European Journal of Applied Sciences – Vol.10, No.5
Publication Date: October 25, 2022
DOI:10.14738/aivp.105.12641.
Faheed, J. K. P., Yusuf, A., Manjusree, P., & Ansari, Z. R. (2022). Monitoring of Flood Dynamics Using Multi Temporal Satellite Data: A Case Study of Kerala Floods 2018. European Journal of Applied Sciences, 10(5).443-480.

Monitoring of Flood Dynamics Using Multi Temporal Satellite Data: A Case Study of Kerala Floods 2018

Faheed Jasin K. P.
Interdisciplinary Department of Remote Sensing &
GIS Applications, A.M.U., Aligarh

Alia Yusuf
Geology Section, Women's College
Aligarh Muslim University, Aligarh, U.P., INDIA

P. Manjusree
National Remote Sensing Centre, Deptt. of ISRO
Govt of India, Balanagar, Hyderabad

Ziaur Rehman Ansari
Interdisciplinary Department of Remote Sensing &
GIS Applications, A.M.U., Aligarh

ABSTRACT

India is one of the worst flood affected country in South East Asia and accounts for one fifth of global death count due to floods. It causes heavy losses to property, infrastructure, agriculture, land and overburdens the country's budget and resources. Around 40 million hectares of land in the country are subjected to floods according to National Flood Commission, and an average of 18.6 million hectares of land is affected annually. During 2018, Kerala was hit by two flood events in July and August. In August, 2018, Kerala experienced the worst ever floods in its history since 1924. The torrential rains triggered several landslides and forced the release of excess water from 37 dams across the state, aggravating the flood impact. The devastating floods and landslides caused extensive damage to houses, roads, railways, bridges, power supplies, communications networks, and other infrastructure. Satellite Remote Sensing has made substantial contribution in flood monitoring and damage assessment. The unique capabilities of satellites to provide comprehensive, synoptic and multi-temporal coverage of very large areas at regular interval and with quick turnaround time have been very valuable in monitoring and managing flood dynamics. The microwave region of the EM spectrum has a greater potential in identification of flooded areas because of almost all weather capability. In this study, multi-temporal microwave SAR data from RADARSAT and SENTINEL-1 satellites was used to map the flood affected areas in Kerala and to capture the dynamics of the spatial flood extent. The analysis showed maximum flood inundation in the second flood event in August. A steady recession of flood was observed in the July flood event. The peak flooding was observed on 18th August 2018. There is a rapid progression of flood from August 11th to August 18th 2018 after which, a slight recession was observed from August 18th to 21st ,2018. The flood could be seen slightly progressing in the

next interval of August 21stto 24th ,2018 after which, again an overall recession in the spatial flood could be observed by 27th August 2018. Kottayam, Pathanamthitta and Alappuzha were some of the worst flood affected districts. The maximum flood affected district is observed to be Alappuzha with a maximum flood inundated area of 27691hectares on 18 August 2018. In the district of Alappuzha a steady progression in the flood is observed after 21 August. Whereas in the other two districts namely Kottayam, Pathanamthitta the flood is found to be receeding after August 24, 2018.This study demonstrated the potential of multi-temporal satellite imageries for capturing the flood dynamics in a spatial domain. The progression and recession maps can be used for relief management by the disaster managers on the ground.

Keywords: Synthetic Aperture Radar, RADARSAT, SENTINEL-1, Flood Dynamics, Flood Analysis and Microwave Remote Sensing

INTRODUCTION

With the long term change in weather pattern, incidences of extreme heat and humidity are rising which manifests itself as global increase in precipitation events and subsequent riverine and flash flood is the manifestation of climate change [1]. According to Federal Emergency Management Agency (FEMA) Flood is defined as a general or temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland or tidal waters and unusual rapid accumulation or run off of surface waters from any source.

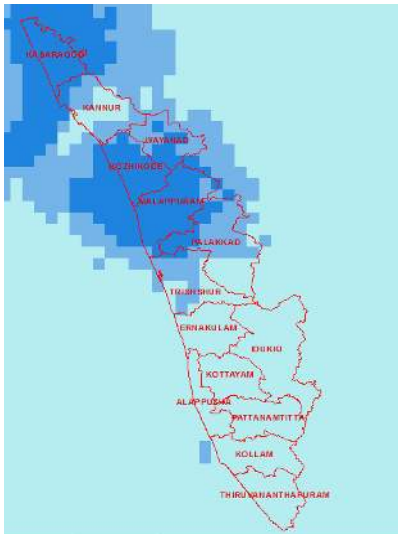
These climate change events occur in India as well on frequent basis. Severe floods occur almost every year in one or the other part of the country causing tremendous loss of life, large scale damage to property, infrastructure, agriculture, land and overburdens the countries budget and resources. Floods mostly occur in the country during the south west monsoon period spread from June to September, though cyclonic storms are common during October to December. India is the worst flood affected country in the world after Bangladesh and accounts for one fifth of global death count due to floods. Around 40 million hectares of land in the country are subjected to floods according to National Flood Commission and an average of 18.6 million hectares of land is affected annually. To avoid such catastrophic loss of life and property it is necessary to map the events of flood in entire country so that better planning for disaster management can be done.

KERALA FLOODS 2018

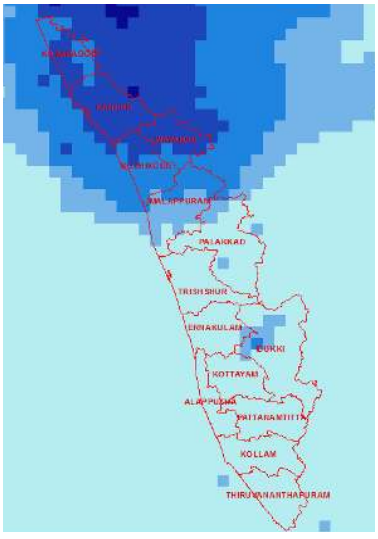
A catastrophic flood event which devastated the southern state of Kerala, India took place in 2018 due to unprecedented heavy rainfall from 1 June –18 August 2018. The normal cumulative rainfall during monsoons in Kerala from June till end of August is around 1795.4 mm, but during 2018 monsoon it got an actual cumulative rainfall more than 2428.9 mm was reported by Indian Meteorological Department (IMD) and Central Water Commission (CWC). All of major 35 odd reservoirs storage was close to the full reservoir level (FRL) and had no buffer storage to accommodate the heavy inflows from 10th August. The continued exceptional heavy rainfall in August (with 170% above normal) in the catchment areas had compelled the authorities to resort to heavy releases downstream into the rivers. Such a scenario that continued for almost a week has caused overflowing of all river banks leading to widespread flooding almost all over the state. During the week of 9th to 15thAugust the rainfall

was severe and Kerala received 255% extra rainfall (Fig.1). Idukki district in which major dams are situated received 679mm of rain just during that week, the normal during that period is only 126 mm, which is 438% extra rain. That leads to the opening of Idukki dam after 26 years. Wayanad received 536.8mm rainfall which is 299% extra for that hilly district, the normal rainfall for Wayanad is only 134mm [2]. This incessant rainfall triggered landslides and snapped road links between Wayanad and rest of Kerala. This catastrophic disaster had created loss of life and property in a dimension unexpected. About 400 people were reported dead in the state and over 1 million people moved to relief and rescue camps. According to the Kerala government, one-sixth of the total population of Kerala had been directly affected by the floods and related incidents, 13 out of 14 districts of Kerala were affected by the event.

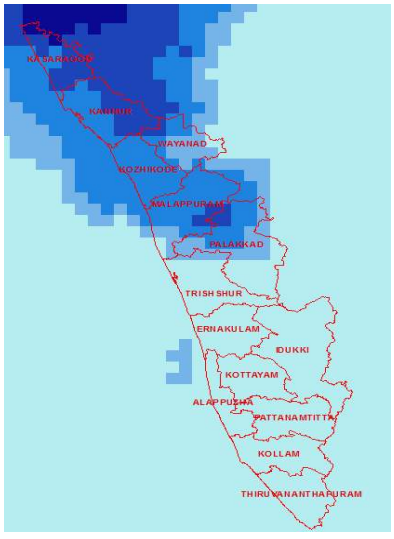
The Indian government had declared it a Level 3 Calamity or "calamity of a severe nature". Thirty-five out of the fifty-four dams within the state were opened, for the first time in history. All five overflow gates of the Idukki Dam were opened at the same time and for the first time in 26 years 5 gates of the Malampuzha dam of Palakkad were opened. Heavy rains in Wayanad and Idukki have caused severe landslides and have left the hilly districts isolated. Such catastrophic events require immediate attention and hence should be mapped to understand the dynamics of the river. Earth observation data is very useful and essential tool for flood monitoring[3], risk assessment [4,5], modelling, prediction and validation for weather forecasting and rainfall-runoff models. These technologies have been the object of substantial interest for all countries and bodies concerned with space and in exacting emergency services and disaster management[6]. Remote Sensing along with has proven to be very effectively for quick assessment of severity and impact caused by natural disasters.



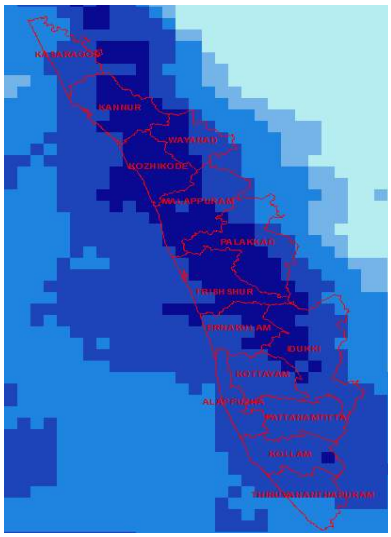
Observed Rainfall as on 11-Aug



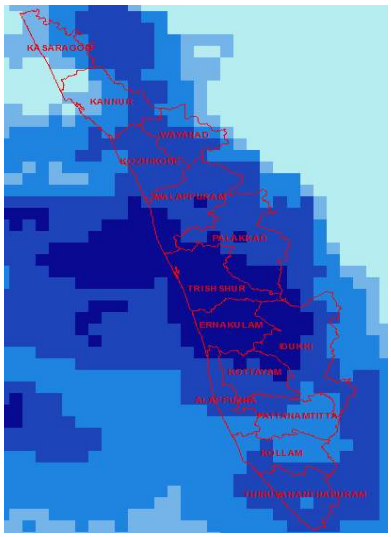
Observed Rainfall as on 12-Aug



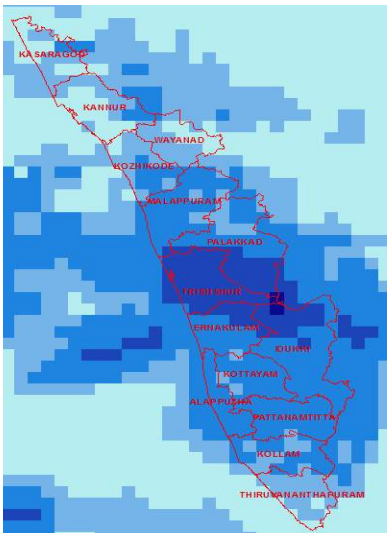
Observed Rainfall as on 13-Aug



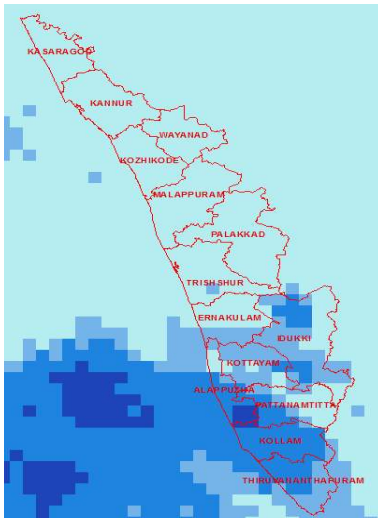
Observed Rainfall as on 14-Aug



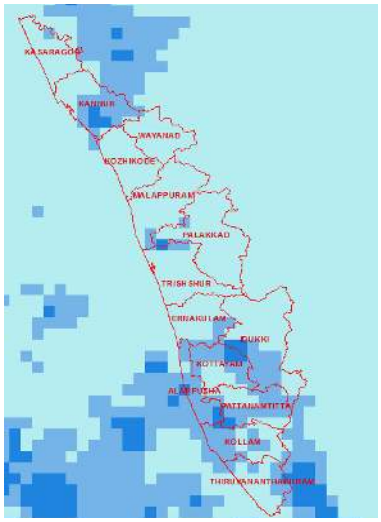
Observed Rainfall as on 15-Aug



Observed Rainfall as on 16-Aug



Observed Rainfall as on 17-Aug



Observed Rainfall as on 17-Aug

Fig 1. Rainfall data during August 2018

REMOTE SENSING AND GIS IN FLOOD APPLICATIONS

GIS is used to manage huge levels of data required for vulnerability and hazard assessment, during disaster prevention stage. In the disaster preparedness stage, it is a tool for planning evacuation routes, designing centres for emergency operations and for the integration of satellite data with other relevant data in the design of disaster warning systems. In the disaster relief phase, GIS, in combination with GPS, is extremely useful in search and rescue operations in areas that have been devastated and where it is difficult to find one's bearings. In the disaster rehabilitation stage, GIS is used to organize the damage information and post-disaster census information and in the evaluation of sites for reconstruction. Natural hazard information needs to be included routinely in developmental planning and investment projects preparation. They should include cost/benefit analysis of investing in hazard

mitigation measures and weigh them against the losses that are likely to occur if these measures are not taken.

