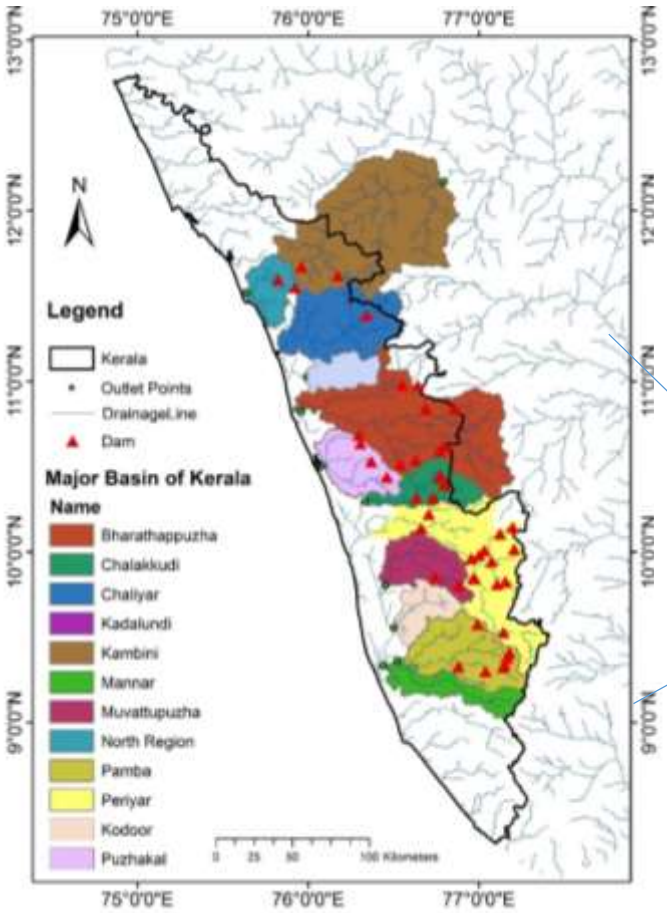
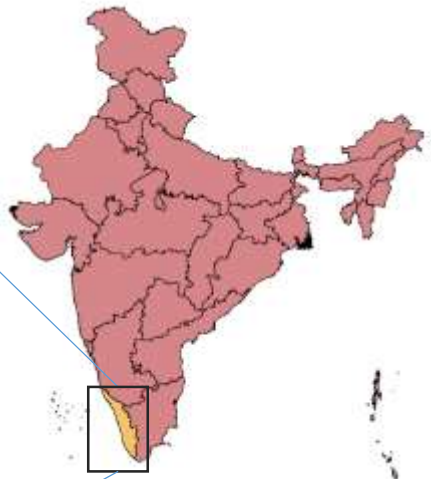
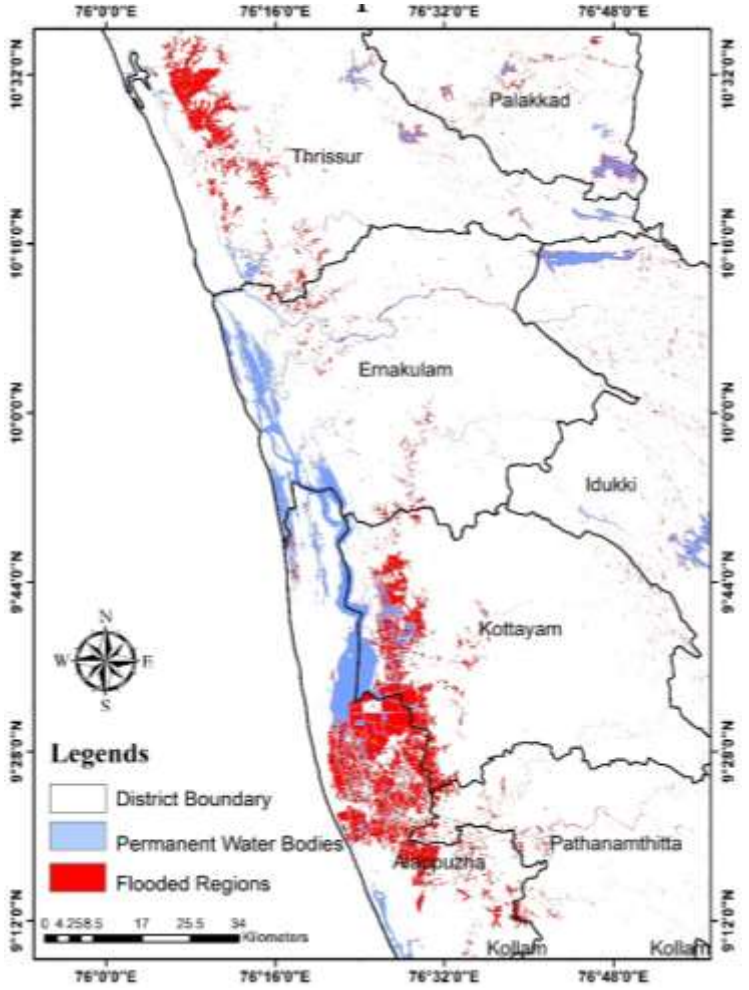
Hydrological Study of August 2018 Kerala Floods using Remote Sensing, Modeling and Geospatial tools

