ESTIMATION OF WATER SPREAD AREA IN SELECTED TANKS OF CUDDALORE DISTRICT OF TAMILNADU USING SENTINEL-1A SAR DATA

Abstract:

The most important aspect of water resource planning and management is mapping and regular monitoring of surface water bodies. Remote sensing has become most widely used method for measuring and monitoring of water body dynamics due its temporal and spatial availability of high-resolution data. A study was conducted to map and estimate the water spread area in the tanks of Kattumannarkoil block of Cuddalore district of Tamil Nadu using Sentinel-1A SAR satellite data. European Space Agency's Sentinel-1A data provides high quality SAR data which is used widely for monitoring of crop and water resources. The acquisition and preprocessing of satellite data was done using Google Earth Engine. The obtained satellite image from Google Engine was processed using ArcGIS. The water spread area was derived from the processed data using thresholding approach. The back-scattering values generated through pre-processing ranges from -18.00 db to -28.12 db for August 2022 (Pre-rainy season), -15.85 to -26.96 for December 2022 (Post-rainy season) and -15.55 to -24.82 for April 2023(Summer time). The estimated water spread area in selected 12 Tanks were 37.191 ha, 58.34 ha and 59.971 ha on 19th August 2022, 17th December 2022 and 16th April 2023 respectively..

Keywords: Remote sensing of water, Sentinel-1A SAR, Thresholding, Google Earth Engine.

Introduction:

Water is a crucial element in the Earth's atmosphere, playing a vital role in sustaining life and supporting the needs of various organisms. It encompasses approximately 70% of the Earth's surface, appearing in the form of Surface water resources, seas, oceans, and other water bodies. Surface water resources, such as rivers, ponds, lakes, channels, reservoirs, and dams, are essential for socioeconomic development, environmental balance, and serve as irreplaceable natural assets for human activities like agriculture, industry, households, recreation, and the environment (Song et al., 2016; Pekel et al., 2016). Water holds great significance as an input for agricultural production, contributing significantly to food security. Water resource management involves the construction of dams or reservoirs along rivers to create storage capacity and regulate water flow.

An integral aspect of water resource planning and management is the mapping and regular monitoring of water bodies at river basins, sub-basins, lakes, ponds, and similar entities (Yun et al., 2016). Traditional methods of measuring water spread area typically involve costly and time-consuming field surveys, requiring substantial manpower and sophisticated instruments. To address these challenges, satellite data has emerged as a valuable tool. Over the past few decades, numerous satellite sensors capable of monitoring waterbody dynamics have been deployed. Remote sensing has become the most widely used method for measuring and monitoring waterbody dynamics due to its timing and accuracy (Dumitru et al., 2015 and Garcia-Pintado et al., 2015). Both Optical and Microwave sensors are utilized for surface water studies. Optical remote sensing is suitable for monitoring changes in water surface areas due to its availability. However, it is limited by cloud cover and cannot provide data during monsoon season, thereby reducing its effectiveness. In contrast, satellite-based Synthetic Aperture Radar (SAR) data is extensively employed in surface water studies due to its all-weather capabilities, and its ability to detect flooded areas covered by vegetation. Sentinel-1A SAR Ground Range Detected (GRD) data in VV polarization is commonly used for its high resolution (10m) and greater accuracy in surface water monitoring (Èotar et al., 2016 and Pham et al., 2017). Several methods have proven effective in monitoring waterbodies and mapping, including thresholding (McFeeters et al., 1996), supervised/unsupervised classification (Lu et al., 2007), Decision tree method (Chen et al., 2015), Image segmentation (Jiang et al., 2014), Fuzzy classification (Martinis et al., 2015), and deep learning (Bonafilia et al., 2020). Thresholding techniques applied to SAR images for surface water mapping are simple, widely used, efficient, computationally less time-consuming, and effective (Gstaiger et al., 2012; Kuenzer et al., 2013).

Materials and Methods:

The study area is the lower Vellar sub-basin is a significant tributary of the Vellar Basin, covering a total area of 1756.186 square kilometers. It encompasses seven blocks in the Cuddalore District, namely Vridhachalam, Kammapuram, Nallur, Mangalore, Kattumannarkoil, Melbhuvanagiri, and Keerapalaiyam. Additionally, it includes three blocks in the Kallakurichi district (Chinnasalem, Thirunavalur, Ulundhurpet) and two blocks in the Perambalur District (Veppenthattai and Veppur). The specific study area selected for analysis is the Kattumannarkoil block in the Cuddalore District, which comprises 12 water storage tanks (as shown in Table 1) with a total tank area of 834.863 hectares. (Figure 1) .The methodology adopted for this study is shown in Figure 3.