Remote Sensing has made substantial contribution in flood monitoring and damage assessment. The unique capabilities of satellites to provide comprehensive, synoptic and multi-temporal coverage of very large areas at regular interval and with quick turnaround time have been very valuable in monitoring and managing flood dynamics [7]. Satellites, by virtue of their remote sensing and data transmission capabilities, provide comprehensive multi-date and multi-spectral information on dynamic phenomena covering very large as well as small river basins, have been found to be admirably suited for mapping/monitoring and studying (i) flood inundated and drainage congested areas, (ii) extent of damages to crops, structures etc., (iii) river configuration, silt deposits, shoals etc., and vulnerable areas of bank erosion (iv) watershed characteristics and land cover/land use in command areas and (v) hydrological and meteorological data transmission from data collection platforms.

Satellite remote sensing provides synoptic view of the widely extended flood-affected areas at frequent intervals for assessing the progression and recession of the flood inundation in short span of time [8] which can be used for planning and organizing the relief operations effectively. For mapping purposes, multi temporal a pre-flood scene and flooded images are analysed to delineate the inundated area and for identification of the changes in the flood scenario. The multi temporal data from satellites are also proved to be very valuable in the identification of the sites, ideal for taking up structural measures to control floods.

In this study using multi-temporal satellite imageries of different flood dates are used to study the flood dynamics and the persistence of flood in different flood affected areas during the Kerala floods 2018 in an attempt to understand flood dynamics of river during heavy rainfall and to create database for urban planning.

STUDY AREA AND DATASETS

Study Area

The study area lies in state of Kerala which is boarded by Arabian Sea to the west with a coastline of 595km (Fig.2). The devastating floods and landslides caused extensive damage to houses, roads, railways, bridges, power supplies, communications networks and other infrastructure; washed away crops and livestock and affected the lives and livelihoods of millions of people in the state. In this study we will be using multi-temporal satellite imageries of different flood dates (Fig.3) to study the flood dynamics and the persistence of flood in different flood affected areas during the Kerala floods 2018 (Fig.4).

Satellite dataset

Optical mosaic imagery prepared by the National Remote sensing centre, Hyderabad is used as the master imagery for Kerala, for 2018 (Fig.5). Microwave satellite datasets were used for complete mapping and analysis of flood in the study area. Six multi-temporal synthetic aperture radar (SAR) datasets were used in the study (Fig.6), out of which two imageries are of Sentinel 1 SAR and the remaining six are from Radarsat 2 SAR (Table 1). The projection of the master image was WGS 84Ability of SAR active sensor to observe the earth's surface at any time of the day or night, regardless of weather and environmental conditions, make is

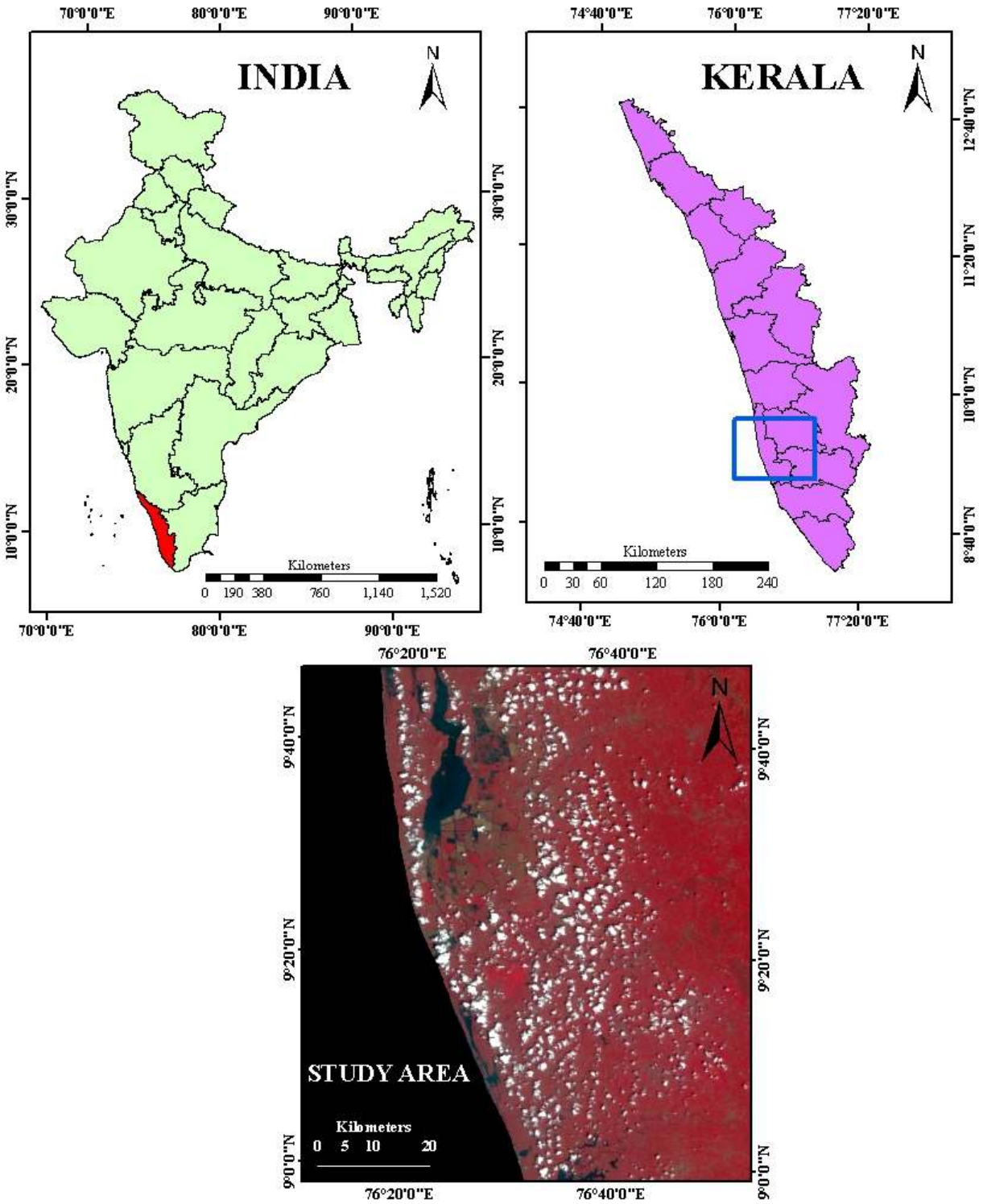


Fig-2. Map of the study area



Fig 3.1 Pre-flood image on Feb 8 2018 by LANDSAT 8 OLI sensor



Fig 3.2 During flood 22 August 2018 by Sentinel 2

Fig 3- Pre-flood image on Feb 8 2018 by LANDSAT 8 OLI sensor and flood image 22 August 2018 by Sentinel 2

Table.1 Satellite data used in the present study

S.no	Date	Satellite/ Sensor	Swath	Resolution
1	16 July 2018	Sentinel-1 SAR	250Km	20 m
2	21 July 2018	Radarsat-2 SAR	500Km	50m
3	11 August 2018	Radarsat-2 SAR	500Km	50m
5	18 August 2018	Radarsat-2 SAR	500Km	50m
6	21 August 2018	Radarsat-2 SAR	500Km	50m
7	24 August 2018	Radarsat-2 SAR	500Km	50m
8	27 August 2018	Sentinel-1 SAR	250Km	20m

favourable for mapping. The SAR instrument provides radar backscatter measurements influenced by the terrain structure and surface roughness.
Generally, the more roughness or structure on the ground, the greater the backscatter. Rough surfaces will scatter the energy and return a significant amount back to the antenna resulting in a bright feature. Flat and smooth surfaces like water bodies reflect the signal away resulting in a dark feature.

The dielectric constant of the materials affects the reflectivity and conductivity of materials. In the microwave region of the spectrum, most natural materials have a dielectric constant in the range of 3 to 8 when dry, whereas water has a dielectric constant of approximately 80. Therefore, the presence of moisture in soil and vegetation results in significant increase in reflectivity [9] and hence make SAR very suitable for flood monitoring and other various applications.

RADARSAT-2 carries an advanced C-band (5.405 cm), HH-, HV-, and VV-polarized SAR with a steerable radar beam. Imaging swaths vary from 20 km (Ultra-Fine) to 500 km (ScanSAR Wide) and resolutions vary from 3 to 100 meters (Table-2). Sentinel1 carry a C-SAR sensor, which offers medium and high resolution imaging with Resolution Class of 4 m – 80 m and swath width of 80 km – 400 km, depending on operation mode in all weather conditions. The C-SAR is capable of obtaining night imagery and detecting small movement on the ground, which makes it useful for land and sea monitoring (Table-3).



Fig.4.1 Aerial view of Periyar river





Fig. 4.2 Flooded residential area **Fig. 4.3 flooded town of Alappuzha**

Fig.4 Field Photograph of Flood affected area



Fig 5 Optical mosaic imagery of Kerala



Fig.6.1 July 16,2018

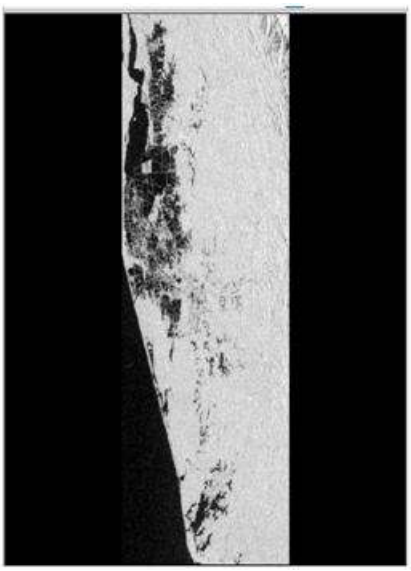


Fig.6.2 July 21,2018

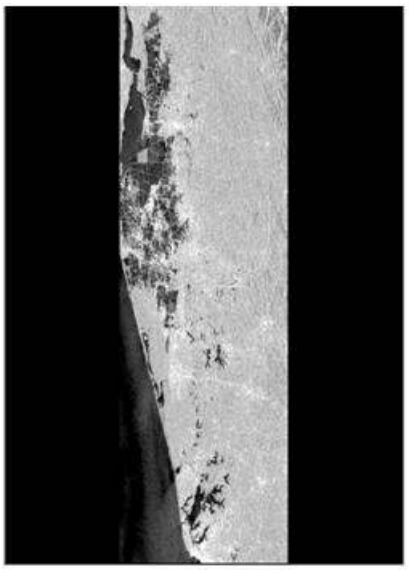


Fig.6.3 August 11,2018



Fig.6.4 August 18,2018

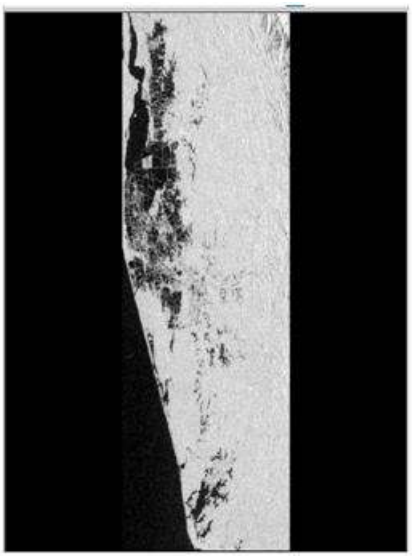


Fig.6.5 August 21,2018

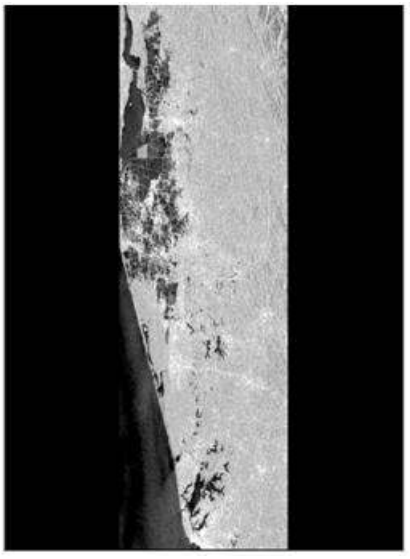


Fig.6.6. August 24,2018

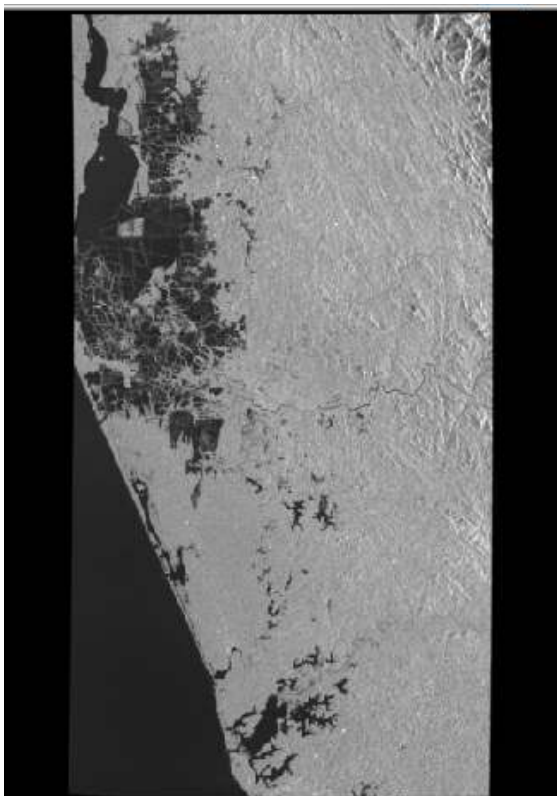


Fig. 6.8 August 27, 2018

Fig.6Multi-temporal satellite imageries

Table.2 Radarsat satellite characteristics

SATELLITE DESCRIPTION	High resolution, operationally-focused SAR satellite
PRIMARY MISSION	All-weather maritime and land observation.
INSTRUMENT TYPE	Synthetic Aperture Radar (C-band)
REPEAT CYCLE	24 days
RESOLUTION CLASS	1 m – 100 m, depending on operation mode
SWATH WIDTH	18 km – 500 km, depending on operation mode
POLARIZATION	Single, Dual or Quad
LAUNCH DATE	2007-12-14
ALTITUDE	798 km
SENSOR SPECIFICATIONS	C-band wavelength 56 mm, frequency 5.4 GHz

Table.3 Sentinel 1 Characteristics

SATELLITE DESCRIPTION	High resolution, operationally-focused SAR satellite
PRIMARY MISSION	All-weather maritime and land observation.
INSTRUMENT TYPE	Synthetic Aperture Radar (C-band)
REPEAT CYCLE	175 orbits in 12 days
RESOLUTION CLASS	4 m – 80 m, depending on operation mode
SWATH WIDTH	80 km – 400 km, depending on operation mode
ALTITUDE	693 km
SENSOR SPECIFICATIONS	C-band SAR, frequency 5.405 GHz

Methodology

The flood dynamic analysis of the study area is doe according to the methodology depicted in the flowchart shown in Fig.7 the study follows six modules which are, preprocessing satellite data, permanent water body (PWB) masking, extraction of flood layer, clumping and sieving and finally flood dynamics and duration mapping. This is followed by statistics generation for finally analysis and discussion.