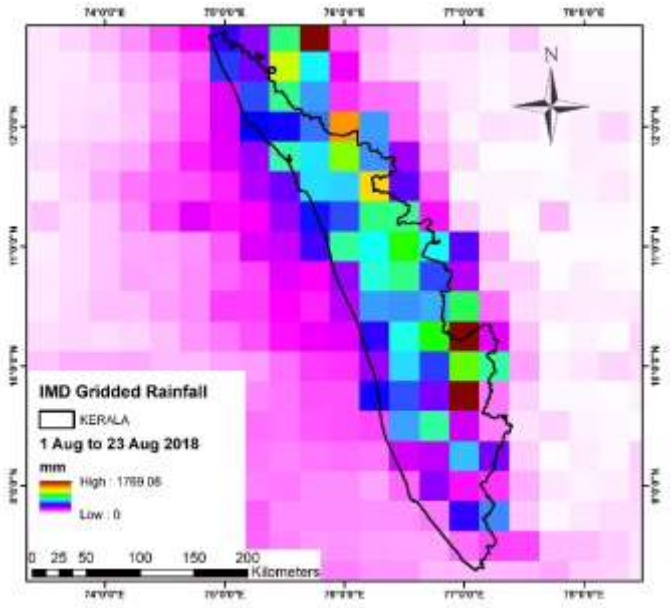




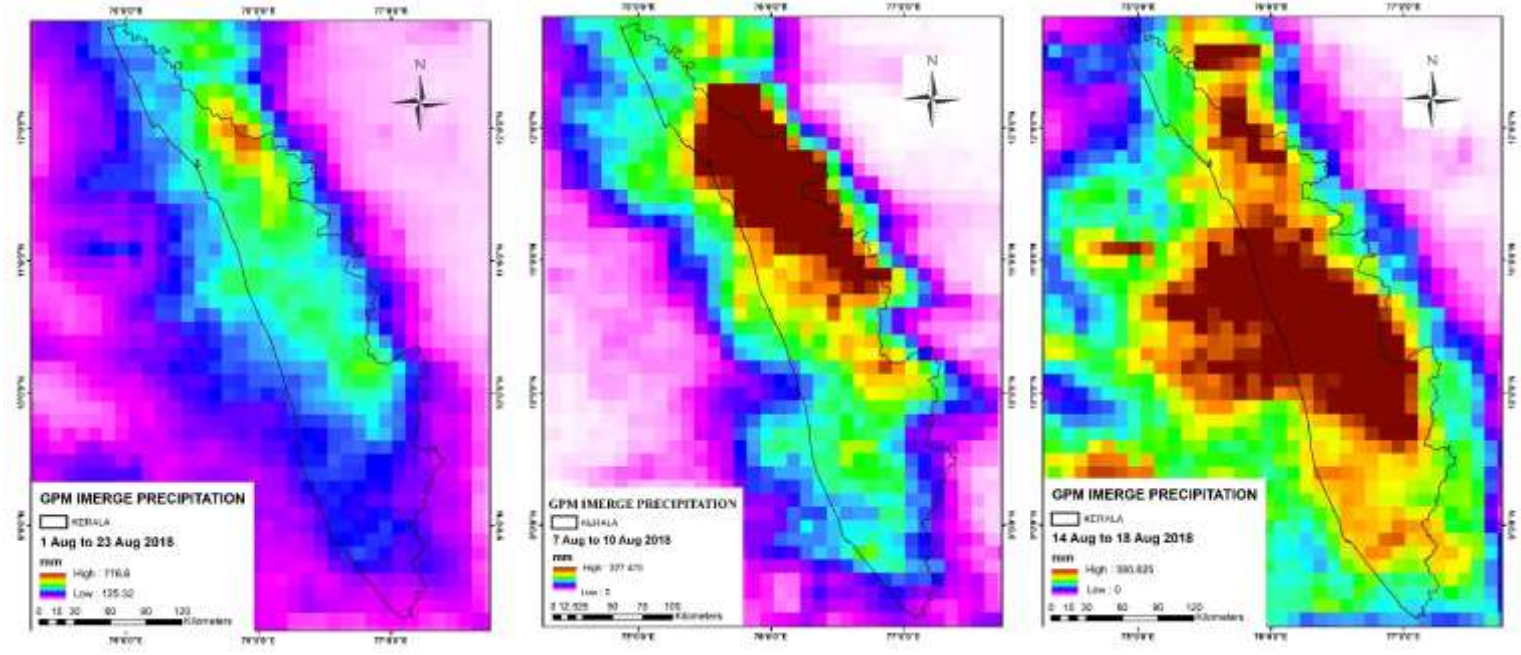


Indian Institute of Remote Sensing
Indian Space Research Organization
DoS, Govt. of India
4, Kalidas Road, Dehradun

Background: August 2018 Heavy Rainfall & Floods in Kerala



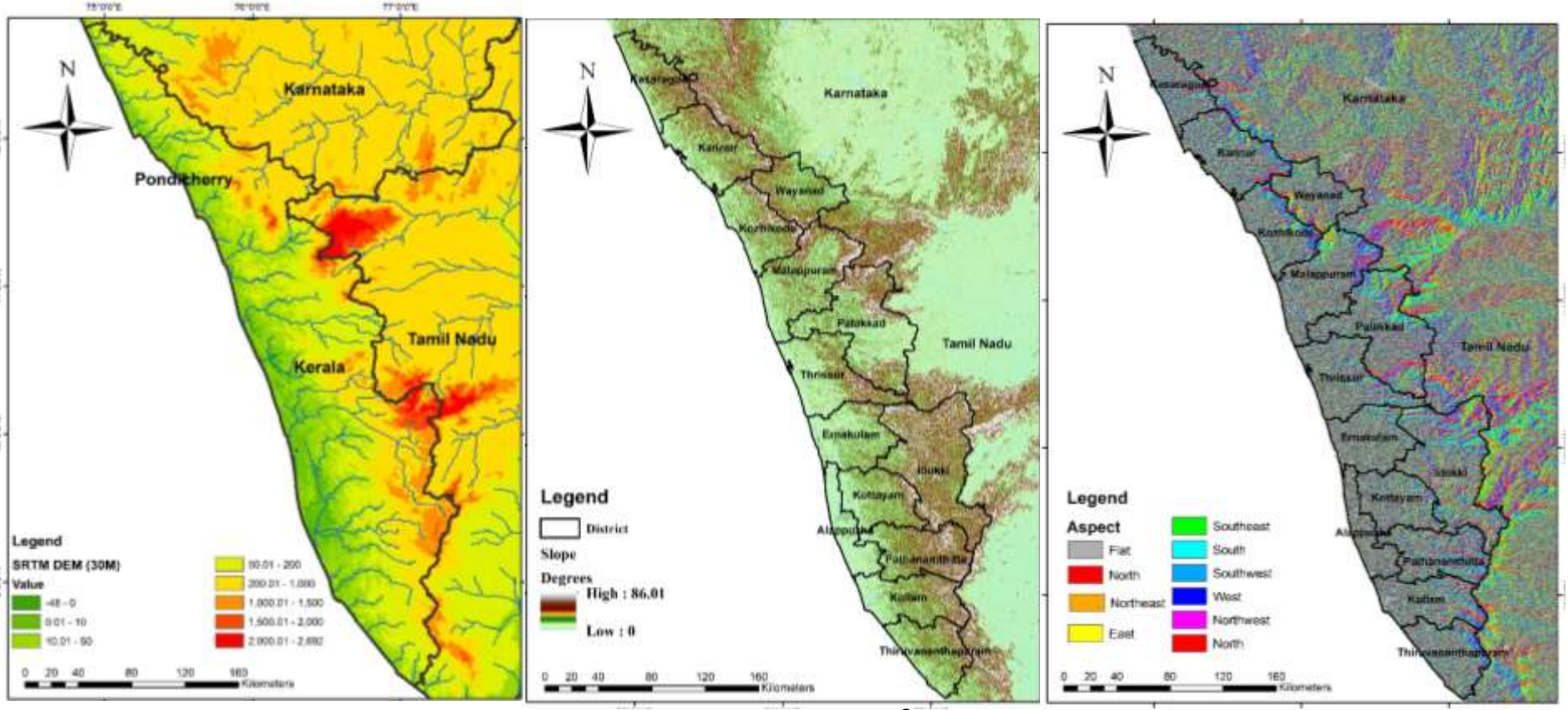
- Kerala received actual rainfall of 2394.1 mm from June 1 to Aug 22, 2018, which exceeds normal rainfall of 1701.4 mm by 41 % (IMD). Rainfall products of IMD-GPM at 0.25 degree area shown in figures.
- Idukki district received highest rainfall of 3555.5 mm during same time, with two major spells of rainfall during Aug 07-10 and Aug 14-18, 2018.
- Heavy rainfall resulted in high surface runoff in major river basins of Kerala, filling of all dams and subsequent opening of these dams, caused widespread flooding in downstream areas, low lying areas near coast and backwaters of Kerala.



Spatial distribution of rainfall over Kerala from GPM rainfall products of 0.1 deg. resolution