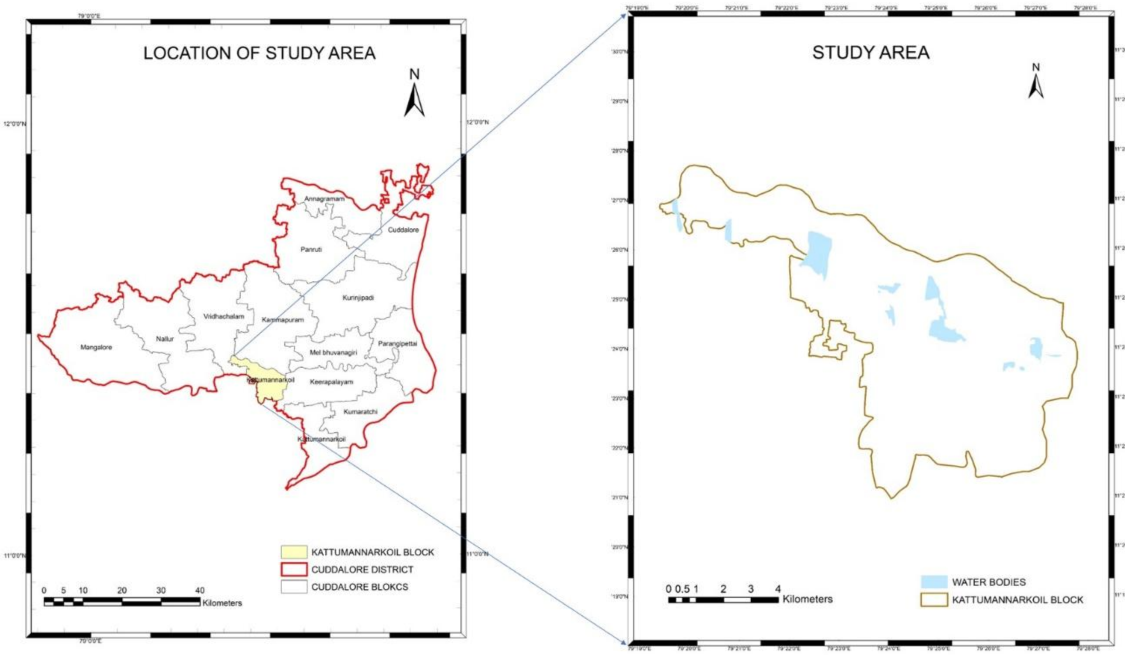

Figure.1 location of water tanks in kattumannarkoil block of Cuddalore District

Table 1. List of Tanks in Kattumannarkoil Block of Cuddalore District

S.No	Tank Name	Area occupied (In Hectares)
1.	Ananthakudi Tank	51.56
2.	Gunamangalam Tank	299.57
3.	Kaliyankuppam Tank	5.80
4.	Keelapuliankudi Tank	038.65
5.	Kokkarasan pettai Tank	43.60
6.	Melapuliankudi Tank	1.70
7.	Nagarapadi Tank	164.12
8.	Sathavattam Tank	6.48
9.	Selavizhi Tank	22.39
10.	Sirunedunj eri Tank	66.53
11.	Sriputhur Tank	103.26
12.	Srivakkaramar Tank	31.23

Methodology: Satellite data used

For the present study Sentinel-1A SAR C-Band (5.405GHz), satellite data acquired in GRD Interferometric Wide Swath (IW) Mode was utilized. The satellite data has dual polarization capacity, including HH+HV and VV+VH, and it provides a spatial resolution of 5m*20m. The swath width of the image is 250 kilometers, and its temporal resolution is approximately 6 to 12 days. Previous research findings indicate that VV polarized data offers significantly higher accuracy compared to VH polarized data for analyzing surface water (Clement et al., 2017). Hence the VV polarized SAR DATA was used here Three datasets were utilized in this study, each taken at 4-month interval, specifically in August 2022 (pre-rainy season), December 2022 (post-rainy season), and April 2023 (summer season).

Processing of Sentinel 1A Satellite data

The pre processing was done with Google Earth Engine tool which demonstrates a methodology for working with satellite data. The code starts by creating a variable, which represents an image collection obtained from the 'COPERNICUS/S1_GRD' dataset. The collection is filtered to include only VV polarization and images captured in the IW (Interferometric Wide Swath) mode. Furthermore, the code filters the images based on a specific date range and an area of interest defined by the variable. The resulting collection is then printed to the console for examination.