In the first module noises are removed from the SAR image and then Master image of SAR is used to rectify its Slave image followed by threshold classification. In next module PWB masking is performed to eliminate any misunderstanding between water bodies and inundated areas. Flood layer is then extracted with the help of mask file. Further Clump and Sieve operations are performed to facilitate flood dynamic and duration mapping finally flood progression and recession analysis is done based on all these modules performed in ERDAS.

Preprocessing and Georectification

Speckle, appearing in synthetic aperture radar (SAR) images as granular noise, is due to the interference of waves reflected from many elementary scatterers. Microwave data contains speckle in it which complicates the image interpretation problem by reducing the effectiveness of SAR image segmentation and classification. To alleviate deleterious effects of speckle, various methods have been devised to suppress it. In the present study median filter which comes under the spatial enhancement toolbar in ERDAS Imagine for the speckle suppression is used. All the satellite images are preprocessed using ERDAS before further processing.

Geometric Rectification is used to convert an image (slave image) into a specific coordinate system. This process requires a master image to rectify the slave image. The master image

uses the projection WGS84, since all the data sets are to be overlaid for flood study, it is ensured that the imageries overlay perfectly. The existing projections were removed and re-projected. The master image is opened in one viewer and slave image (16th July2018) in another viewer. Geometric correction is done by selecting a ground control point (GCP) from slave image and corresponding point from the master image. At least 5 to 6 points covering the common area between slave image as well as master image were selected. After the GCPs are allotted re-sampling is done. After the geo rectification of the first image it is chosen as the Master image for geo-rectification of the next slave image. All the eight multi-temporal images were geo-referenced in the same manner.

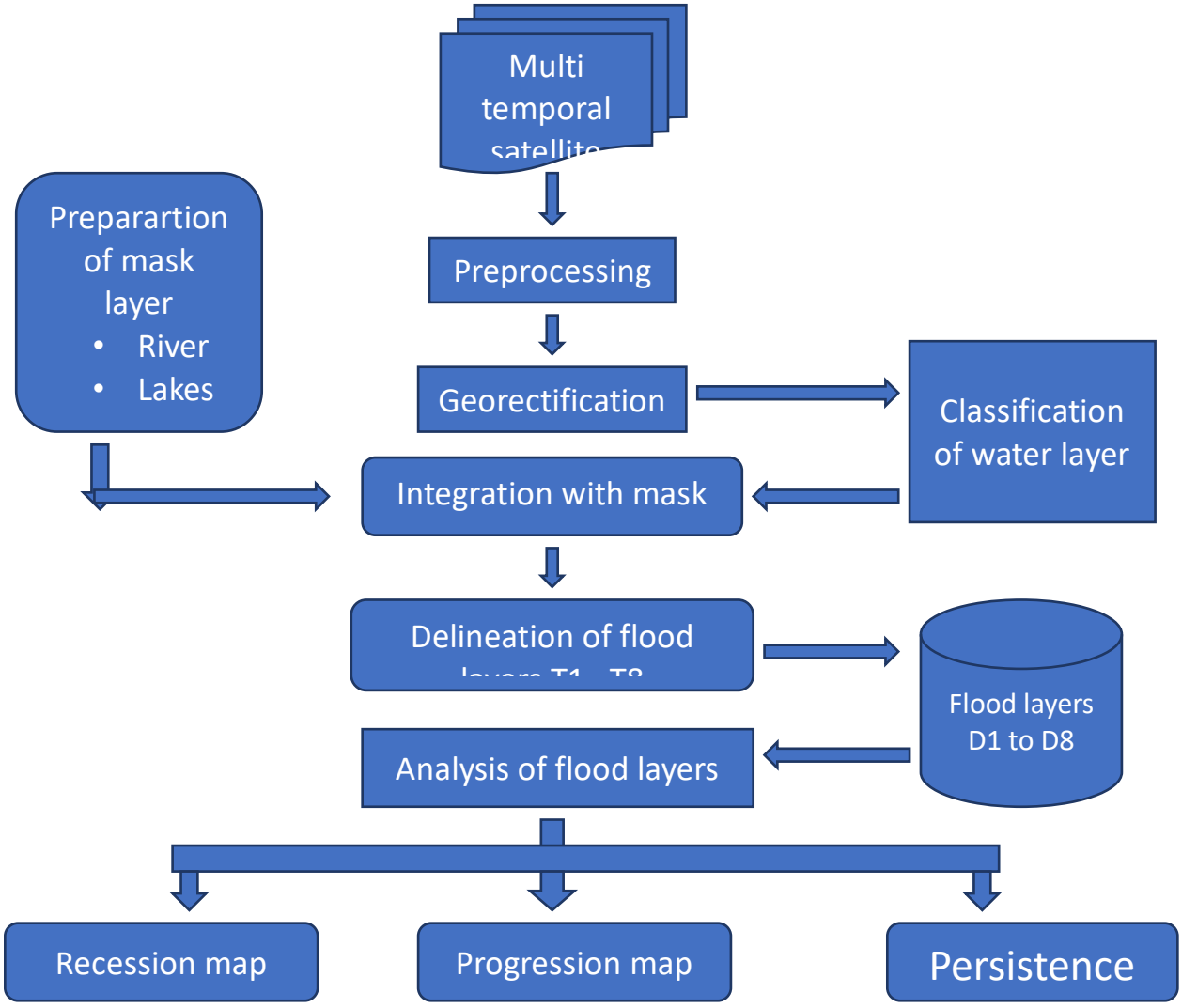


Fig 7 methodology flowchart

Classification

Classification of satellite image for delineation of flood layer can be done in 3 different procedures which are Supervised Classification, Unsupervised Classification and Thresholding. In the present study thresholding method was used for classification.

Threshold is one of the techniques used to classify different features in a single band image. After examining the pixel values (DN) of the feature, the maximum and minimum limits have to be fixed. This technique is preferably used to classify water in a microwave image [10]. Thresholding can be done either by using the spatial profile tool or by using the inquire cursor to find the threshold values of water. By the spatial profile tool, the threshold values can be identified using the polyline option in the spatial window draw a line across the river or water body in the image. A profile of the water values appears in the spatial profile window.

At different cross-sections of the river note the pixel values and fix the minimum and maximum range of the water values in the image. The original values are provided in the lookup Table-4, if the minimum and maximum values for water are 4 and 30 (threshold range), change the values in the lookup table as and click “apply” in the breakpoint editor. This will assign a value zero to all the non-water entities in the image:

1. Click the interpreter option in the ERDAS Tool Bar. Choose Radiometric Enhancement>LUT stretch in the submenu and a window appears
2. Give the input and output file names and choose the output file type as “Unsigned 1 bit” and enable “gray scale “option.
3. After the process is complete, display the classified file in a viewer and check whether classification has come correctly or not. If it is not, then check the threshold range of the water class and repeat the process again.

Using the threshold value, a model was created in the modeler of ERDAS the image is given to the modeler and a conditional statement depending on the threshold values of water in each image is stated and the water pixels are given a value one and non-water pixels are given a value of zero. Run the modeler giving the input image and specifying the output file. Threshold values of each satellite image are obtained and the modeler is run to delineate the water layer from all the images (Fig.8).

S.No	Satellite Image	Threshold
1	16 July 2018	20
2	21 July 2018	11
3	11 August 2018	25
4	18 August 2018	12
5	21 August 2018	55
6	24 August 2018	65
7	27 August 2018	16

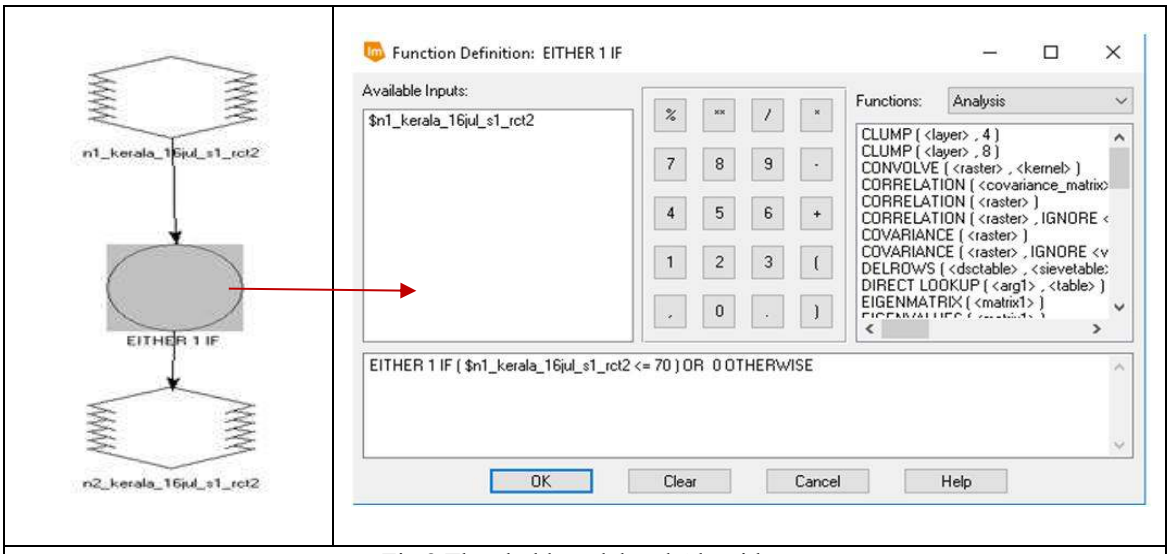


Fig 8 Threshold model and Algorithm

Permanent Water Body (PWB) Masking

All the water pixels delineated using thresholding are not flood, so to separate the flood from the water bodies present in the image, masking is performed [11]. For this a mask file was created embodying all the water bodies of the area. To create a mask file, the pre-flood master image of the study area was used (Fig.9). All the water bodies are delineated from the master image and the mask was prepared by allotting all the non-water entities as one and the other pixels zero. For creation of the mask all features such as rivers, lakes, ponds, dams, bunds, other small water bodies, shadows and airstrips were considered.



Fig 9. Mask File

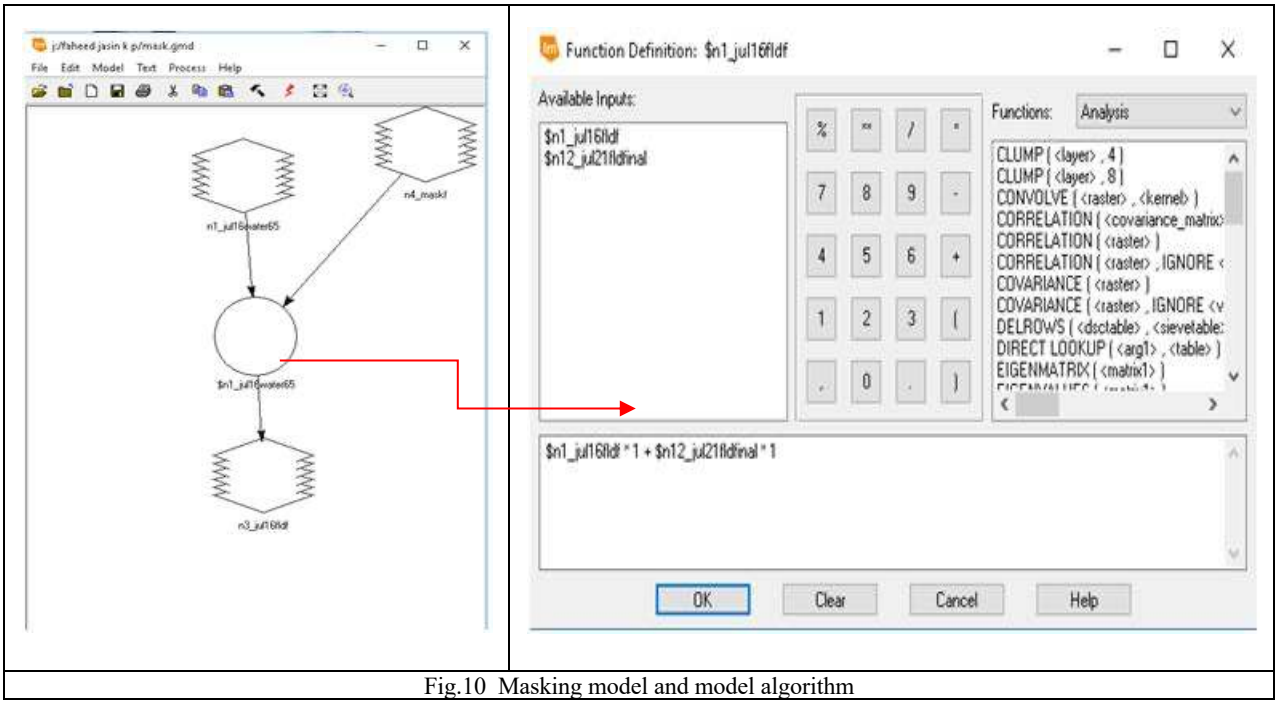


Fig.10 Masking model and model algorithm

Extraction of Flood Layer

To obtain the final flood layer, the mask file created above is integrated with the water layer extracted (Fig.10). A model is made using the modeler in ERDAS to delineate the flood layer. The water layer and mask file is given to the model as input and both the layers are multiplied to obtain the flood layer.

