irrigation planning and agricultural advisories in the region.

Water bodies are liable to extreme uses, regularly mapping and monitoring is important to determine the availability of water resources at the sub basin, regional, state and country level for

planning and management of water resources in India (2). In general, the storage capacity of tanks, determined by the size, shape, slope of the tank bed, water supply and other factors. However, it will be difficult to identify and estimate the changes in these parameters through field-based measurement as it involves field surveys which is a costly, time consuming method and require immense amount of man power along with advanced instruments (3). To overcome this problem numerous satellite sensors capable of monitoring water body dynamics were launched in the past decades.

Remote sensing technology is widely used for mapping, extracting and monitoring changes and real-time information acquisition for surface feature. This analysis technique in the water spread area has proven a cost effective and less time-consuming tool in both qualitatively as well as quantitatively (4). For surface water studies both optical (5–8), hyperspectral (9) and microwave sensors are used. Due to cloud cover the optical satellite sensors cannot provide data during monsoon season and limited to daytime as it is a passive remote sensing technique, thereby reducing its effectiveness. On the other hand, satellite-based synthetic aperture radar (SAR) data is widely used in surface water

research due to its day-and-night sensing capabilities, its ability to capturing data under all weather conditions, including rain and cloud cover and ability to detect flooded areas (10). Some of the other technique such as proximal sensing through unmanned aerial vehicles (UAVs) such as bathymetry radar can be costly.

Several methods have shown effective results in monitoring and mapping waterbodies, including thresholding, supervised/unsupervised classification, decision tree method, image segmentation, fuzzy classification and deep learning. With SAR based satellite data, water monitoring can be approximated and can be utilised for several baseline policy decisions. Several other studies that utilised SAR datasets for water parameter retrievals, such as flood mapping and water body monitoring was found to be effectively estimated and tracked, limited studies have focused on seasonal tank dynamics (11). The aim of the study is to detect changes in water spread area of Chembarambakkam lake in kharif, rabi, summer period by incorporating thresholding algorithms on Sentinel -1 A (SAR) imagery using ArcGIS platform from 2024 to 2025.

Material and methods

Study area

The current study encompassed one of the major irrigation tanks i.e., Chembarambakkam tank, as depicted in (Fig. 1). The Chembarambakkam tank was the first artificial lake built by Rajendra Chola I. It was in Kanchipuram district in Tamil Nadu state, India and lies between 13.01158° N Latitude - 80.06063° E Longitude. The full tank level is 85.40 ft. (26.03 m) and the tank capacity is 3645 million cubic ft or 3.64 TMC ft or 103215 million L (12). Historically, lands around the lake have been notified as ayacut and used for agriculture, but agricultural activity in the ayacut has reduced drastically in recent decades due

to land conversion and uneconomic production, as documented in the Second Master Plan of CMDA (Volume 3) (13). In the local agro-ecological context (Kancheepuram, Tiruvallur), paddy is the dominant crop, with groundnut, black gram, green gram and sugarcane as important rotations; paddy aligns with the SW monsoon (June–September) and NE monsoon (October–December) rainfall regimes typical of the North-Eastern Zone (14–16). More broadly in Tamil Nadu, tank irrigation systems are designed to supply water close to the command area (ayacut) and predominantly support small and marginal farmers, underscoring the sensitivity of local livelihoods to seasonal tank storage (17).

Water spread area analysis

Sentinel-1 A (SAR) Data

In this research, Sentinel 1A (SAR) is a microwave data which was acquired from the Copernicus browser website (<https://browser.dataspace.copernicus.eu>). It is a sun synchronous near polar orbit satellite launched in 2014, by European Space Agency (ESA). An imaging radar mission that collects SAR data. It operates in C-band with both H and V polarisations, emphasising the Interferometric Wide swath (IW) mode over land and it has temporal coverage of 12 days. Previous researches suggested that in Sentinel-1A VV polarisation favourable for detecting surface water than VH polarisation (18–21). The datasets with the beginning and ending months of the kharif (June–September), Rabi (October–January) and Summer (February–May) seasons

Table 1. Sentinel 1A data acquisition dates during kharif, rabi and summer seasons for Chembarambakkam tank