Next, the code generates a median composite image, by calculating the median values from the filtered image collection. This composite is clipped to the defined area of interest. The composite image is added to the map for visualization using the `Map.addLayer()` function, and the map display is centered on the area of interest using `Map.centerObject()` function .

Finally, the code exports the image to Google Drive using the `Export.image.toDrive()` function. The exported image is assigned a description and is saved in a specified folder in the Google Drive. The overview of the web interface adopted for the study is presented in the Figure 2. The region of interest, coordinate reference system (EPSG:4326), and scale are also defined for the exported image. This method provides a systematic approach for filtering, processing, visualizing, and exporting satellite data, allowing for further analysis and utilization of the extracted information as shown in figure 3.

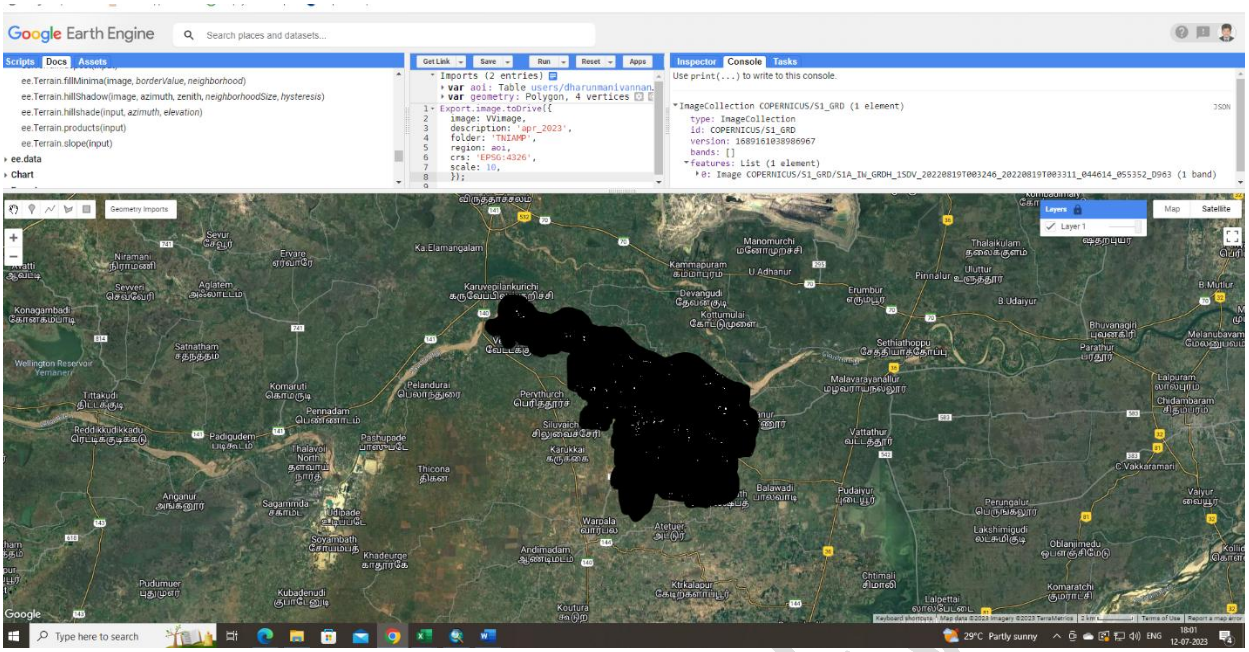

Figure 2. Overview of preprocessed Sentinel 1A image acquisition for the study area

Approach to data classification

Different research studies have utilized a thresholding approach with SAR data to detect water feature (Tavus et al., 2018; Liang et al., 2019). Thresholding techniques are widely employed on SAR images because they are efficient and require less computational time. In this case, the detection of water from non-water areas is achieved through the use of histogram thresholding method (Schumann et al., 2009; Pulvirenti et al., 2011). By applying histogram thresholding, maps indicating the areas of water have been created.