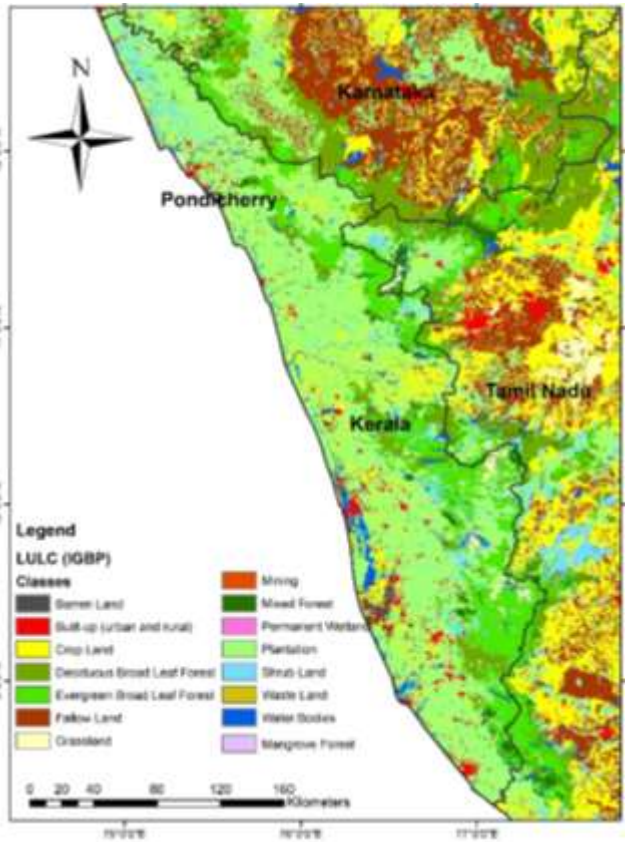
Source: Internet

Physical characteristics of Kerala and surrounding states

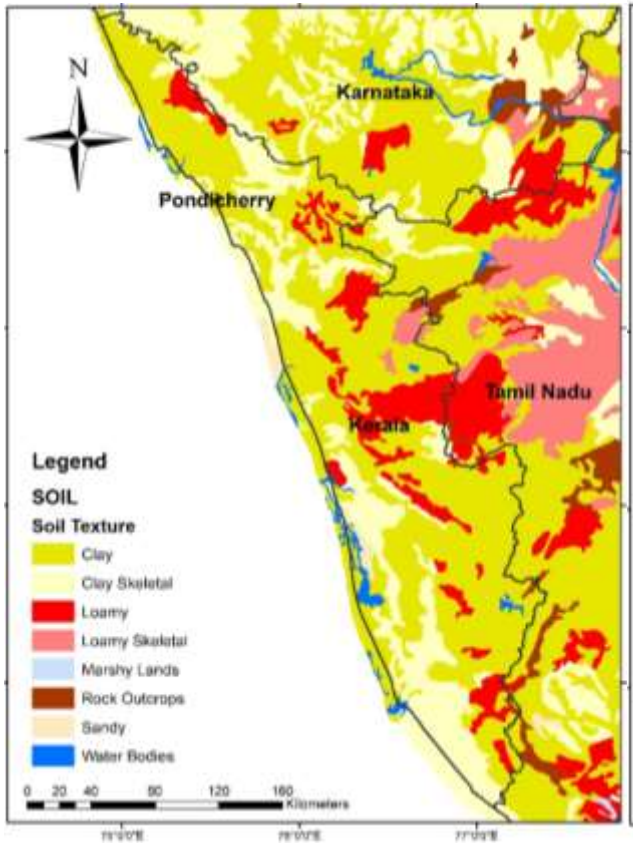


- Kerala has a total geographical area of 38863 km^2, with a North-South orientation and elongated Shape. It has approximate length of 561 km and very short width of approximately 100 km, which gives a short time of travel for water to reach downstream areas from its farthest point at ridgeline
- The elevation ranges from -48 m below sea level to +2692 m above mean sea level, with 35 % area between 0-50 m, 39.82 % are between 50-500 m and 24 % of area above 500m
- Slope ranges from near flat area near coast to steep slopes at ridge line of watersheds
- The Major aspect of all sub-basins of Kerala is in South and South West direction

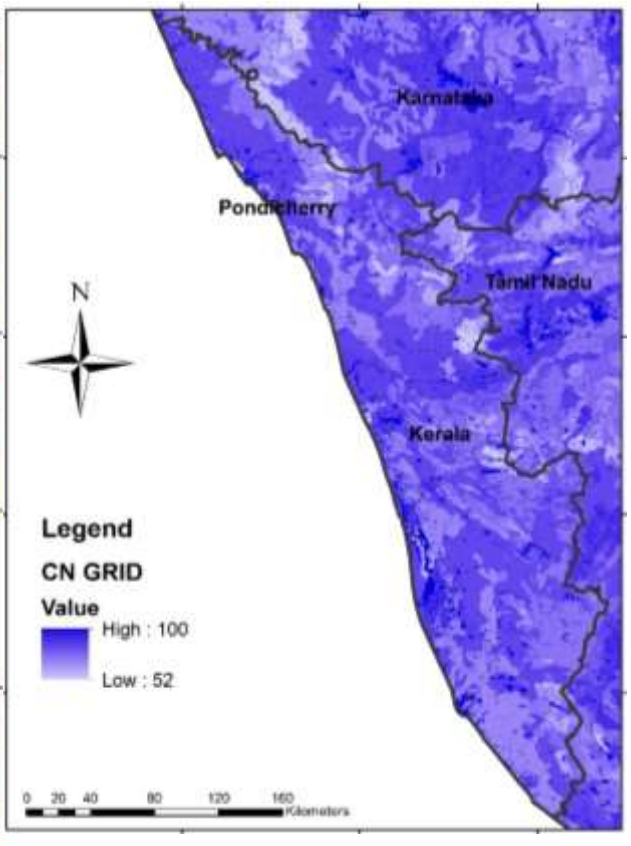
2005 LULC map from ISRO-GBP project



Soil texture map from NBSSLUP

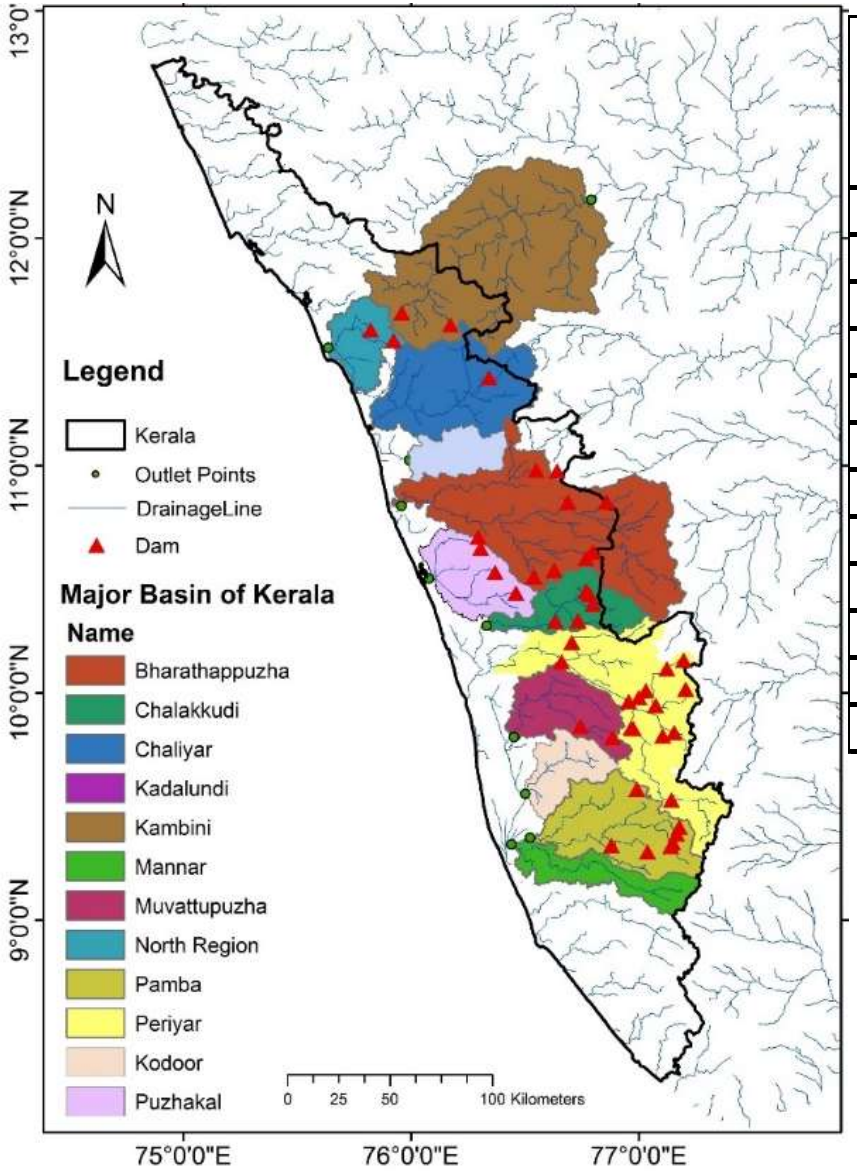


CN grid map



- The major Land Use and Land Cover (LULC) in Kerala is Plantation (22255 km^2 58.23 %), Deciduous and Evergreen Broad Leaf Forest (7849 km^2, 20.5%), Cropland/Shrubland/Grassland (4307 km^2, 11.27 %) and Waterbody/Urban/Others (3806.5 km^2, 9.95%)
- The major soil type of Kerala are Clay/Clay skeletal (31963 km^2, 83.83%), Loamy/Loamy skeletal (5339.20 km^2, 14%), small fractions of soil sandy. This high area under clayey soils can result in high runoff potential during heavy rainfall in all major catchments of state.
- The NRCS Curve Number (CN) ranges from 52 to 100 for this area, with area under CN 52-64 as (0.46 %), 65-74 as (23.02 %), 75-85 as (65.98 %) and > 85 as (6.8%)

Hydrological characteristics of Kerala and surrounding states



The major flood affected rivers basins were Periyaar, Kambini, Puzhakal, Pamba, Kodoor.