Sl.No.	Season	Date of acquisition
1.	Kharif (June–September)	21.06.2024 13.09.2024
2.	Rabi (October–January)	19.10.2024 23.01.2025
3.	Summer (February–May)	16.02.2025 11.05.2025

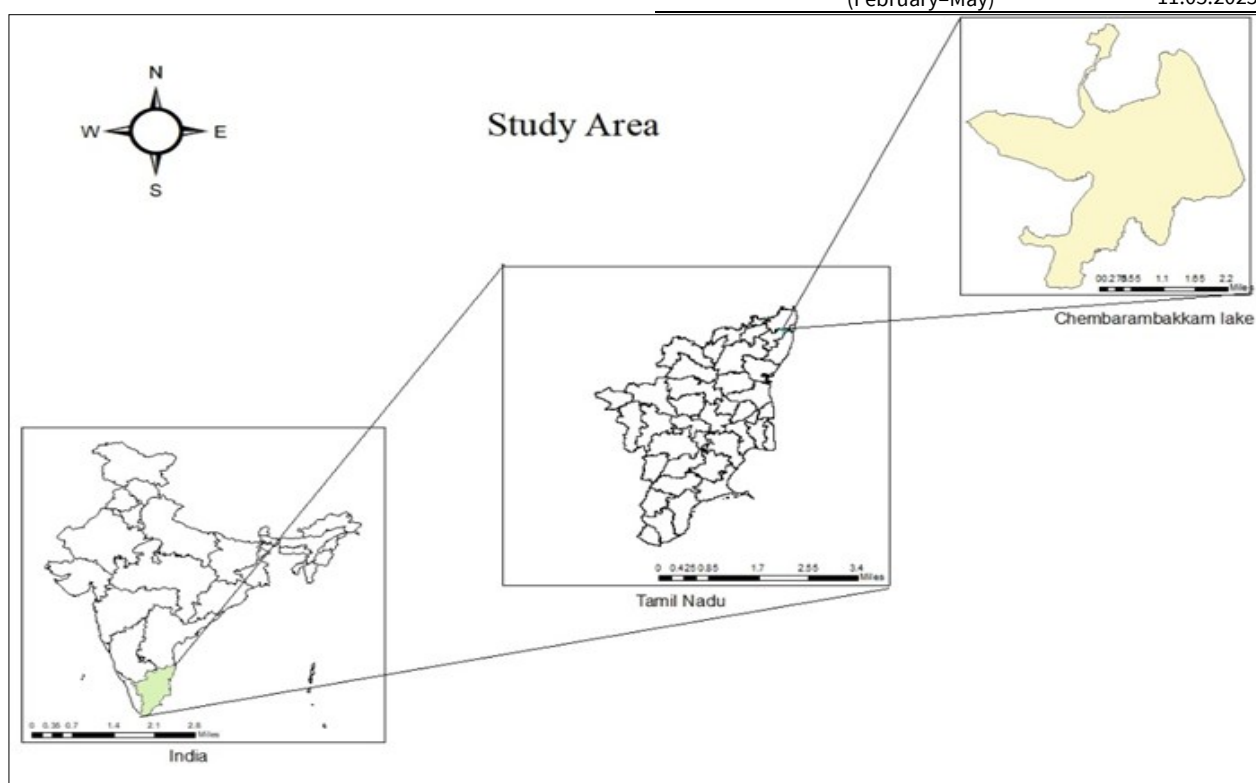


Fig. 1. Study area map showing the location of the selected tanks in Cuddalore district, Tamil Nadu, India [Source: diva-gis website- <https://diva-gis.org/data.html>].

were taken for this study (Table 1). This study focused on a single agricultural year (2024–2025) to evaluate the applicability of Sentinel-1 SAR data in monitoring surface water dynamics of Chembarambakkam tank. To interpret better seasonal water spread variations derived from Sentinel-1 SAR, corresponding rainfall data were obtained from the India Meteorological Department (IMD, 0.25° daily gridded rainfall product) as mentioned in the (Table 2). While inter-annual variation in monsoon intensity is indeed significant in Tamil Nadu, the aim of this work was to demonstrate a methodology for seasonal monitoring rather than long-term trend analysis. Multi-year datasets could further strengthen understanding of inter-annual variability and this remains an important direction for future research.