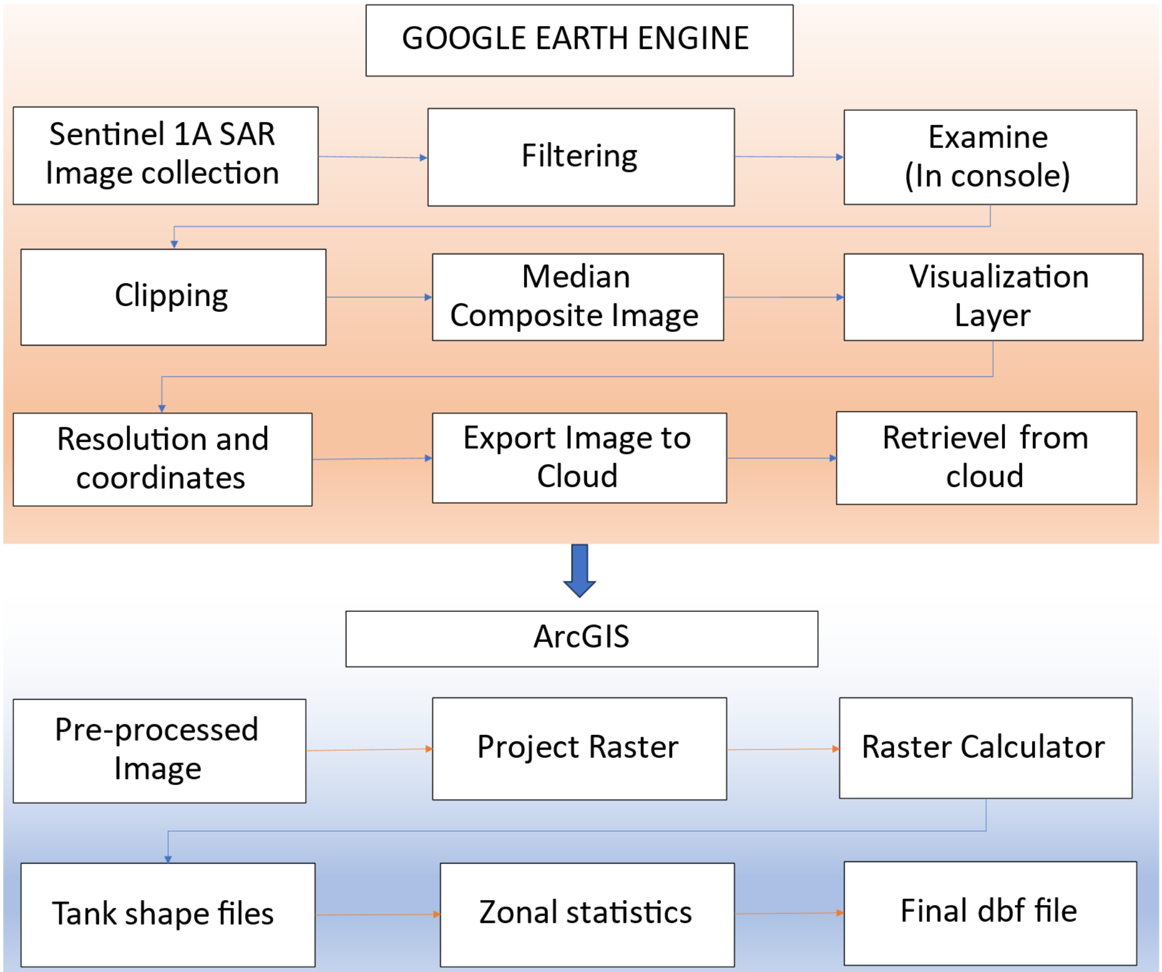

Figure 3: Methodology adopted for mapping of water spread area

Results and Discussion:

In the present study Synthetic Aperture Radar (SAR) satellite data for the month of August 2022, December 2022, and April 2023, were obtained and downloaded. The downloaded data underwent pre-processing using the Google Earth Engine software. During pre-processing, backscattering values were calculated and represented in decibel units. For August 2022 (pre-rainy season), the backscattering values ranged from -18.00 db to -28.12 db . In December 2022 (post-rainy season), the values ranged from -15.85 db to -26.96 db , and in April 2023 (summertime), the values ranged from -15.55 db to -24.82 db. Lower backscattering values, indicated by darker tones, which corresponded to water pixels, while higher backscattering values, indicated by brighter tones, corresponded to constructions and settlements. Intermediate backscatter values corresponded to vegetation, bare land, and dry soils.

Water spread area estimation:

The Water spread area was estimated using histogram thresholding method, a commonly used and effective technique for generating binary images. The threshold values (-26 for August 2022, -28 for December 2022, and -18 for April 2023) were determined empirically through manual analysis. These values were utilized to estimate and map the water spread area in the tanks. The results showed a total water spread area of 37.191 hectares in August 2022, 58.34 hectares in December 2022, and 59.971 hectares in April 2023 , as presented in Table 1. The variation in water spread may be attributed to support this fact provide monthly rainfall of cuddalore district block during these seasons. Previous studies by Huang et al. (2018) and Tavus et al. (2018) also found the thresholding approach effective for mapping surface water.