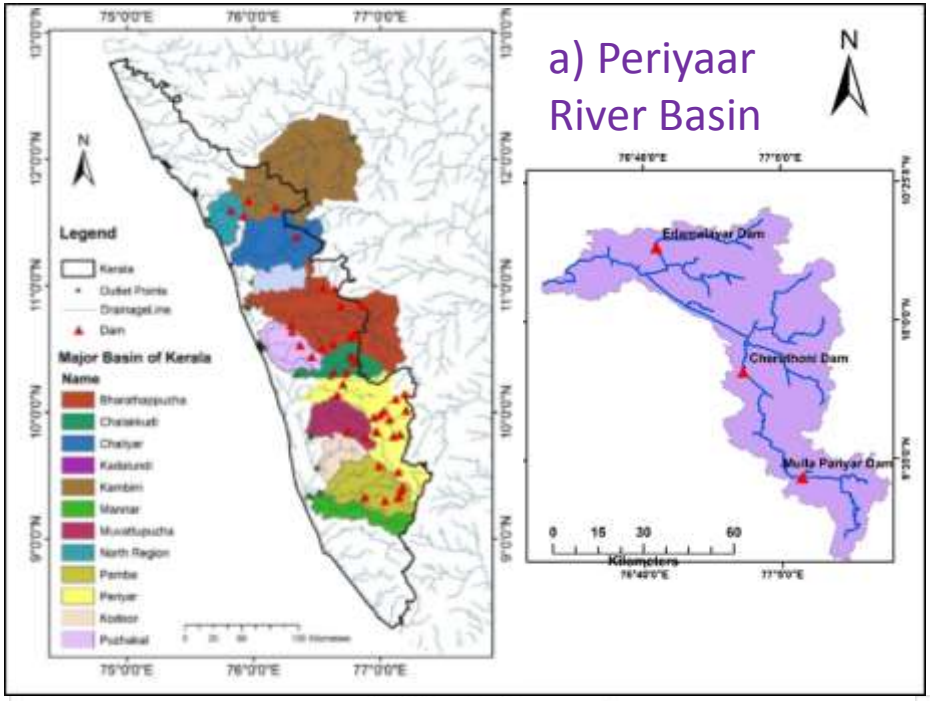
S. No	Basin name	Area (km^2)	Total Drainage* (km)	No. of sub-watersheds*	Mean Tc (hours)**	No of major dams/reservoirs
1	Periyar	4276.91	527.16	47	6.92	12
2	Pamba	2486.7	320.37	17	12.14	4
3	North Region	1008.4	114.73	11	11.21	2
4	Muvattupuzha	1560.7	196.15	15	13.35	2
5	Mannar	1234	155.83	7	20.48	0
6	Kambini	6853	834.87	89	9.75	5
7	Kadalundi	886.79	109.5	8	14.54	0
8	Chaliyar	2915.73	329.93	37	7.16	1
9	Chalakudy	1309.84	187.04	15	5.94	4
10	Bharathapuzha	5884.24	782.92	73	9.88	6
11	Kodoor	1045.28	107.15	14	10.69	0
12	Puzhakal	1523.473	176.7	19	12.4	3

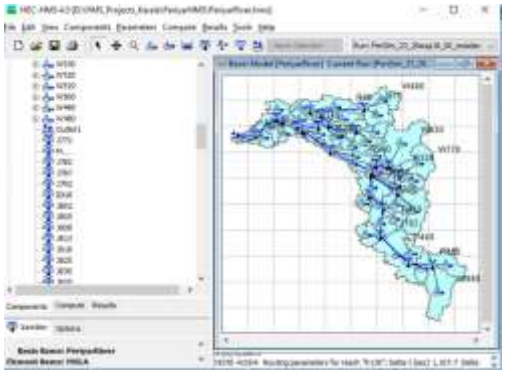
*The watersheds are delineated using SRTM-30 m DEM, and minimum watershed area threshold for defining a stream is given as 50 km^2. The derived drainages and number of sub-watersheds are based on this threshold. The total drainage length and number of sub-watershed will increase if we decrease this threshold.

** The Time of concentration is calculated for each sub-watershed of each river basin with 50 km^2 area threshold and TR-55 method. The actual time of travel for entire basin will be higher than the mean Tc.

Hydrological modelling (1-23 August 2018) using HEC-HMS

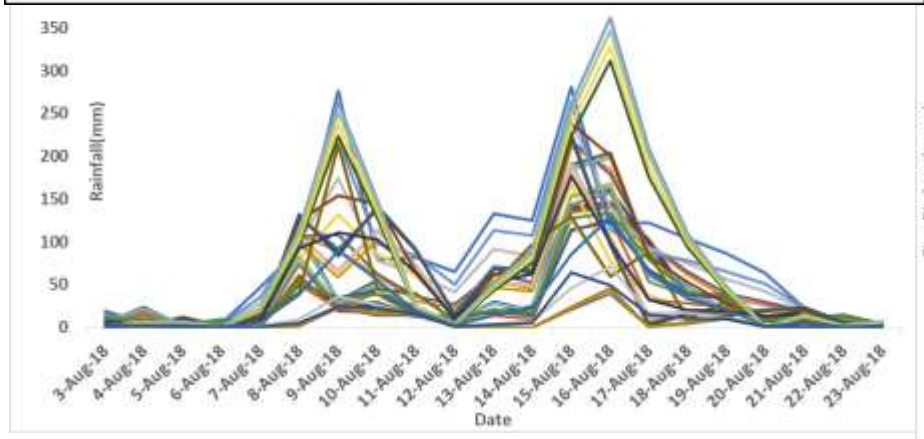
- All 12 major flood affected river basins are studies for detailed basin wise DEM based hydro data processing and virgin hydrological simulations using Hydrological Modelling System (HMS)
- IMD-GPM gridded data used as input met data, SCS method for loss, and SCS unit hydrograph as runoff transformation, Muskingum-Cunge as routing & constant monthly baseflow, in all basins simulations

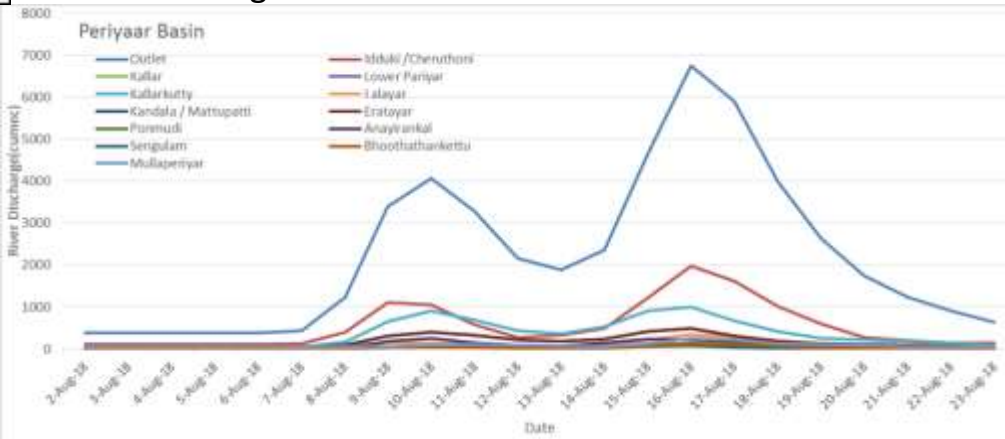




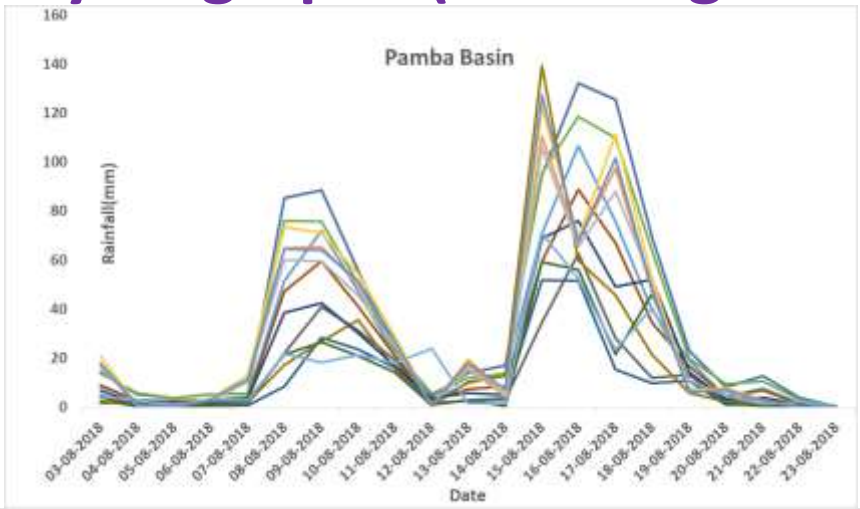
The detailed hydrological modelling was done for Periyaar basin with outlet at Alluva Manappuram Rail Bridge, Periyaar Nagar using HEC-HMS model.