Clump and Sieve

Clump is a commonly used technique for converting thematic class values in a raster into uniquely numbered "polygons" representing contiguous groups of the original class values. Clumping is the process of aggregating the contiguous pixels of same theme into a group (polygon). This process is essential if smaller polygons have to be removed by sieving method Clump identifies clumps, which are contiguous groups of pixels in one GIS class. This clumped data are saved in a new .img file, which can be used as it is, or as input to the Sieve or Eliminate functions. Sieve eliminates clumps of specific sizes. In combination with Sieve, Clump can be used effectively for applications such as facilities siting. For example, Clump can identify areas of a specified soil type, and Sieve can screen out the areas that would be too small for the facility's acreage requirements. When the clumped data are input to the Eliminate model, we can produce a classification utilizing a minimum mapping unit. We may specify which neighbors of a pixel will be considered contiguous. The value can be chosen as 4 or 8.

1. The clump is available in the interpreter menu in the ERDAS Tool Bar
2. Click GIS Analysis>clump> button.
3. Give the name of the input file and output file.
4. Give the connected neighbors as 8 and click “OK”.

Sieving is the process of removing unwanted pixel groups (Polygons). This can be specified in terms of area or number of pixels. The Sieve component removes clumps which are smaller than a user-specified size tolerance. Removes raster polygons smaller than a provided threshold size (in pixels) and replaces them with the pixel value of the largest neighbor polygon. It is useful if we have a large amount of small areas on our raster map:

1. To start, click interpreter in the ERDAS Tool Bar and click <GIS Analysis <sieve> button.
2. A window appears
3. Give the name of the input file and output file.
4. Choose the option "Hectares" and give minimum size as "50" or choose the option "pixels" of minimum size". This is the condition for removing the group of pixels (polygons).
5. Press "OK" and check whether it has come properly or not otherwise change the condition and redo.

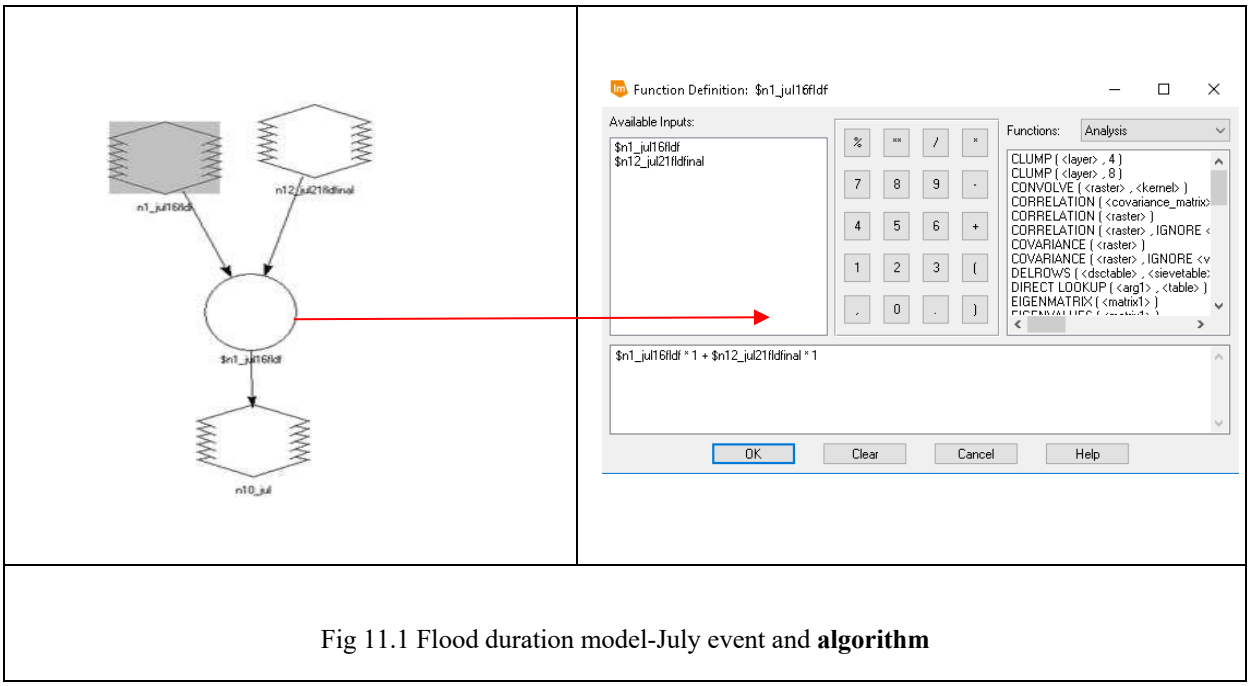


Fig 11.1 Flood duration model-July event and **algorithm**

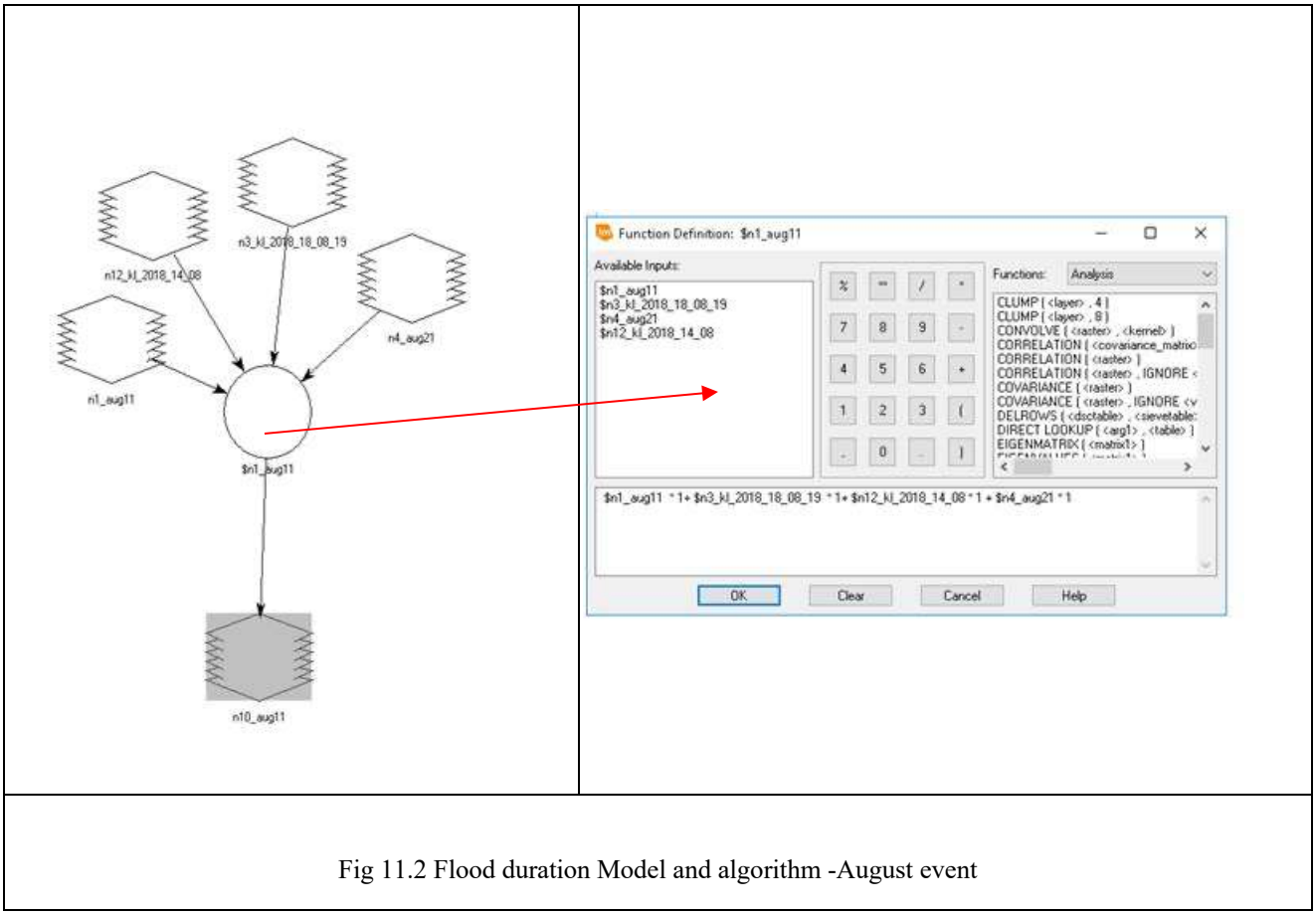


Fig 11.2 Flood duration Model and algorithm -August event

Fig 11 Flood duration Model and algorithm – July and August event

Flood Dynamics and Flood Duration Map

Using the flood layers delineated from multi temporal satellite data flood recession and progression map is created by overlaying the flood layers of different dates. Flood progression maps where first made for two consecutive dates and separate ones for the July event and the August event. The flood progression and recessions were analyzed to study the flood dynamics through the two flood events, the flood affected areas were also obtained.

Flood duration map gives the duration of flood in a region; it gives an idea about how long an area was inundated. To create the flood duration, map a model was created using the modeler in ERDAS. All the flood layers are given as input to the model (Fig.11) and the model is executed to obtain the flood duration map. Separate flood duration map was made for the July event and the August event. Flood maps for all the multi temporal satellite images were obtained by masking the water layer with the mask file. The flood inundated areas are clearly visible for each date. The flood map for each corresponding to the raw satellite imagery is shown (Fig.12).

Generation of Statistics

The district-wise flood inundation statistics is obtained using the summary tools. Firstly, all the flood layers were re-projected to Lambert conformal conic projection. To obtain this the raster flood layers were converted into vector. This conversion from raster to vector is done using the vector toolbox in ERDAS. The vector file created is opened in Arc GIS, select operation is done also a grid code value of 1 is assigned. After the selection union operation is done inputting the vector flood layer and the district file. Once the union operation is performed the output file attribute table is opened and the sum area is summarized for the entire flooded region.

RESULTS AND DISCUSSIONS

As a result of the study it was observed that there were actually two major flood events that hit Kerala during the Kerala Floods 2018, the July and August event. The progression and recession maps were separately made for these two events.

Flood Dynamics

July 2018 event

When the flood layers of 16th and 21st July were overlaid, it was observed that there is a clear recession in flood. Flood could be seen at its peak during 16th July. Flood inundated areas on 16th July were flood free by 21st July which is observed at three recession pockets (Fig.12.2). Areas near Pallikayal namely Chithirapally, Kainakary, Kuttamangalam, Chennamkary, KadavuMullakal, Nedumudy, Pomga, Mannanchery, Kumarakam where found to be flood inundated. Some areas clear recession of flood could be observed like in Chennamkary, Kadavu and Paravoor. Mainly recession is along the banks of the river Pamba, Manimala and Ambalapuzha. Roadways including National highway NH 66 which connects Panvel to Kanyakumari could be seen flooded in areas near Thakazhi and Kalpakavadi. State highways, SH 11 connecting Amabalapuzha with Veliyinad and SH 12 connecting Ambalapuzha to Thiruvalla could also be seen flooded in many regions. Schools including SDV government UP School, St Mary's HSS Champakulam and hospitals such as Government hospital champakulam were also flooded.

August 2018 event

There is a significant progression of flood from 11th to 18thAugust as seen (Fig.12.3). Three progression pockets were identified. In the first subset area the flood could be seen progressing to areas near the Pamba river and Kollam – Karumadi ferry namely Thottappally, Kuttanad, Kunnumma, Kelamangalam, Cheruthana. Some points of interests like St Joseph's church, Kurichikal temple, Mukkadadevi temple and Naluchira temple were inundated in this period.