Pre-processing of Sentinel 1 A

The pre-processing was done with MAPscape software developed by SARMAP (Switzerland). This software contain a fully automated processing chain, created by previous researchers, is employed to transform multi-temporal space-borne SAR data into terrain-geocoded σ^0 values (22). However, the methodology is not tool-specific and can be implemented using open-source platforms such as the Sentinel Application Platform (SNAP) and Google Earth Engine, which support equivalent preprocessing and threshold-based water extraction steps. Thus, the approach is fully transferable and reproducible across widely available platforms. The preprocessing steps include the following (23): radiometric calibration, speckle filtering, strip mosaicking, time-series terrain geocoding, co-registration, normalisation, anisotropic non-linear diffusion (ANLD) filtering and removal of atmospheric attenuation,

as illustrated in Fig. 2 (24, 25). The ANLD filtering was chosen for its ability to perform adaptive smoothing on local gradients in the images (26), reducing speckle in homogeneous areas such as open water surfaces while preserving the edges and boundaries between water and land. The ANLD filtering is commonly used in reservoir mapping, where accurate delineation of shorelines and small water patches is required.

Thresholding

Different research studies have utilised a thresholding approach with SAR data to detect water and non-water area for estimating water spread area (11, 27). Thresholding algorithms on SAR images are most used because of their efficiency and take up very less time for processing. Histogram thresholding is the most widely used technique for the detection of water from non-water pixel. The optimal threshold ranges are obtained from the average radar backscatter signatures of different water bodies in different polarisations (28). The backscattering coefficient of water in Sentinel-1A data ranges from -6 to -15 dB for WV polarisations and -15 to -24 dB for VH polarisation (29). By using a manual fixed dB value of -15 for WV polarisations was utilised for assessing the dynamics of water spread in this study. A threshold of -15 dB was selected based on the bimodal distribution of pixel values, where water surfaces consistently exhibited low backscatter (30). Unlike automated methods such as Otsu's or adaptive thresholding, a fixed threshold was adopted to ensure consistency across multi-temporal datasets and to avoid variability in class separation due to seasonal changes in backscatter characteristics. The results were validated by ground truth data. Previous studies used the thresholding technique for mapping the water spread area and found it effective (18, 31).

Table 2. Seasonal wise rainfall

Season	Total rainfall (mm)
Kharif	273
Rabi	342
Summer	93

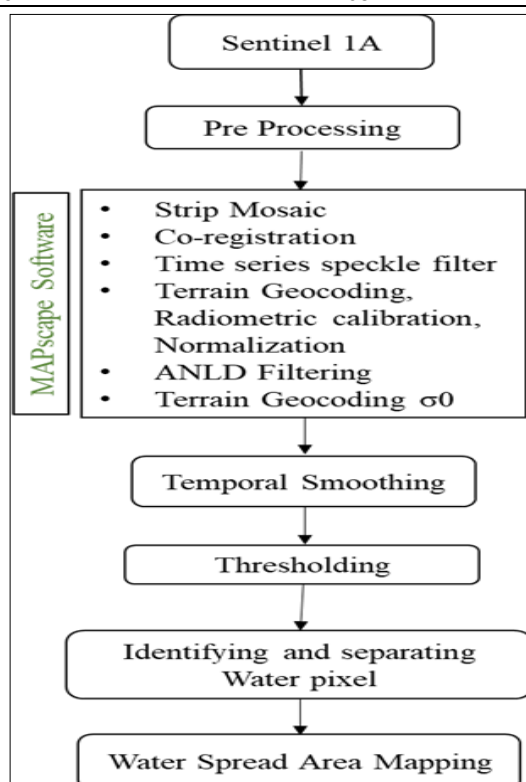


Fig. 2. Methodology flow chart for estimating water spread area using Sentinel-1A SAR data.

Results and Discussion

In the present study SAR data for kharif, rabi and summer seasons were downloaded from Sentinel-1A satellite and pre-processed with MAPscape software. Based on backscattering values obtained after pre-processing the objects on the earth can be recognised for example, the higher backscattering values (brighter tone) signify buildings and cities and lower (darker tone) backscattering values indicate water pixels. The intermediate backscatter values represent vegetation, barren land and dry soils.