- Basin has 47 sub-watersheds, with total area of 4276.9 km^2 and 527.16 km of drainages.
- Rainfall data from IMD product at 0.25 degree was used for simulating the river flows. Rainfall at various sub-watersheds and simulated river flood flow hydrographs are shown in figures. Two flood peaks are seen on 10 and 16 August 2018

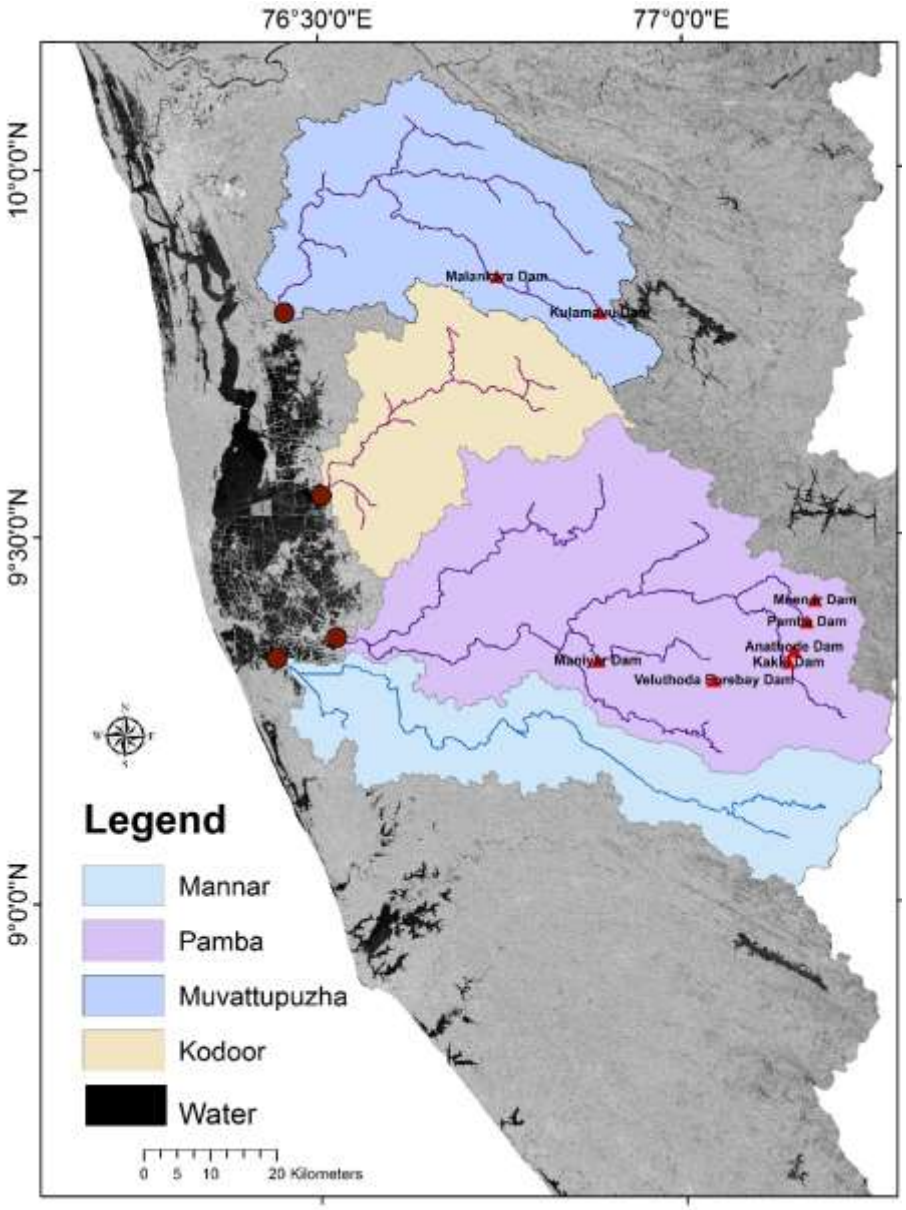




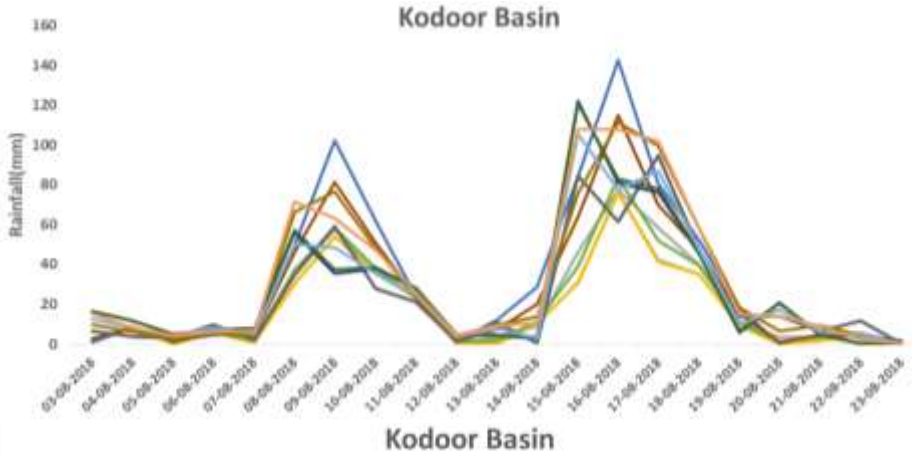
Hydrological modelling for estimating potential flood flow hydrographs (1-23 August 2018) in major rivers of Kerala

