FLOOD INUNDATION MAPPING USING SENTINEL 1A SATELITE DATA IN MAJOR BLOCKS OF MAYILADUTHURAI DISTRICT, TAMILNADU, INDIA

ABSTRACT

A research study was carried out for mapping flood affected areas from Sentinel 1A satellite data in the major blocks of Mayiladuthurai district, Tamil Nadu. A very high-resolution Sentinel 1A satellite data was acquired and processed with GIS tools. Ground truth gathered during the survey were utilized to identify the dB values for flood affected areas, which were then used to classify the flood pixels in the study regions. The flood affected areas of Mayiladuthurai district was found to be 18002 ha during the year 2022. Accuracy assessment and cross validation was done using confusion matrix with the ground truth points collected. The classification resulted with an overall accuracy of 86.2 % area with a Kappa score of 0.72.

Keywords: *flood, area mapping, Satellite Aperture Radar (SAR), software.*

1. INTRODUCTION

Flood occurs as one of the most common and catastrophic natural disasters in the world, wreaking havoc on people, infrastructure, and economies. Flood mapping and modelling are so critical for flood hazard assessment, damage estimation, and long-term urban planning. These are the most abundant natural disasters that can occur at multiple tiers, affecting the environment, ecology, agriculture, and civilization. Damage and loss assessment are important for flood management, but they are generally challenging tasks due to the complexities of dealing with vast data, damage types, spatial and temporal scales, i.e., depth of study (Torbick *et al*., 2017).

Floods can affect soil pH by leaching alkaline or acidic chemicals. Plant growth may be impacted by this in terms of nutrient availability. Prolonged flooding can cause oxygen depletion in soil pores due to limited gas exchange with the environment. Due to the anaerobic (low oxygen) conditions created, helpful soil organisms like earthworms and aerobic bacteria may not function as they should. In anaerobic environments, poisonous gases like hydrogen sulphide that are detrimental to plants can also be released. Erosion and compaction caused by flooding can disrupt the natural aggregation of soil particles, leading to degradation of soil structure. Reduced root penetration, higher runoff, and decreased water-holding capacity can all be effects of poor soil structure. The entire Mayiladuthurai district is a plain terrain with the slope less than 1%. The topographical slope is towards east and southeast. The total length of the coast in the east is 90 km. The geology of the district is sedimentary rock type and soil type is Sand, Sandy Clay and Marine Deposits.

Rice is considered to be one of the world's most predominant crops in mankind for nourishment, revenue support, and its contribution in planetary biological processes. Numerous lowland rice-cultivation areas in Asian countries are prone to flooding. Such situations typically impact crops and incur damage. The vulnerability curves have been generated through assessing the degree of crop yield fluctuation and flood parameters. (Hendrawan *et al*., 2021). The availability of food is a fret for the entire nation, as the cultivation of rice is being hindered by climate-related natural hazards which include floods, droughts, and cyclones. Flooding becomes probably the most prominent of all such disasters and exerts a significant effect on rice production (Singha *et al*., 2020).

Remote sensing, with its advantages of synchronized and frequent observations, has been demonstrated as a promising tool to monitor large-scale floods in a time and cost- efficient manner. Several research on incidents of flooding and their implications have been accomplished. Backscattering from microwave sensors offers exceptionally beneficial data for emphasising inundated areas, which could potentially be used in predicting floods, tracking, and precision-based flood anticipation tactics shortly before, during, and following flood events (Adedeji *et al*., 2021).

2. REVIEW OF LITERATURE

(i) *Importance of Flood:* (George *et al.*, 2022) sheds light on the dynamic behavior of groundwater in a flood plain that has been heavily drained and emphasizes the need of documenting flood episodes in order to calculate the overall groundwater contribution to floodplain water balances. A strong correlation between surface water radon readings and groundwater level suggested cyclical dynamics of connection-disconnection between shallow ground water and drains. In order to better manage groundwater in flood plains that have undergone hydrological modification, he discovered that 72–76% of the groundwater released throughout an annual cycle occurred after flood events and was augmented by artificial drainage.

(ii) *Conditions of flood occurrence in India & Tamil Nadu:* (Climatic & Kansal, 2022) summarizes the most significant flood-related episodes and analyzed the state's delicate geology, and points out both natural and human-caused causes of the flood as a calamity. An Indian state in the Himalayas known as Uttarakhand is well known for its natural surroundings and ability to rejuvenate the body. Geographically, it is divided between the Bhabar and the Terai and is divided into the two main areas of the Garhwal and the Kumaon. The main natural disasters that cause the most fatalities and property damage in this state include floods, cloud bursts, glacial lake out bursts, and landslides. It examines the difficulties in managing floods and shows a good flood risk management strategy that might be used to lessen the negative effects.