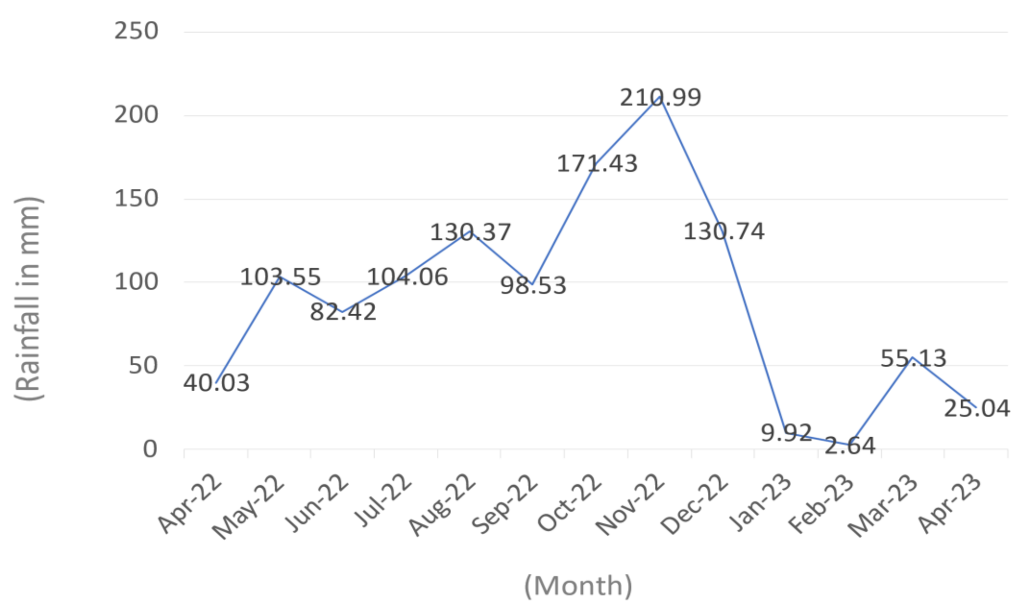

Figure 4: Rainfall pattern for Cuddalore district from April-2022 to April-2023

Table 2. Water Spread of the Tanks in Hectares.

	Tank Name	Water spread area (Ha)		
		August 2022	December 2022	April 2023
1	Ananthakudi Tank	0.53	0.40	0.45
2	Gunamangalam Tank	38.3	38.05	29.13
3	Kaliyankuppam Tank	0.4	0.07	0.07
4	Keelapuliankudi Tank	2.17	2.59	1.51
5	Kokkarasan pettai Tank	0.01	1.51	0.50
6	Melapuliankudi Tank	0.20	0.05	0.04
7	Nagarapadi Tank	0.48	2.44	1.33
8	Sathavattam Tank	0.41	0.19	0.02
9	Selavizhi Tank	0.86	1.45	0.11
10	Sirunedunj eri Tank	6.25	10.36	0.74
11	Sriputhur Tank	2.76	2.85	0.80
12	Srivakkaramar Tank	5.75	3.32	2.59

Notably, there was a significant difference in the water spread area observed in the Kokkarasanpettai tank, due to variation in rainfall as shown in Figure 4, which was nearly dry in August 2022, had a water spread of 1.5 hectares in December 2022, and decreased to 0.5 hectares in April 2023. Gunamangalam tank had consistently high water spread throughout the period, with the highest value in August 2022. Sirunedunjeri tank experienced significant fluctuations in water spread, with the highest value in December 2022. Kokkarasanpettai tank showed a substantial increase in water spread from August to December 2022. Sathavattam Tank had a decreasing trend in water spread, with the lowest value in April 2023. Sriputhur Tank demonstrated moderate water spread levels, with a slight increase from August to December 2022 as shown in Table 2.

Conclusions:

The application of the Thresholding method using Sentinel-1A SAR in conjunction with Google Earth Engine and ArcGIS software proved to be successful in estimating and monitoring the water spread area in the Kattumannarkoil block of the lower Velar sub-basin. The results indicate that the water spread area can be effectively estimated and tracked using this approach. On August 19, 2022, December 17, 2022, and April 16, 2023, the estimated total available water spread areas in the selected 12 tanks were found to be 37.191 hectares, 58.34 hectares, and 59.971 hectares, respectively.

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