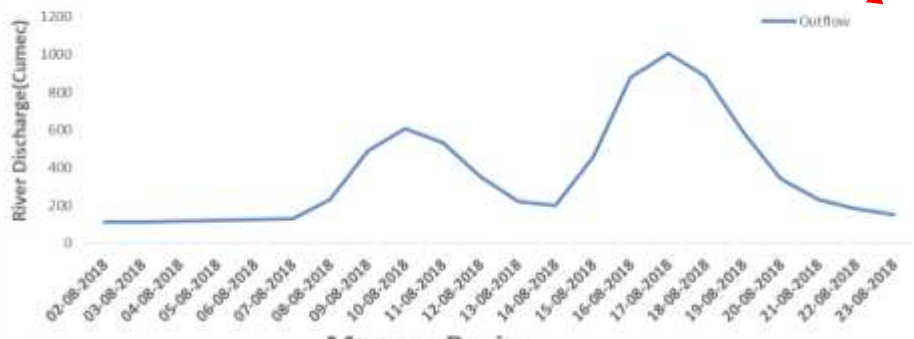


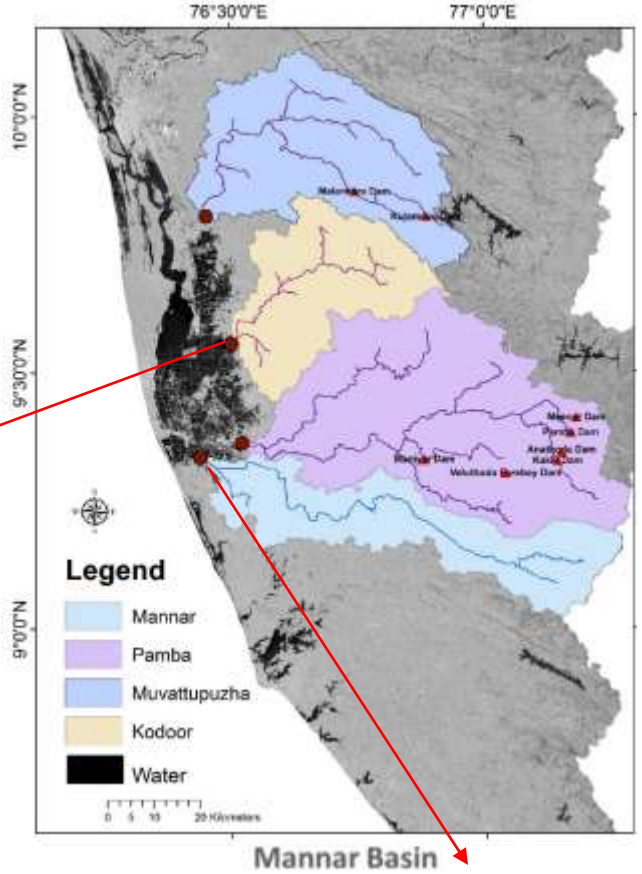
Pamba, Mannar, Muvattupuzha and Kodoor were the major river basins responsible for heavy rainfall induced flood at Kottayam, Alappuzha, Ernakulam and Pathanamthitta districts.

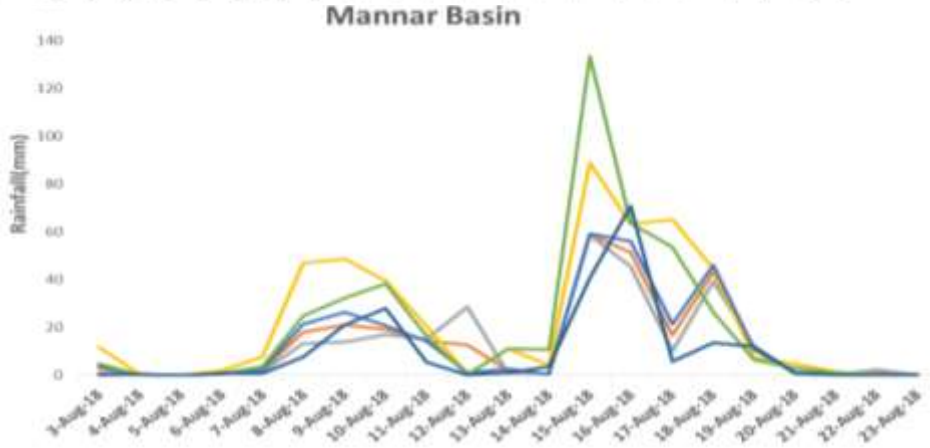


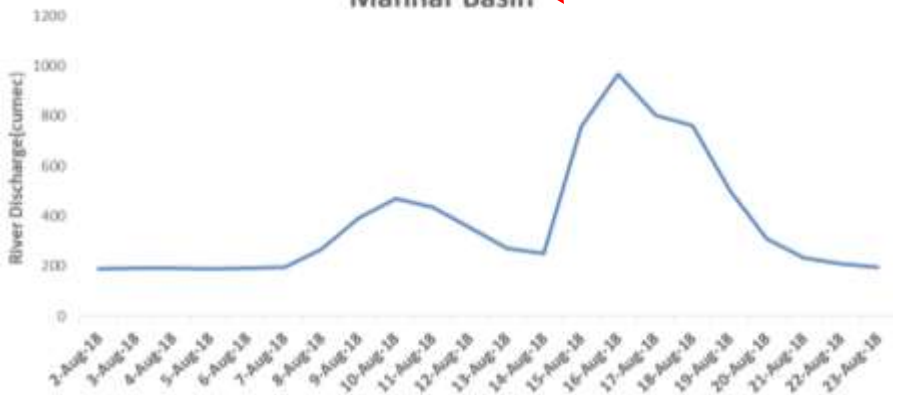
Hydrological modelling for estimating potential flood flow hydrographs (1-23 August 2018) in major rivers of Kerala





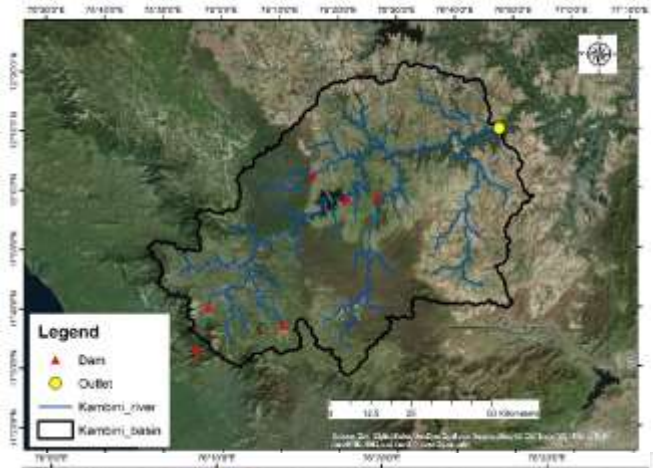


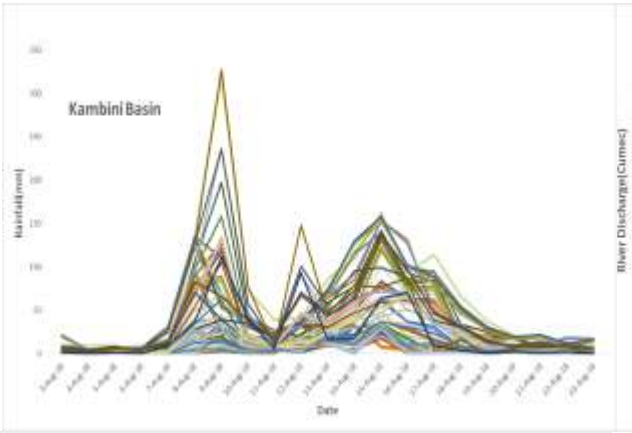


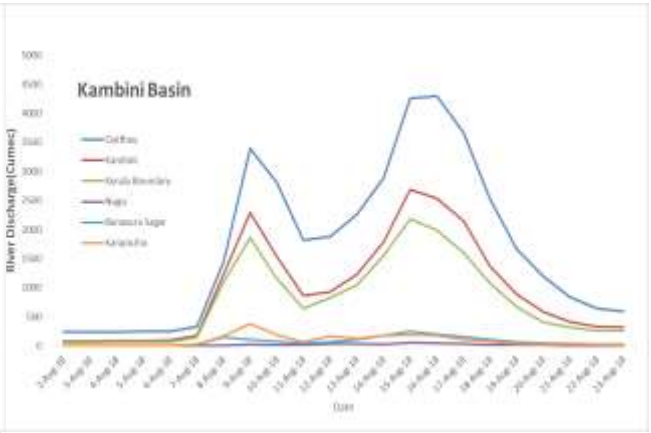


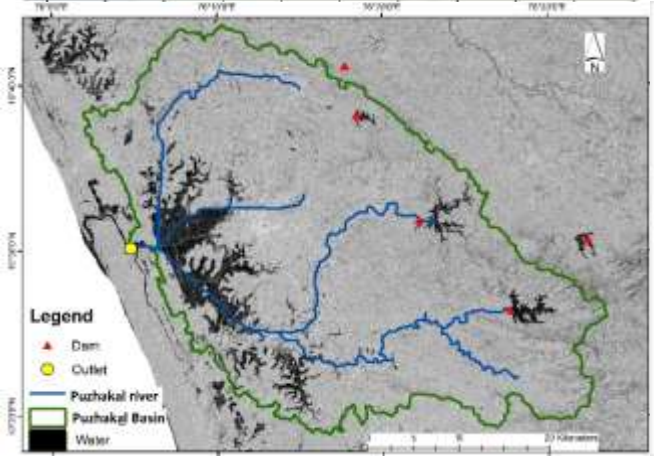
Hydrological modelling for estimating potential flood flow hydrographs (1-23 August 2018) in major rivers of Kerala