In the second progression pocket the flood extent near Paravoor have significantly increased. Areas to the south of state highway SH-11 Alappuzha- Veliyanadroad namelyThookukulam, Olavathara, Valiyathara, Kalarcode, Kithavana could be seen flooded in this progression. Point of interests like SD College, Kalarcode Sri Mahadeva temple, Sathanapuram Post office, Yes Kay Convention Center were flooded

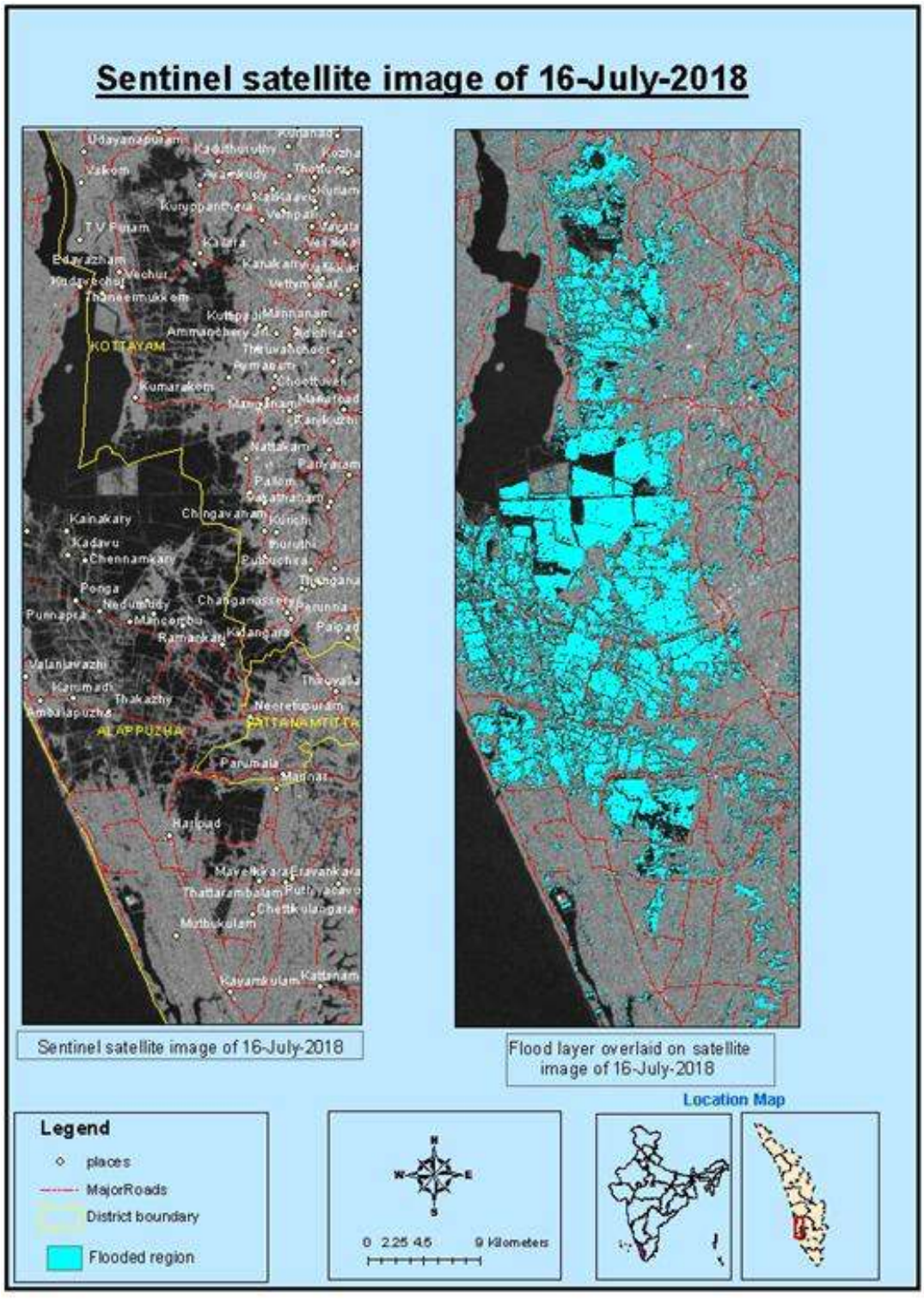


Fig 12.1 Flood map July 16 2018

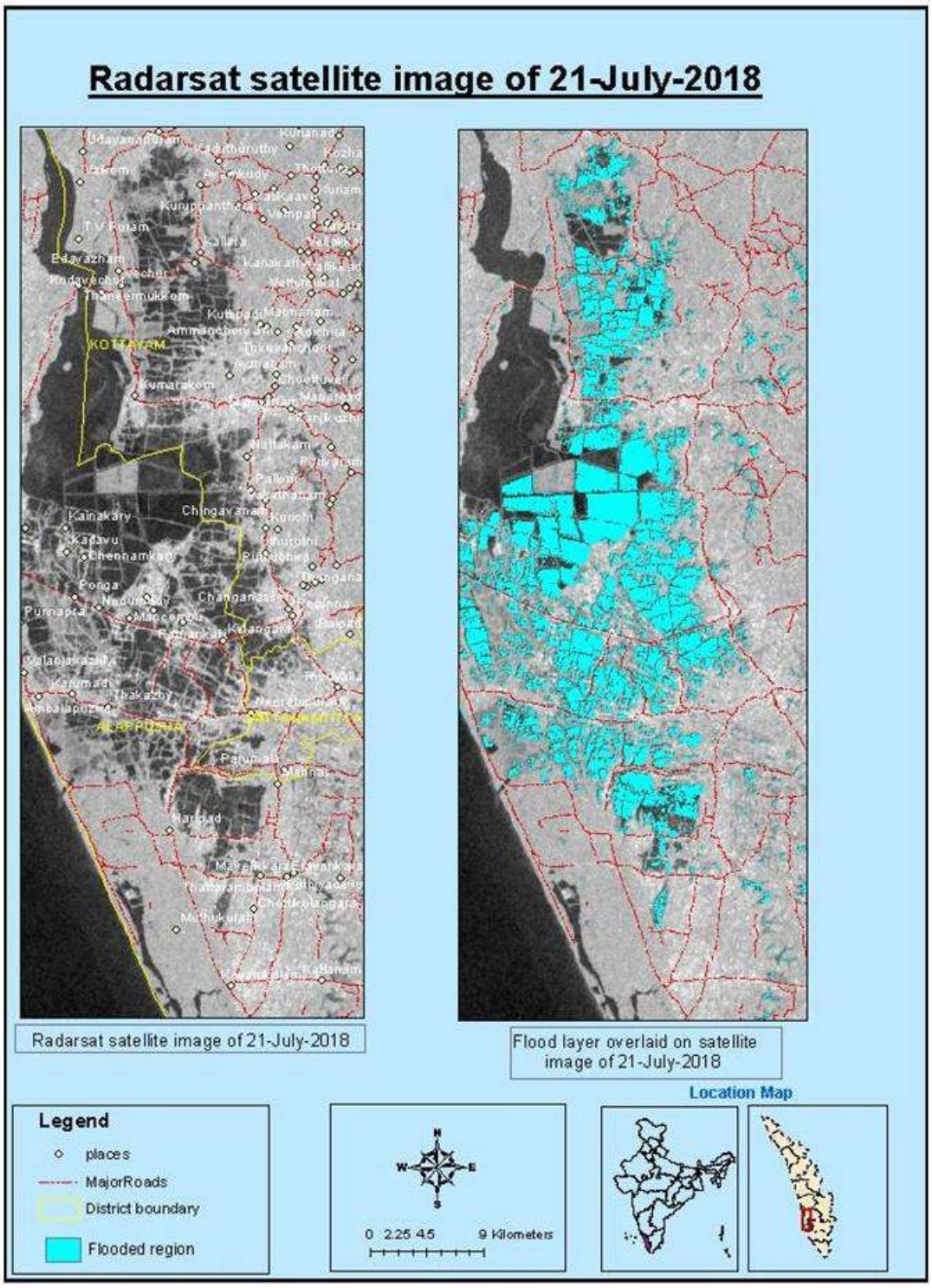


Fig 12.2 Flood map July 21 2018

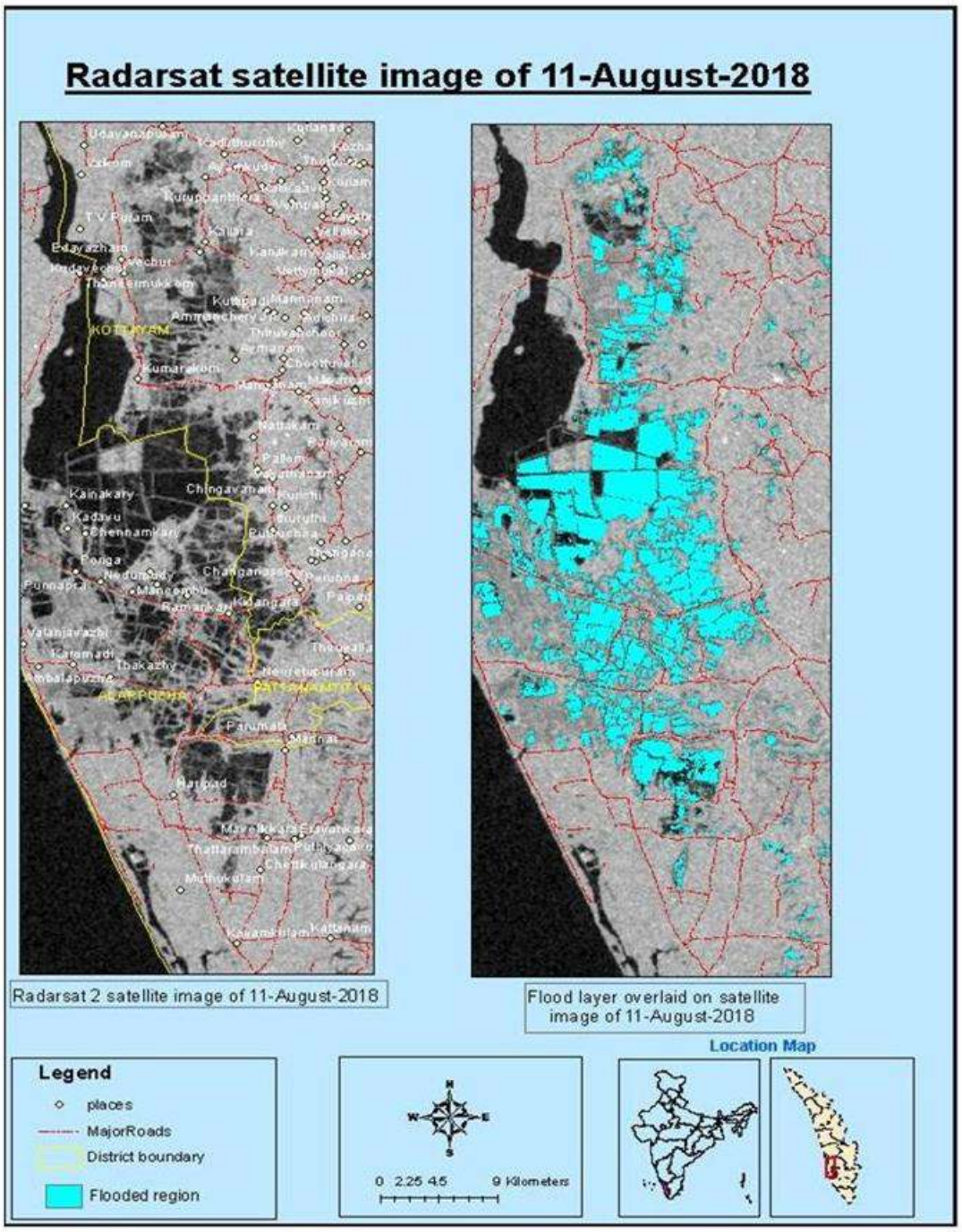


Fig 12.3 Flood map August 11 2018

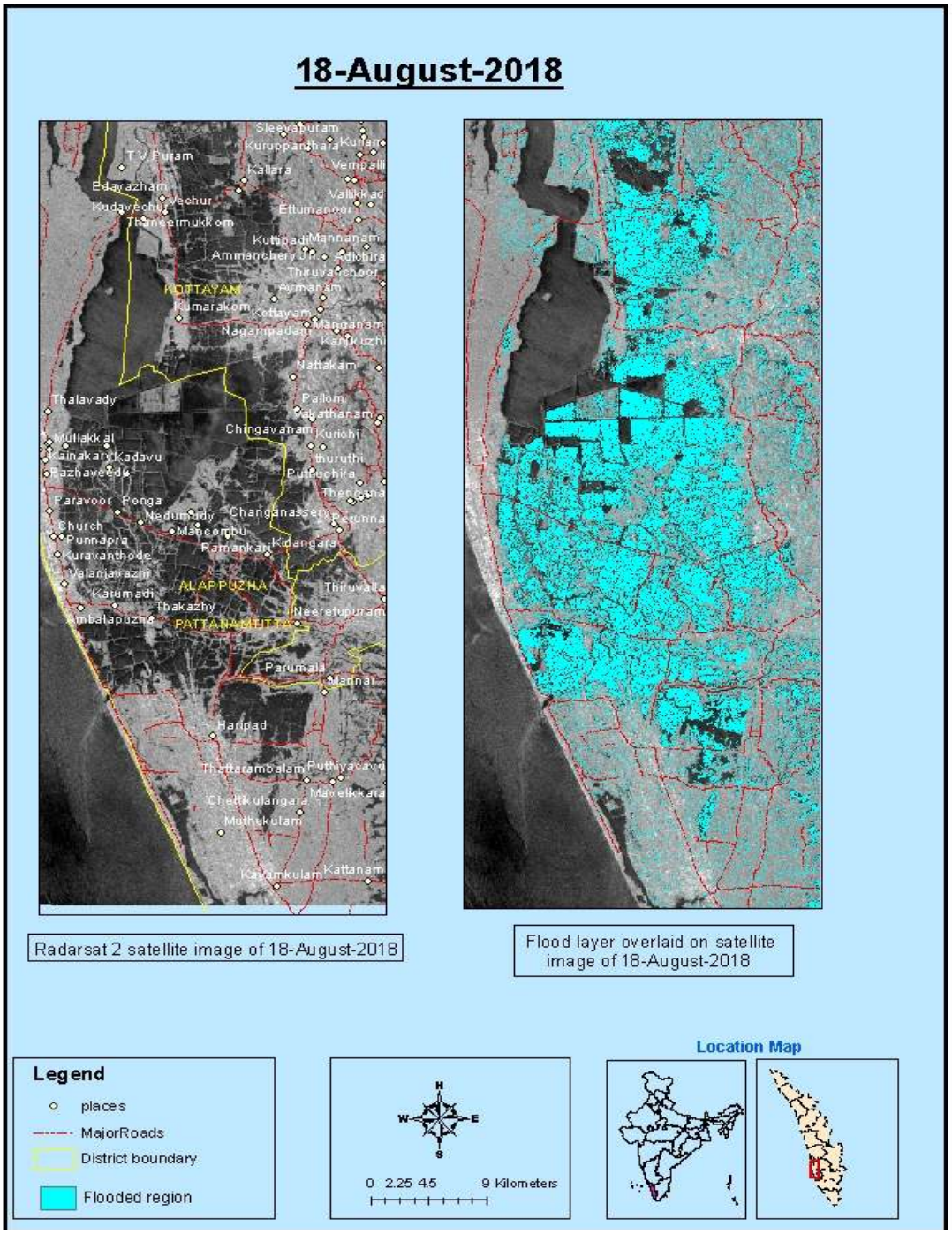


Fig 12.4 Flood map August 18 2018

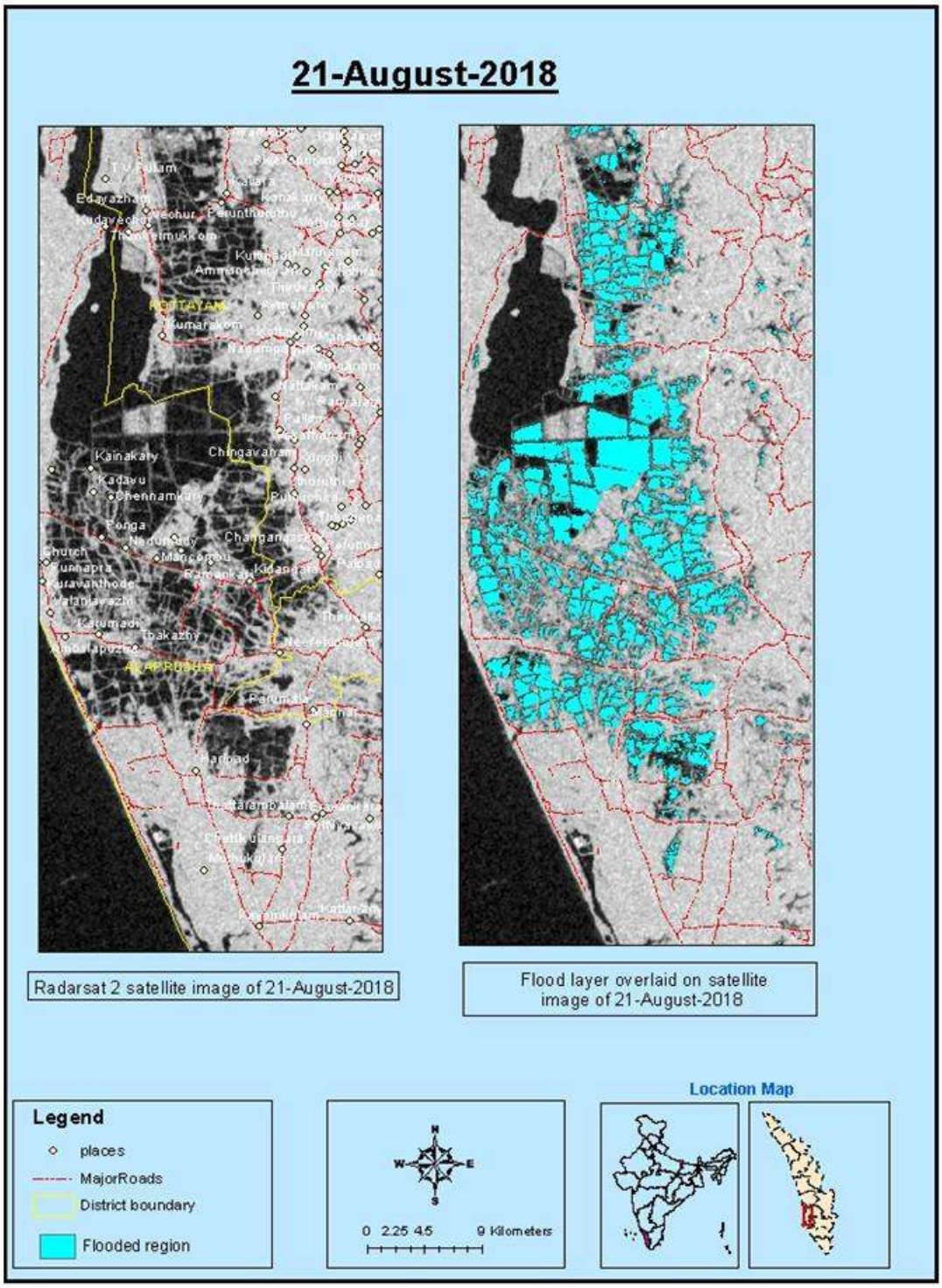


Fig 12.5 Flood map August 21 2018

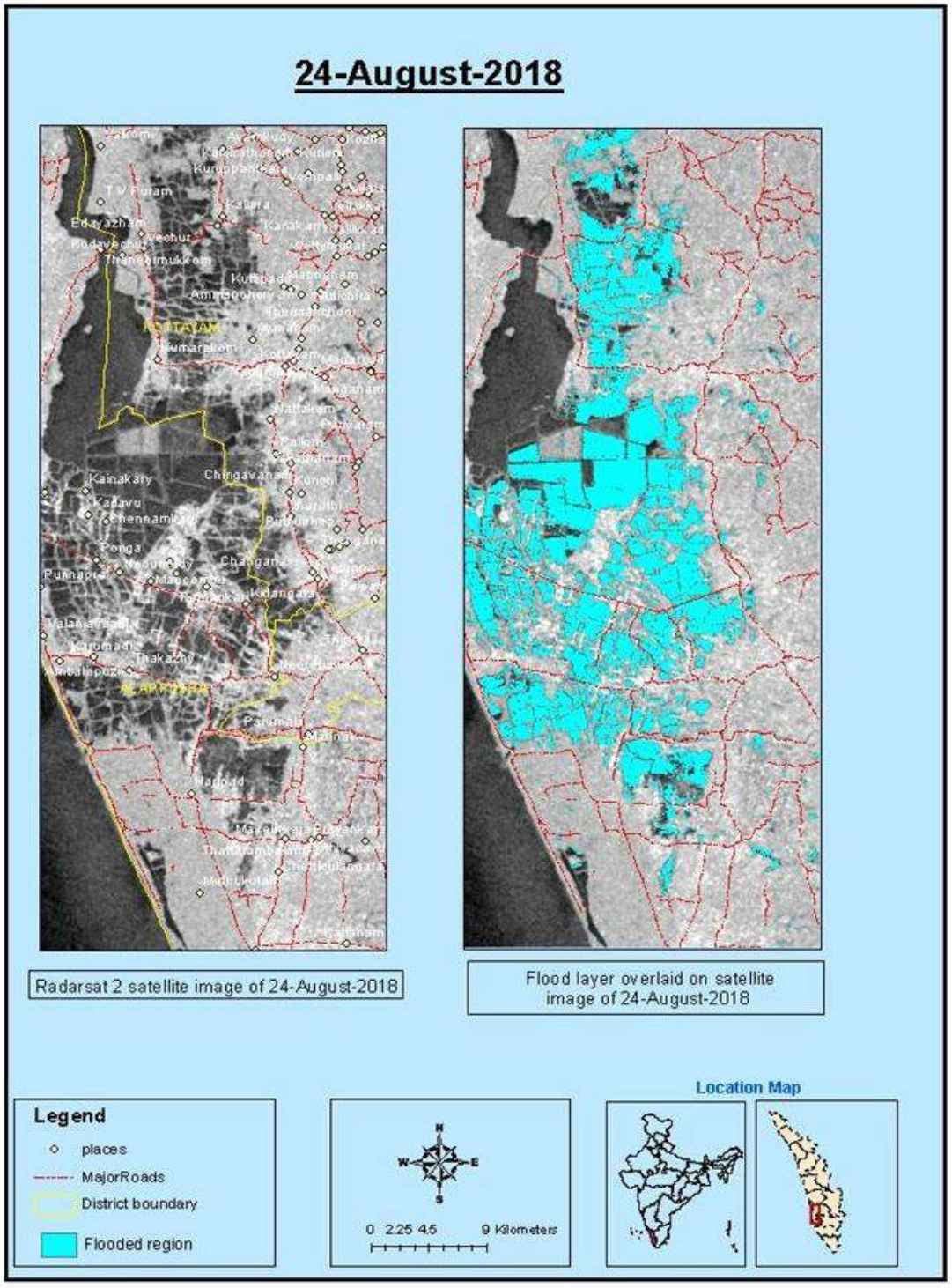


Fig 12.6 Flood map August 24 2018

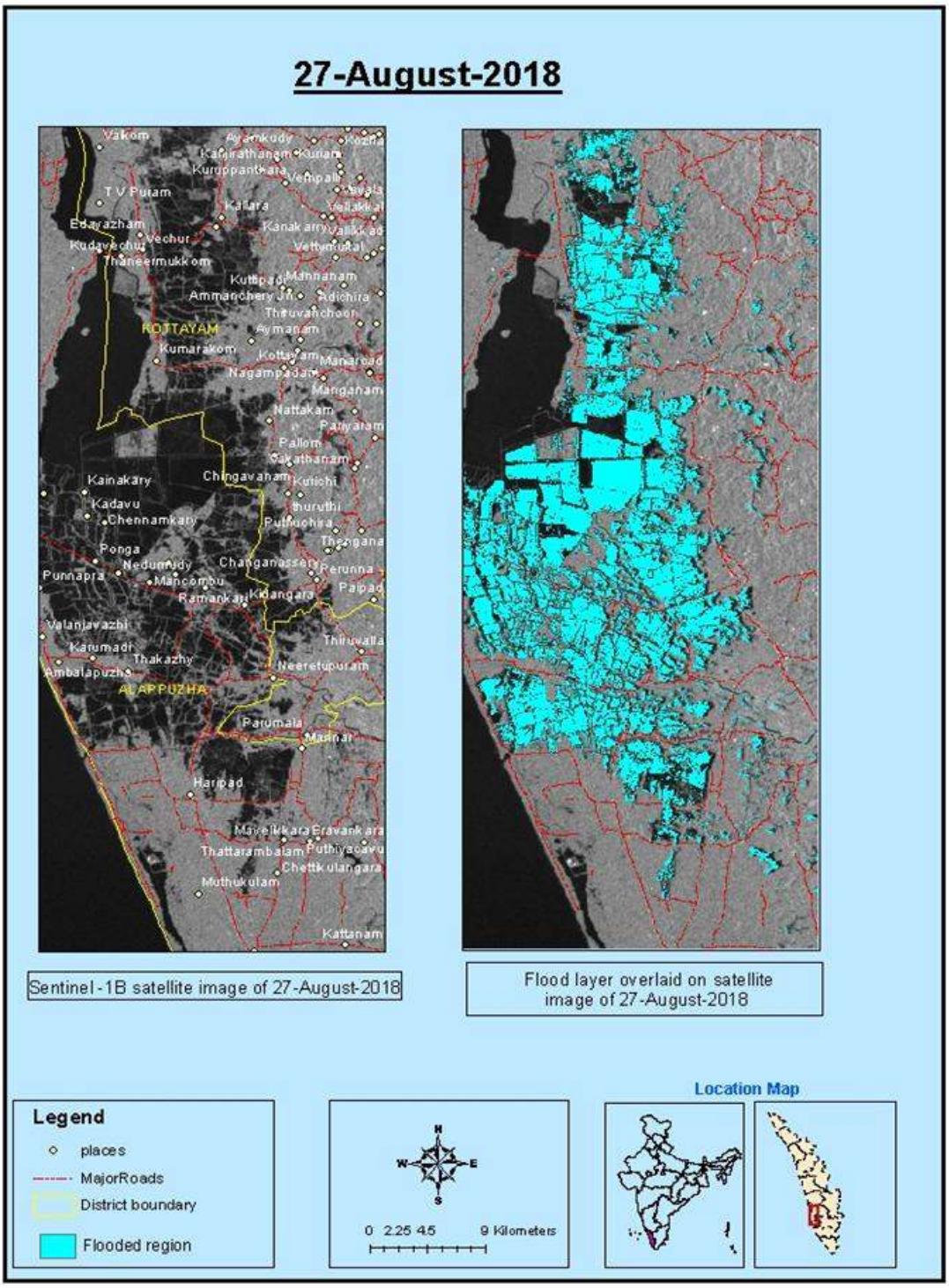


Fig 12.7 Flood map August 27 2018

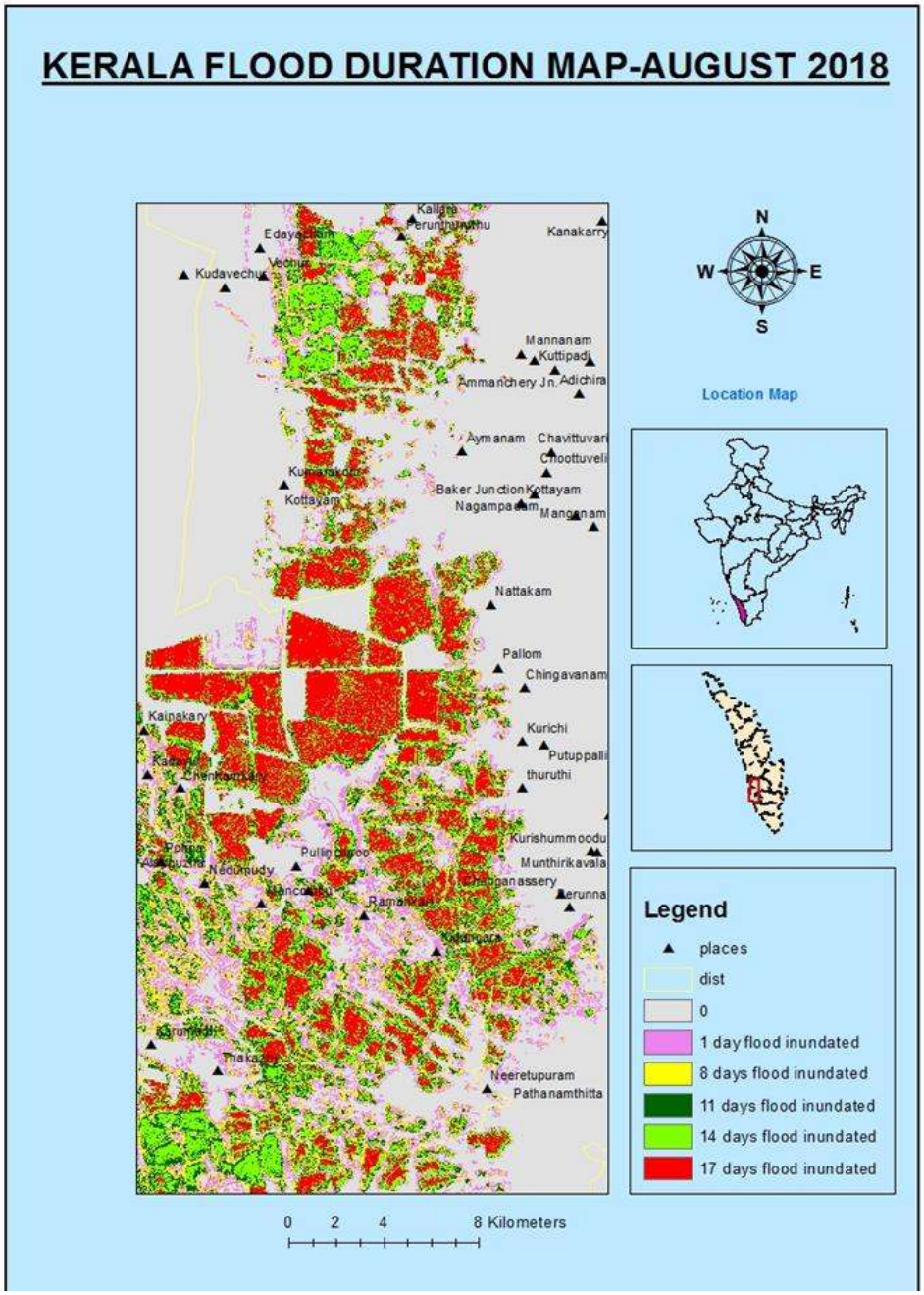


Fig 13.2 Flood duration August 2018 event

Fig 13. Flood duration July and August 2018 event

In the third pocket of progression the progression is comparatively lower than the other two pockets. There is small progressions in Vezhapra, Mithrakari, Koduppunna, Muttar, Poonthuruthy. Local roads including Vezhapra – Thayankaryroad, Edathua – Mampuzhakari road, Veazhapra – Mithrakari road were partially flooded.
From 18th to 21st August there is a recession in flood as observed (Fig.12.4). The peak flooding was observed on 18th August 2018. After the peak, the flood slowly started receeding in many regions. Recession could be observed in Thottappally, Kuttanad, Kunnumma, Kelamangalam, Cheruthana.

From 21st to 24th August there is a slight progression in flood as observed (Fig.12.5). The district of Alappuzha is having the highest progression of flood. After the recession after the peak flooding event, the flood could be identified progressing in this interval.