Water spread area estimation

The results obtained for the spatio-temporal fluctuation of the water spread area of the Chembarambakkam tank have been investigated for starting and ending months of kharif, rabi and summer crop seasons between the years 2024–2025 are reviewed in this section. The water spread area for the kharif, rabi and summer seasons has expanded and reduced during the study period, as seen in the figure (Fig. 3) shows that during kharif, the water spread decreased from 1919.68 ha in June to 1752.24 ha in September, despite a cumulative seasonal rainfall of 273 mm. This decline is largely attributable to increasing irrigation withdrawals for crops such as rice and maize, combined with evapotranspiration losses. Although initial rainfall and runoff enhance storage, progressive demand during the peak growth stage leads to surface water reduction, potentially resulting in water stress in the absence of supplemental irrigation. Similar reductions in water spread during the late kharif period have been documented in other tank-irrigated systems of Tamil Nadu, where limited supplemental irrigation often leads to crop water stress and

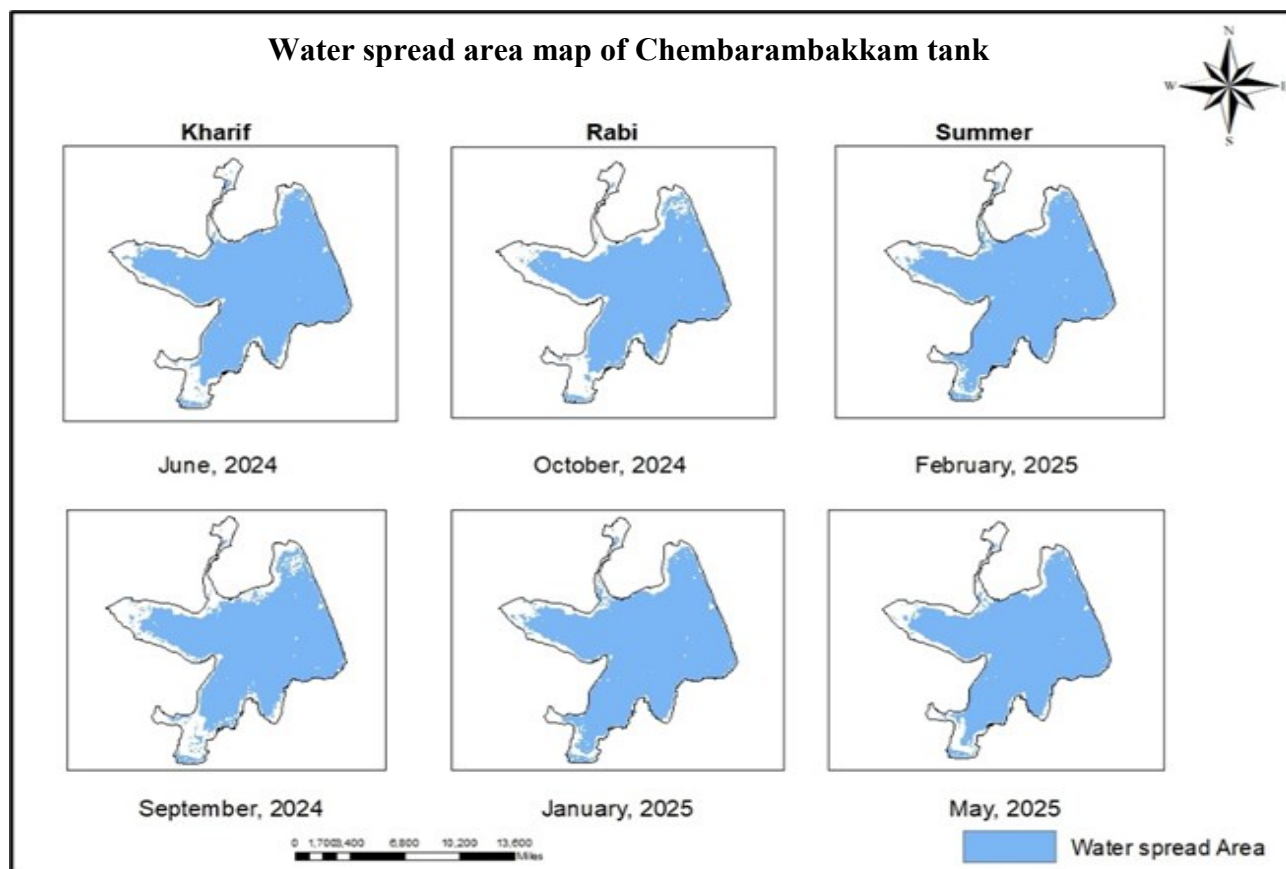


Fig. 3. Seasonal water spread area of Chembarambakkam tank during kharif (June–September 2024), rabi (October 2024–January 2025) and Summer (February–May 2025).