(iii) *Conventional methods of Flood assessment:* (Leitao & Sousa, 2018) examined the effects of mixing several DEMs on the outcomes of flood modeling and offers the first implementation of the MB lend merging technique. The accuracy of flood modeling outcomes can be improved by using accurate elevation datasets, such as Digital Elevation Models (DEMs) created from imagery from terrestrial LiDAR (Light Detection and Ranging) systems or Unmanned Aerial Vehicles (UAVs).This research emphasized the value of DEM merging while undertaking flood modeling and offered advice on the most effective DEM merging techniques.

(iv) *Role of Sentinel 1A Satellite Data in Flood Assessment:*(Hoang-Phi *et al.*,2020) described the association between the pattern of saline intrusion and the Spatio-temporal distribution of rice production in the winter-spring harvests of 2015, 2016, 2019 and 2020 in coastal provinces of the Vietnamese Mekong Delta was examined in this research. Based on a rice age algorithm, Sentinel-1 (S-1) data were utilized to derive the geographical distribution formation of six rice development stages. With a Kappa value of 0.80 and an overall accuracy of 85%, the classification accuracy of rice crop development phases was discovered (n=373).

3. MATERIALS AND METHODS

3.1 Study Area

Among the Coastal districts of Tamil Nadu, Northeastern district, Mayiladuthurai which comes under Cauvery delta region was affected by severe flood. The district is bounded on the North by Cuddalore district, on the west by Thanjavur district, on the south by Thiruvarur district and Karaikal district of Puducherry, and the Bay of Bengal to the East. The study area geographically lies between 78° 50’ to 79° 55’ East longitude and 10°15’to 11°55’ North latitude with an altitude of 90 m above MSL. Different field locations across the study area were selected as monitoring fields to assess the areas prone to flooding.

The study area is clearly shown in Fig. 1.

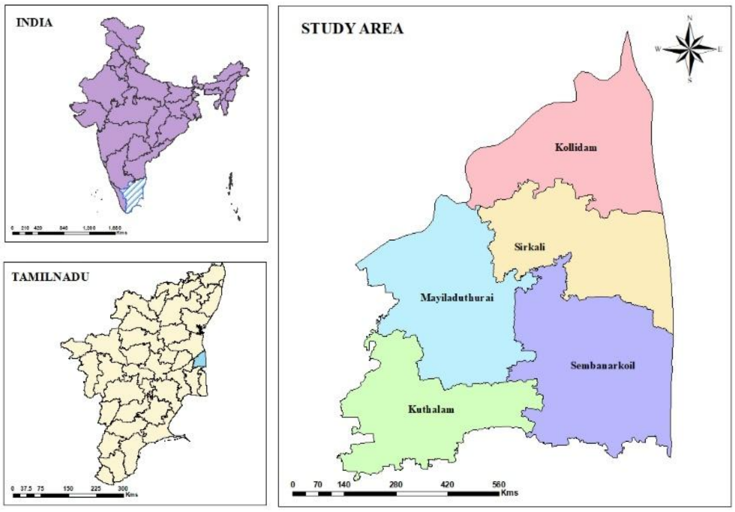

Fig. 1. Study area map of flood affected areas in Mayiladuthurai district

3.2 Satellite Data

Sentinel 1A is a SAR sensor that operates in the microwave region launched by the European space Agency in 2014. It provides polarization of VH (Vertical-Horizontal) and has a temporal resolution of 12 days and spatial resolution of 20 m. Sentinel 1A carries a single C-band synthetic aperture radar instrument operating at a centre frequency of 5.405 GHz. Sentinel 1A with its C-SAR instrument can offer reliable and repeated wide area monitoring. High resolution data was acquired from October to November from the website (https://scihub.copernicus.eu/dhus/.) were used in this study. The source of satellite data was then optimized for classification methodology through a series of processing techniques (Fig. 2).