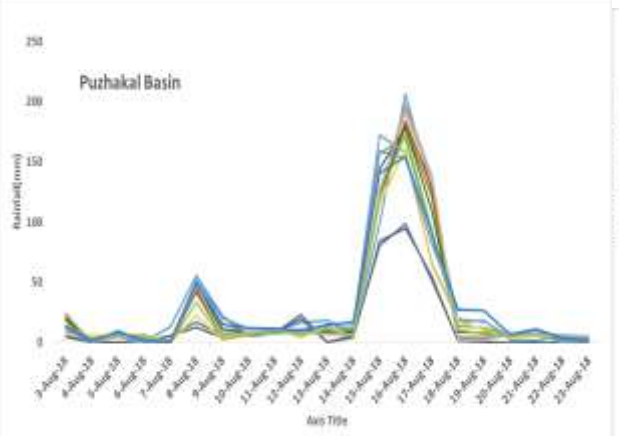
The Northern Kerala river basins such Kambini and Puzhakal also received heavy rainfall during 7-10 and 14-18 Aug. 2018, which resulted in many landslides in upper catchments of Kerala and Karnataka, flooding along river and major flood inundation in Wayanaad and Thrisoor areas

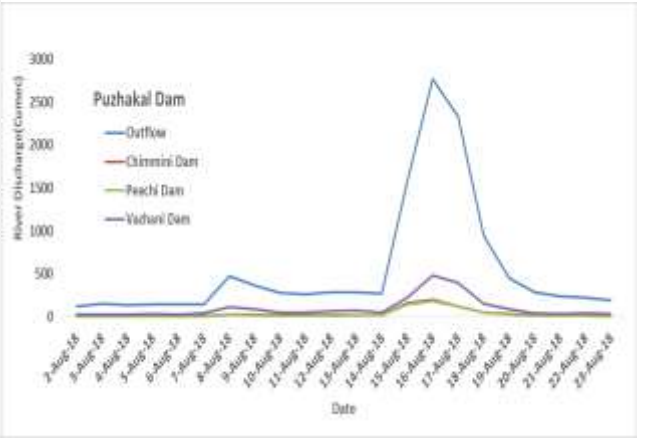




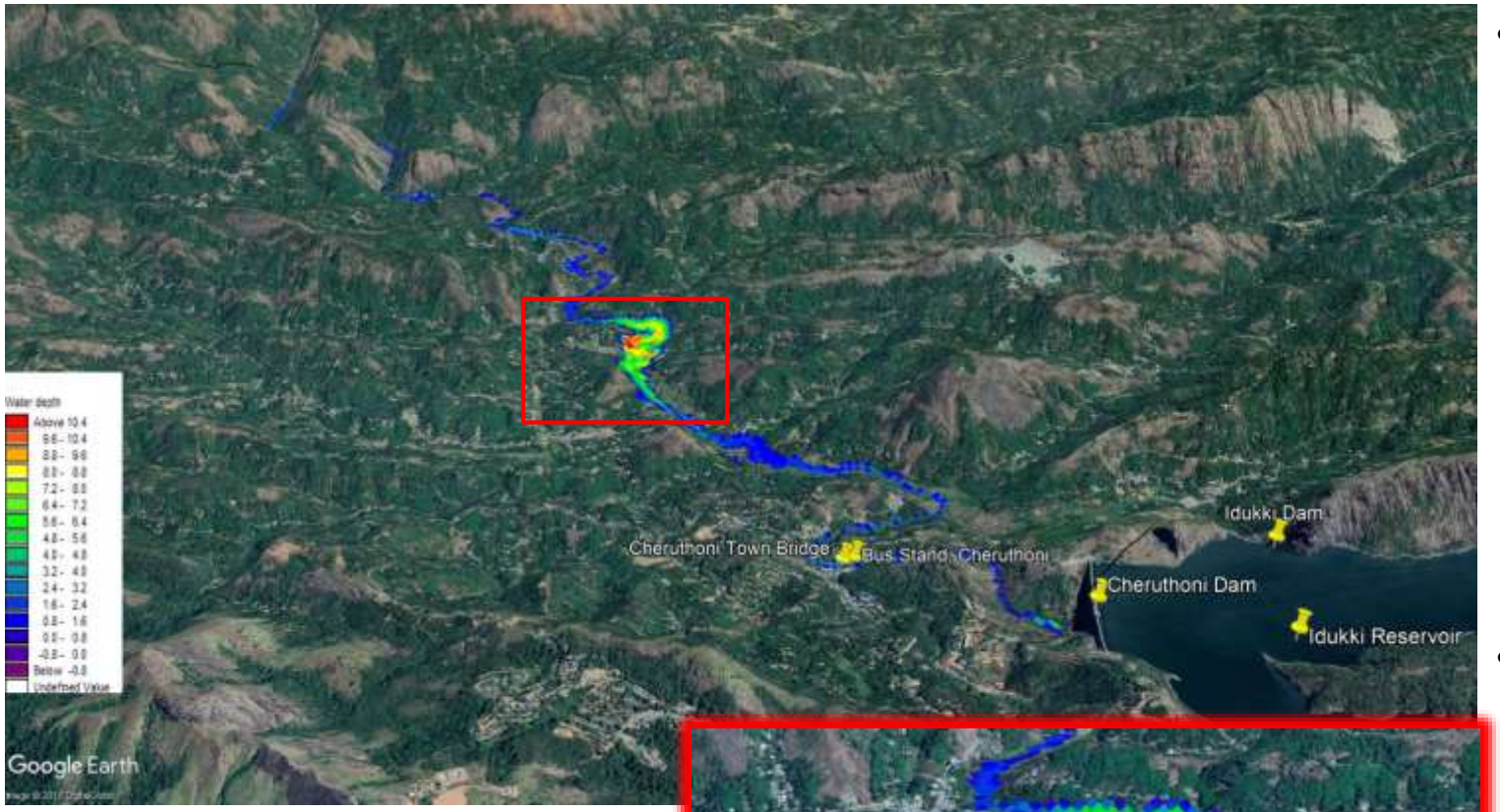








Flood inundation mapping using hydrodynamic modelling – MIKE 11 HD model



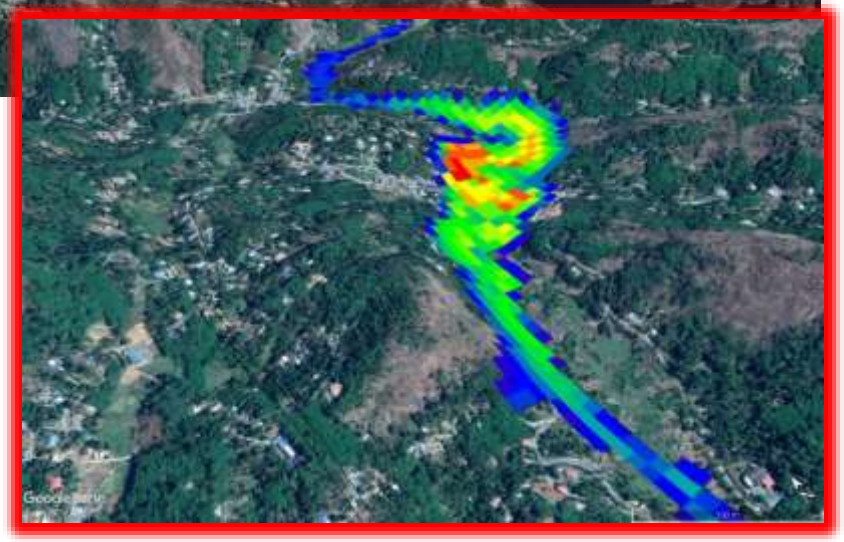
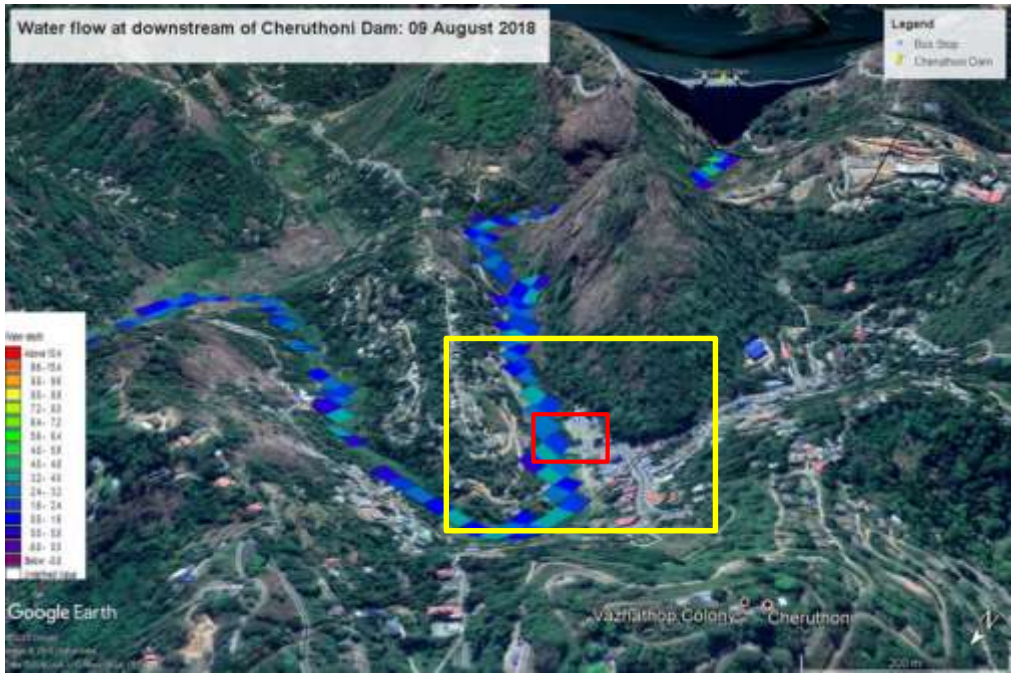