yield variability (11, 16). In rabi, the lowest water spread was observed in October (1740.08 ha), coinciding with delayed recharge after the southwest monsoon and residual depletion from the preceding season. However, by January, the spread expanded to 1970.08 ha, supported by the northeast monsoon rainfall (342 mm, October–January). This seasonal replenishment highlights the dominant role of the northeast monsoon in Tamil Nadu, as observed in other studies that reported tank refilling and improved water availability for rabi crops such as paddy and pulses (32, 33). The increase in spread during January is particularly important, as it sustains irrigation during late crop stages, reducing vulnerability to water stress. The summer season is typically characterised by high evapotranspiration and limited rainfall. In 2024, rainfall was only 93 mm, yet the tank maintained a relatively high spread of 1967.92 ha in February, before declining to 1915.68 ha in May. This persistence indicates the buffering role of Chembarambakkam, which provides water security through controlled releases and storage retention, a trend also noted in similar tank studies across Cuddalore and Cheyyar sub-basins (11, 27). In contrast, summer 2025 recorded unusually high rainfall (217 mm), that helps to maintaining the storage and highlights the tank's buffering role during low-rainfall months. Overall, these results suggested that rainfall is the primary driver of seasonal water spread in Chembarambakkam, but tank operation and evapotranspiration processes strongly influence intra seasonal dynamics. The lowest spread in October and the highest in January as shown in Table 3. This study demonstrated the combined effects of seasonal recharge and regulated storage. These results align with earlier work in South Indian tanks that reported maximum water spread during post-monsoon and minimum water spread during pre-monsoon seasons (16, 27, 32). For irrigation planning, the results suggest that supplemental water management during late kharif and early rabi is

Table 3. Seasonal wise water spread area for Chembarambakkam lake

Season	Month	Water spread area
		Chembarambakkam lake (ha)
Kharif	June	1919.68
	September	1752.24
Rabi	October	1740.08
	January	1970.08
Summer	February	1967.92
	May	1915.68

critical to sustaining crop productivity, while efficient summer storage is necessary to buffer against rainfall deficits.

Conclusion

This study used Sentinel-1 SAR data to monitor seasonal water spread dynamics in Chembarambakkam tank during 2024–2025. Clear spatio-temporal fluctuations were observed: water spread declined from June (1919 ha) to September (1752 ha) in kharif despite 273 mm rainfall, reached its lowest in October (1740 ha) and peaked in January (1970 ha) supported by 342 mm of northeast monsoon rainfall. In summer 2024, the tank maintained 1968–1916 ha of water spread despite only 93 mm rainfall, while unusually high summer 2025 rainfall (217 mm) sustained storage. These results confirm that rainfall is the primary driver of seasonal tank dynamics, while evapotranspiration and irrigation demand shape intra-seasonal variation. The approach demonstrates the potential of SAR for operational monitoring of semi-arid irrigation systems, with direct implications for crop planning and water management. This study highlights the potential of Sentinel-1 SAR images and MAPscape based methods as an effective and reliable solution, for all kind of weather events such as cloudy, rainy etc., where optical data are often unreliable. Despite minor

uncertainties like speckle noise, mixed pixels at water boundaries and seasonal backscatter variations along with the limitation of a single year study, the methodology is scalable, transferable and suitable for near real-time water resource assessment and the methodology is replicable using open-source tools. Future studies should extend to multiple year datasets and integrate optical indices and dual polarisation to SAR for better understanding inter annual variability and strengthen crop water assessments by adding rainfall runoff models with crop yield models to enhance the predictions and support climate resilient agricultural water management.

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Authors' contributions

PI and KPR conceptualised the study, collected and curated data and prepared the original draft. PI, KPR, SP, RK, SS and APS contributed to writing, reviewing and editing. Supervision was provided by PI, KPR, PS, RK, SS and APS. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly software for grammatical corrections. After using this tool, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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