Again in this interval recession could be observed but in a more rapid pace than before as observed (Fig.12.6). In the district of Alappuzha there is however a progression in many regions. Even by 27thAugust 2018 the flood has not completely receded and most of the study area is flood inundated (Fig.12.7).

DISCUSSION

Flood duration maps were created for both the events July and August 2018 (Fig.13) which shows gradual progression of flood from day one to seventieth day. However some areas inundated on day first of July were not further affected but areas affected on day six of July (Fig.13.1) were severely affected later on (Fig.13.2). fluctuation of flood can be observe during the flooding period in the study area. Maps depicting progression and recession of flood clearly shows change in inundated region within the study period (Fig. 14). Severity and extend of flooding appears to be maximum on 14th day which continued up till 17th day of August. On July 16th 2018 Alappuzha was severely affected with about 26,105 hectare area completely inundated followed by Kottayam and Pathanamthitta (table-5, Fig15) which gradually reduced to 19746, 11870 and 1190 hectare respectively on 21 July 2018 (Fig.14).

But again on 11th August 2018 there was an increase in over flown region with Alappuzha again having maximum extend (20,888 hectare) followed by Kottayam and Pathanamthitta. The submerged area further increased to 27691, 13411 and 2257 hectare in Alappuzha, Kottayam and Pathanamthitta respectively. However there was little reduction in inundated area on 21st August, 2018 which then again witnessed surge of water on 24th August, 2018. There was slight reduction inundated area in Kottayam and Pathanamthitta but in Alappuzha water continued to increase (table-5). A map depicting the extend of inundated region of Kerela in July and August 2018 was prepared using these statistics to have a clear view of extend of flooding (Fig.16).