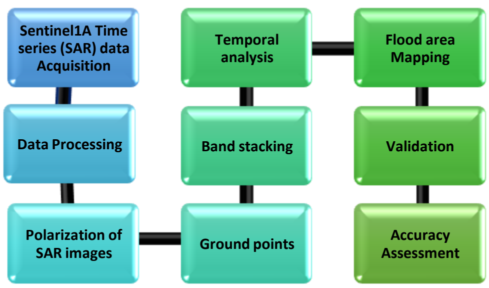

Fig. 2. Methodology for mapping Flood area from Sentinel 1A Satellite data

3.3 Software used for Analysis

High resolution Sentinel 1A SAR data processing involves rigorous pre-processing, which is tedious and time-consuming process. Hence, this study utilizes specialized software customized to perform sequential data processing and spatial analysis steps with advanced GIS tools. The data processing and spatial analysis achieved with the following software package:

MAP scape RICE: SAR data processing and rice area estimation

ArcGIS and QGIS: Handling spatial datasets and GIS operations

MS-Excel: Generation of graphs and driving statistics

3.4 Ground Truth Data Collection

Ground Truth points of flood affected areas were collected covering the entire study area. A total of 65 points (55 flood affected points and 10 non flood points) were collected during ground truth survey which were used for mapping and validation purposes (Fig. 3).

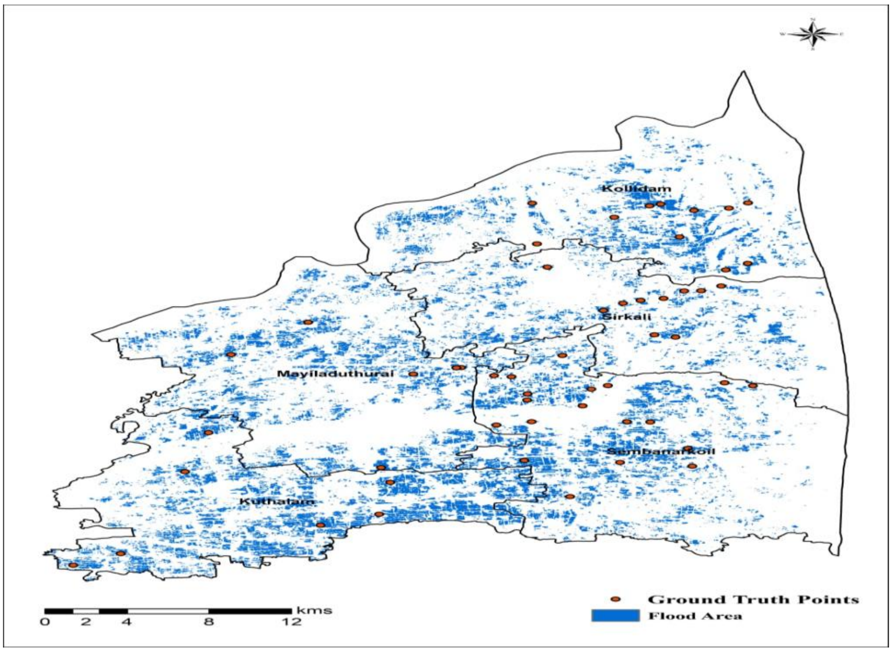

Fig. 3. Ground truth points collected from the study area

4. Accuracy Assessment

Error matrix and Kappa statistics were used to determine the accuracy of classification. An error matrix is created using the pixels of agreement and disagreement (Lillesand *et al.*, 1994). Validation points were divided into two classes namely flooded and non-flooded areas. This error matrix can be used to calculate the Kappa coefficient, producer's accuracy, user's accuracy and overall accuracy (Congalton, 1991).

5. Results and Discussion

The estimated flood affected areas in major blocks Mayiladuthurai were 18002.84

hectares. Kuthalam block was recorded with high flood affected area of 4909.24 hectares, Flood affected area in Sembanarkoil and Mayiladuthurai block was 4190.96 and 4022.08 hectares. The Kollidam and Sirkali blocks was distributed with flood affected area of 2770.60 and 2109.96 hectares (Table. 1).

Sentinel-1 SAR earth observation data, which is freely available and frequently sampled, has a tremendous potential for creating flood information with high accuracy and high spatial resolution due to the prevalence of severe weather conditions during flooding season (Uddin *et al.*, 2019).

The post-processing step consisting of morphological operations and extraction improves the homogeneity of the extracted flood segments, discards isolated pixels, and gives the final flood map. The accuracy of the proposed method is assessed at three test sites in Pakistan. In comparison with the more recent studies, results indicate the best spatial agreement with GF-2 panchromatic multi-spectral (PMS) water classification, with an encouraging overall accuracy ranging from (91.10%) to (96.60%), and Kappa coefficients ranging from 0.893 to 0.954 (Zhang *et al.*, 2020).

Flood area map generated for the study area Mayiladuthurai district using time series Sentinel 1A SAR imagery (Fig. 3).

Table 1.