Fig 14.1. Recession map_July 2018

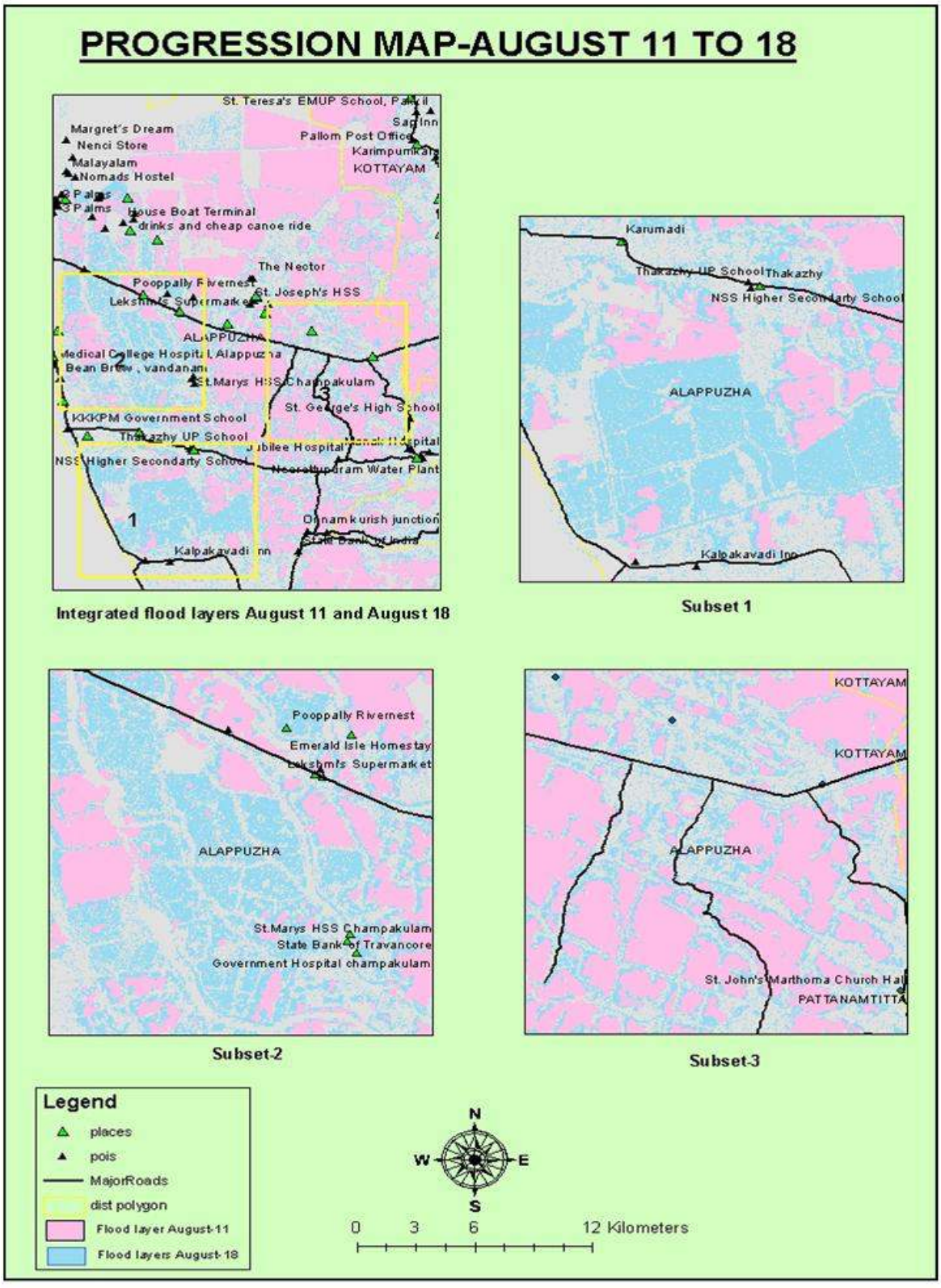


Fig 14.2 Flood progression map August 11 to 18,2018

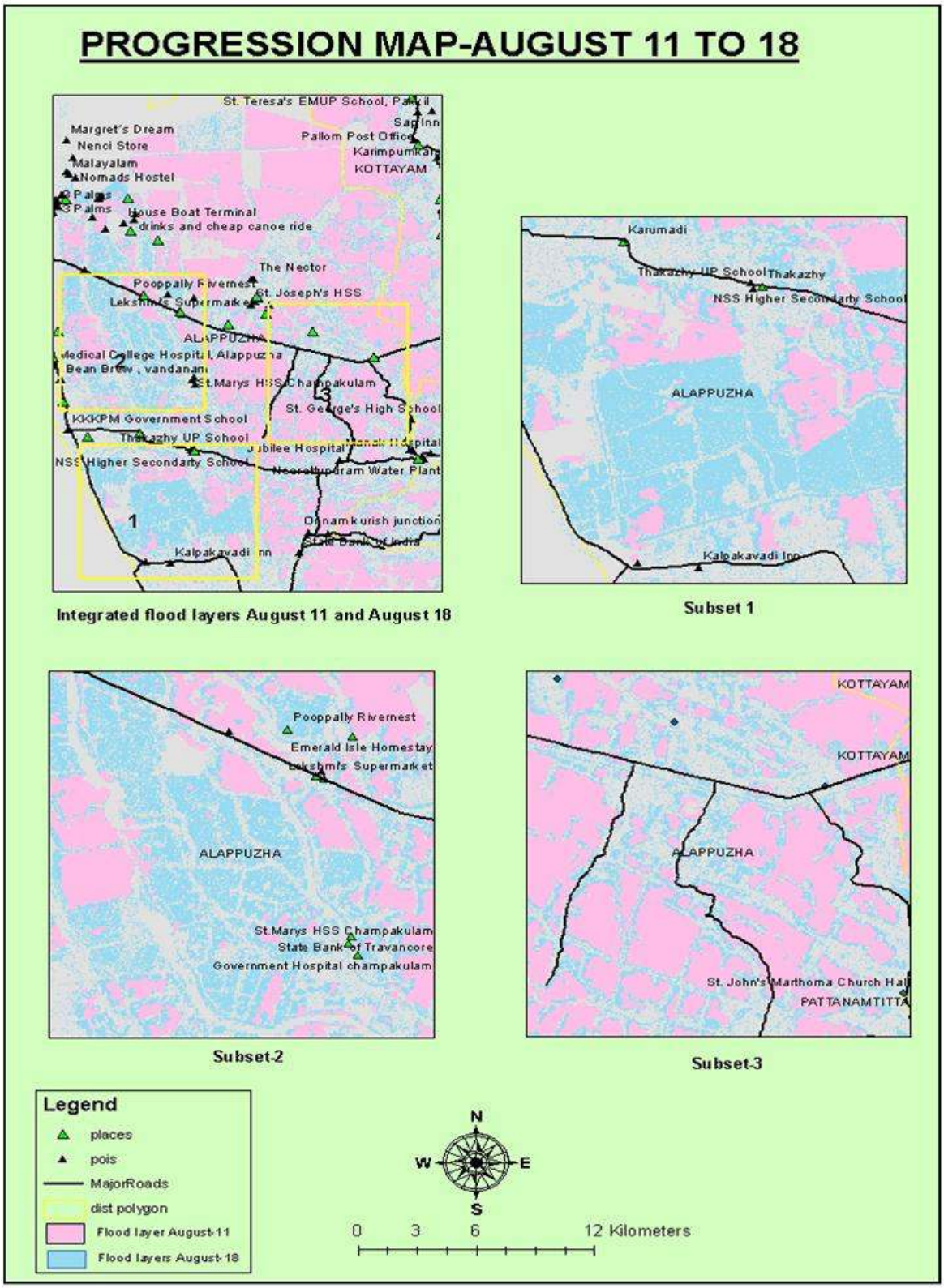


Fig 14.2 Flood progression map August 11 to 18,2018

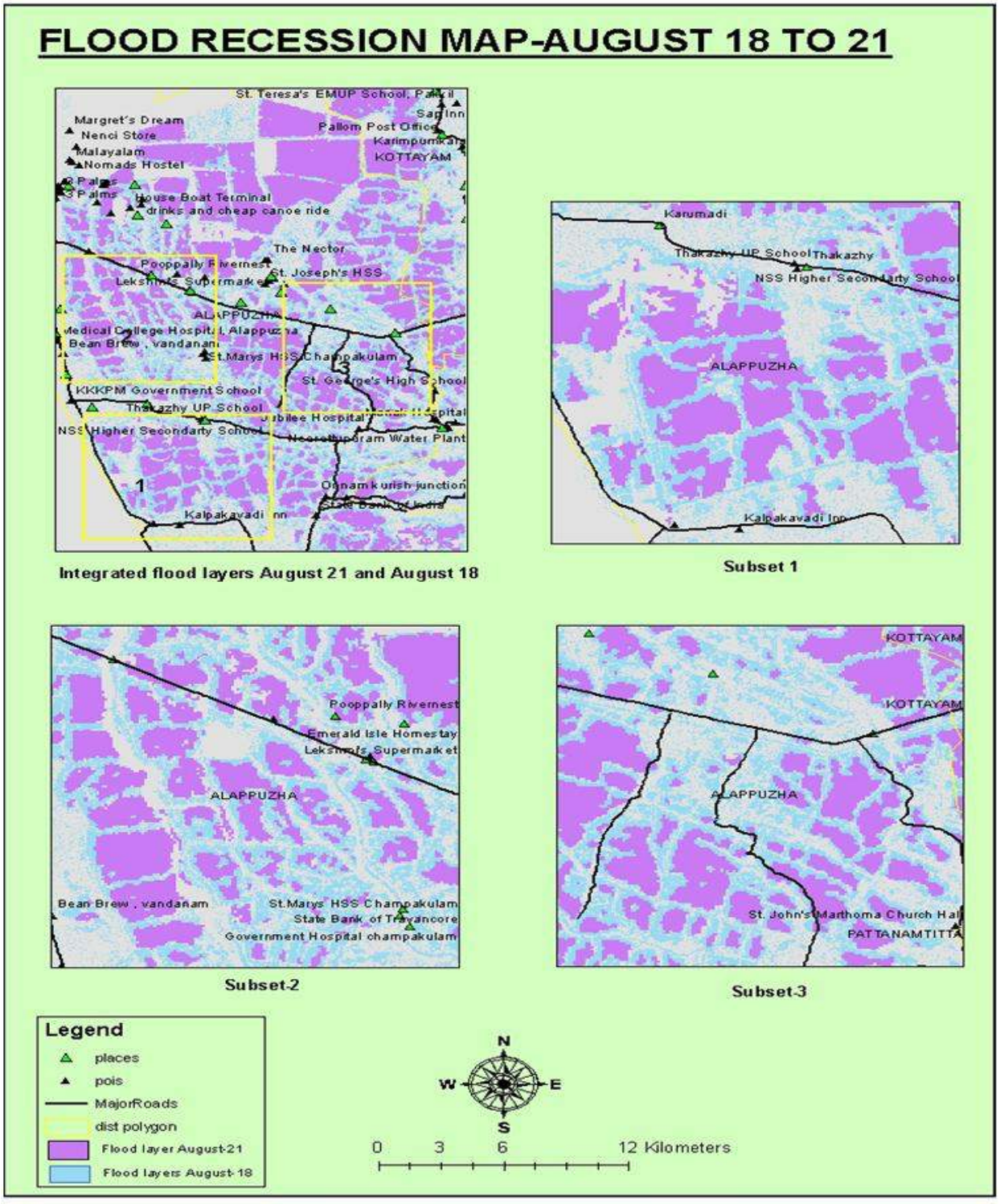


Fig 14.3 Flood recession map August 18 to 21, 2018



Fig 14.4 Flood recession map August 21 to 24, 2018



Fig 14.5. Flood recession map August 24 to 27, 2018

Fig.14. Fluctuation of flooding in the study area

Table 5. Flood inundated area statistics

S.No	Dates	Flood inundated area in Hectares		
		Alappuzha	Kottayam	Pathanamthitta
1	16 July 2018	26105	16159	1822
2	21 July 2018	19746	11870	1190
3	11 August 2018	20888	12228	1649
4	18 August 2018	27691	13411	2257
5	21 August 2018	16357	8236	751
6	24 August 2018	23702	14563	1761
7	27 August 2018	25799	13680	1594

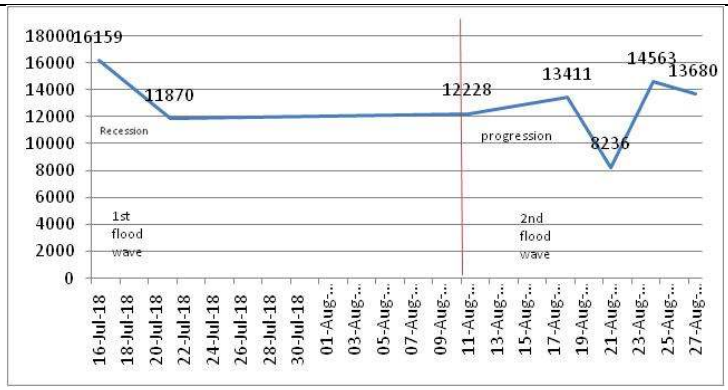


Fig 15.1. Flood inundated area graph- Kottayam district

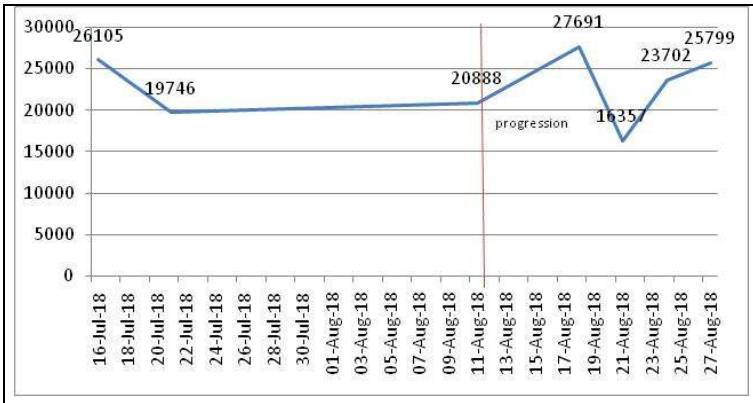


Fig 15.2. Flood inundated area graph-Alappuzha district

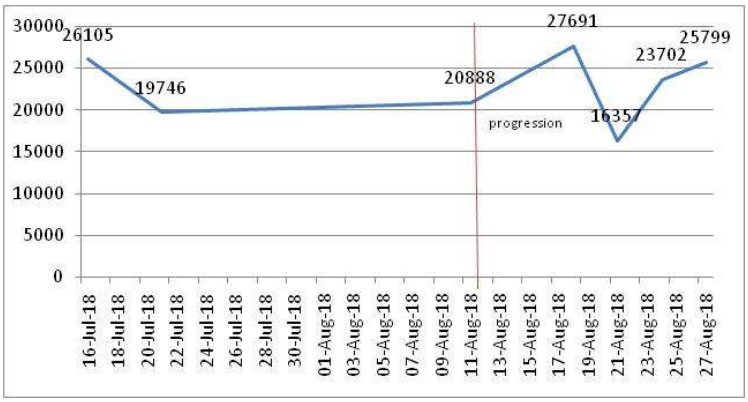


Fig 15.3. Flood inundated area graph-Alappuzha district

Fig.15 Graphical Representation of inundated area

CONCLUSION

Multi temporal microwave imageries proved to be very useful in the delineation of flood and to study the progression and recession of flood during different time period in the present study. Multi-temporal Satellite data obtain for different region which was inundated helped in identifying the extent of flood. The persistence and fluctuation of flooded region was observed by integrating all the multi temporal data and running the model for flood duration in GIS environment.

Microwave data being all weather capable remote sensing technique, have an upper hand in flood mapping. The limitation of using multi temporal satellite imageries for flood mapping is the non-availability of continuous data and even though if data sets are available, they may not cover the flood affected areas. Due to the lack of satellite data at continuous time intervals, there would be a gap in understanding the flood dynamics. Sometimes, the exact flood peak incident also may be missed. This can be reduced when satellite data will be available from constellation of satellites.

Even with all the limitations, satellite remote sensing based technique is very useful in the study of flood dynamics. It also proves to be very useful in damage assessment and could be very valuable on the onset of such a disaster again. Further using this study, the flood prone areas could be identified and ideal location for relief camps and shelters could be identified. Combining the rainfall data with the flood dynamics would help in modeling any similar flood events in the current study area.

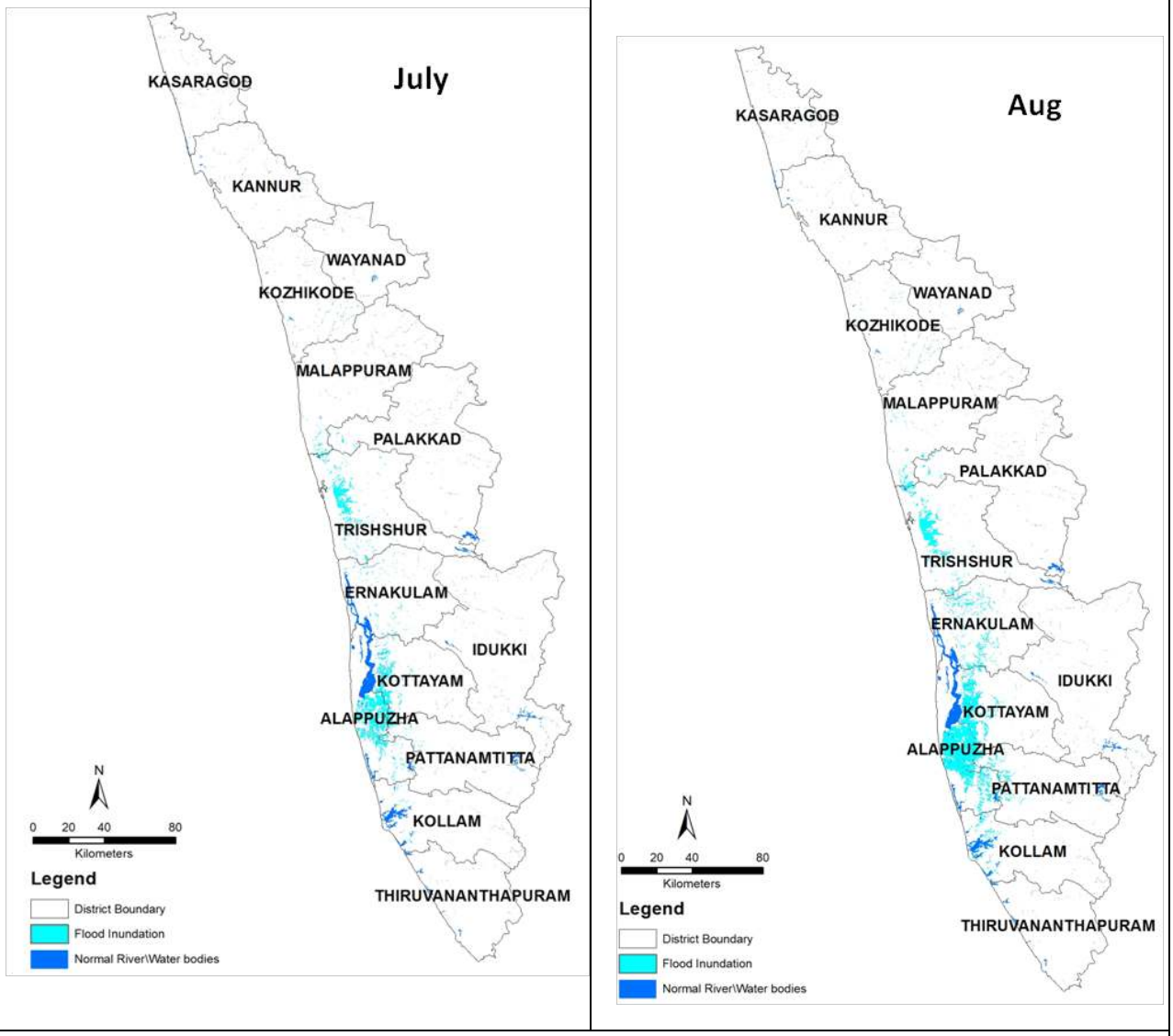


Fig.16. Flood inundated area in Kerala during Jul & Aug 2018

Referenes

Cian, F., Marconcini, M., & Ceccato, P. (2018). Normalized Difference Flood Index for rapid flood mapping: Taking advantage of EO big data. *Remote Sensing of Environment*, *209*, 712–730. https://doi.org/10.1016/j.rse.

Indian Meteorological Department. (2018). *Performance of South West Monsoon 2018 Over Kerala*. Meteorological Centre. https://www.imdtvm.gov.in/images/cumulativerainfallforkerala-swmonsoon2018.pdf

Inge Sandholt, Jens Andersen, Gorm Dybkjær, Lotte Nyborg, Medou Lô, Kjeld Rasmussen, Jens-Christian Refsgaard, Karsten H Jensen and Assize Touré (2003) Integration of earth observation data in distributed hydrological models: the Senegal River basin, Canadian Journal of Remote Sensing, 29:6, 701-710, DOI: 10.5589/m03-045.

Ologunorisa, T.E. and Abawua, M.J. (2005) Flood Risk Assessment: A Review. Journal of Applied Sciences and Environmental Management, 9, 57-63.

Panhalkar, Sachin and Jarag, Amol. (2017). Flood Risk Assessment of Panchganga River (Kolhapur District, Maharashtra) Using GIS-Based Multicriteria Decision Technique. Current science. 112. 785-793. 10.18520/cs/v112/i04/785-793.

Kabir Uddin, Deo Raj Gurung, Amarnath Giriraj and Basanta Shrestha, Application of Remote Sensing and GIS for Flood Hazard Management (2013): A Case Study from Sindh Province, Pakistan, *American Journal of Geographic Information System*, Vol. 2 No. 1, 2013, pp. 1-5. doi: 10.5923/j.ajgis.20130201.01.

Sghaier O, Moslem, Hammami, Imen, Foucher, Samuel and Lepage, R.. (2018). Flood Extent Mapping from Time-Series SAR Images Based on Texture Analysis and Data Fusion. Remote Sensing. 10. 10.3390/rs10020237.

Rahman, Md and Thakur, Praveen (2017). Detecting, mapping and analysing of flood water propagation using synthetic aperture radar (SAR) satellite data and GIS: A case study from the Kendrapara District of Orissa State of India. The Egyptian Journal of Remote Sensing and Space Science. 21. 10.1016/j.ejrs.2017.10.002.

Pierdicca N, Pulvirenti L, Fascetti F, Crapolicchio R and Talone M (2013) Analysis of two years of ASCAT-and SMOS-derived soil moisture estimates over Europe and North Africa. Eur J Remote Sens 46(1):759–773. https://doi.org/10.5721/EuJRS20134645.

Nallapareddy, Anusha and Varadharajulu, Bharathi. (2019). Flood detection and flood mapping using multi-temporal synthetic aperture radar and optical data. The Egyptian Journal of Remote Sensing and Space Science. 23. 10.1016/j.ejrs.2019.01.001.

Donchyts, G.; Schellekens, J.; Winsemius, H.; Eisemann, E.; Van de Giesen, N. (2016): A 30 m Resolution Surface Water Mask Including Estimation of Positional and Thematic Differences Using Landsat 8, SRTM and OpenStreetMap: A Case Study in the Murray-Darling Basin, Australia. *Remote Sens.* 2016, *8*, 386. https://doi.org/10.3390/rs8050386.