Block Name	**Block Area (ha.)**
Kollidam	2770
Kuthalam	4909
Mayiladuthurai	4022
Sembanarkoil	4190
Sirkali	2109
Total Area	**18002**

Flood area of major blocks in Mayiladuthurai district

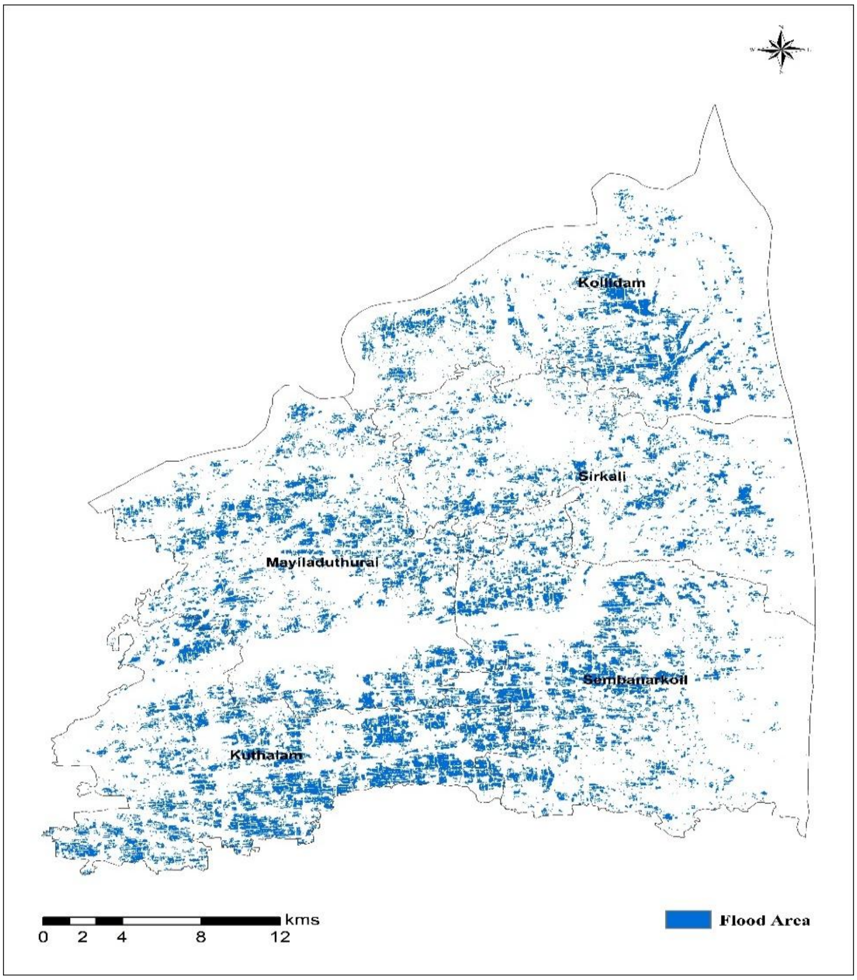

Fig. 3. Flood area map for major blocks of Mayiladuthurai district

6. Accuracy Assessment

Ground truth points collected during survey were utilized for accuracy assessment purpose. With categorized outputs, these points were validated. Out of the 65 ground truth points collected, 55 were flood points and 10 were non-flood points. A Confusion matrix was generated to determine the flood area estimation and to determine the accuracy of classification. Among the 55 ground truth flood points collected, 49 were correctly classified as flooded areas. The overall accuracy was (86.20%) with the producer and user accuracy for flood affected areas being (89.10%) and (94.20%), respectively. The producer and user accuracy for non-flood areas were (70.00%) and (53.80%), respectively. The Kappa index of 0.72 was obtained, indicating high defining accuracy (Table. 2).

Table. 2. Confusion matrix for accuracy assessment

		Predicted class from the map		
		Flood	**Non-Flood**	**Accuracy**
Actual class from survey	**Flood**	49	6	89.10%
	Non-Flood	3	7	70.00%
	Reliability	94.20%	53.80%	86.20%

Average accuracy	79.50%	
Average reliability	74.00%	
Overall accuracy	**86.20%**	**Good Accuracy**
Kappa index	**0.72**	**Good Accuracy**

7. CONCLUSION

As novel approaches and technologies developed throughout the years, flood area estimation utilizing remote sensing studies have advanced. Although flood mapping by different technologies delivers a convincing outcome with better accuracy, there is ample opportunity for improvement. High-resolution data and technological advances can help to narrow the estimation accuracy gap. When using high-resolution satellite data coupled with diverse algorithms for categorization, the present study revealed more accuracy in flood area estimation versus preceding techniques.

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