Fig. 7 shows the flood inundation at downstream area of Cheruthoni dam.

- Hydrodynamic model was established for a Periyar river reach of 17.5 Km with upstream end at Cheruthoni dam using MIKE 11
- Simulation was carried out in steady state condition for discharge of 770 cumec generated after opening of 05 gates of the dam

Flood inundation d/s of Cheruthoni dam as simulated using MIKE 11



During Flood

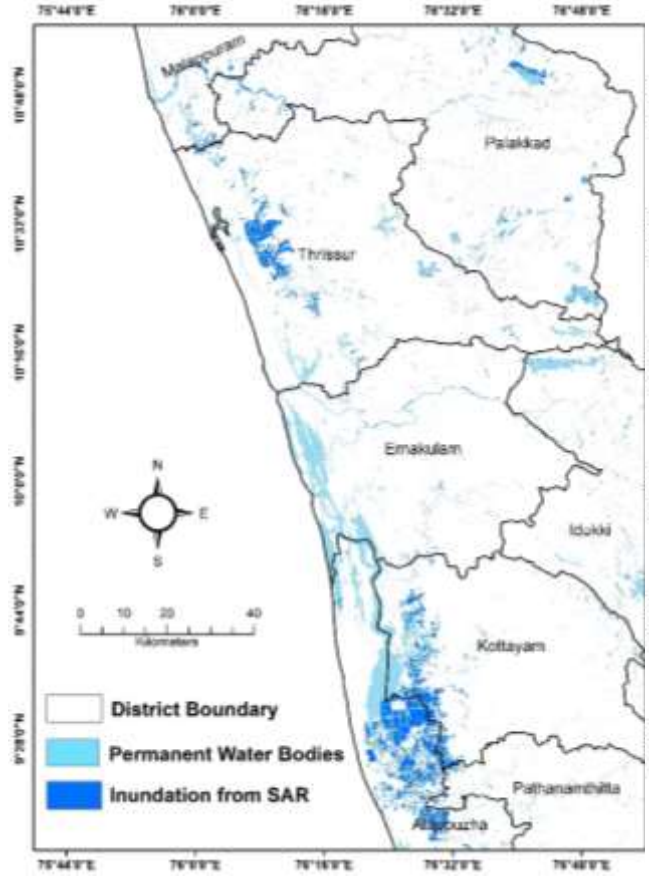
Source:http://www.newindianexpress.com/states/kerala/2018/aug/11/kerala-floods-53500-people-in-relief-camps-water-level-at-idukki-dam-recedes-1856128.html

After Flood

Source:https://www.mathrubhumi.com/environment/specials/kerala-floods-2018/news/post-flood-cheruthoni-bus-stand-1.3109085

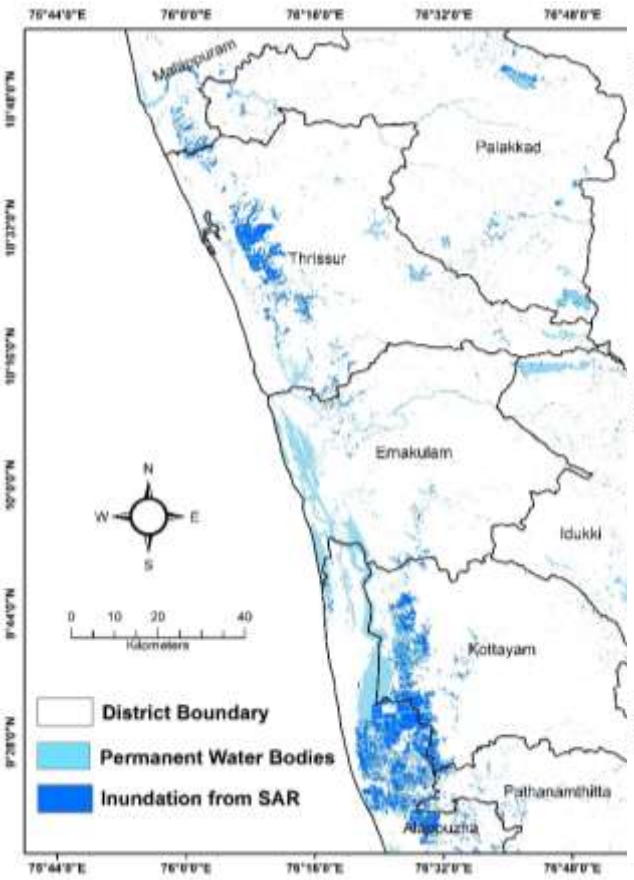
Flood inundation mapping using remote sensing data

Aug 09, 2018, Sentinel-1



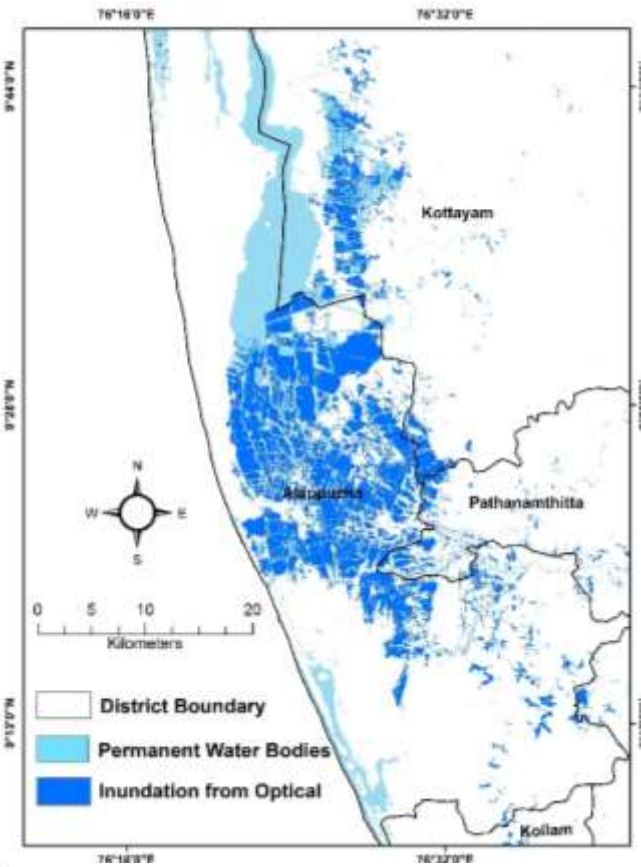
Inundation Area: 702 km^2

Aug 21, 2018, Sentinel-1



Inundation Area: 905 km^2

Aug 22, 2018, Sentinel-2



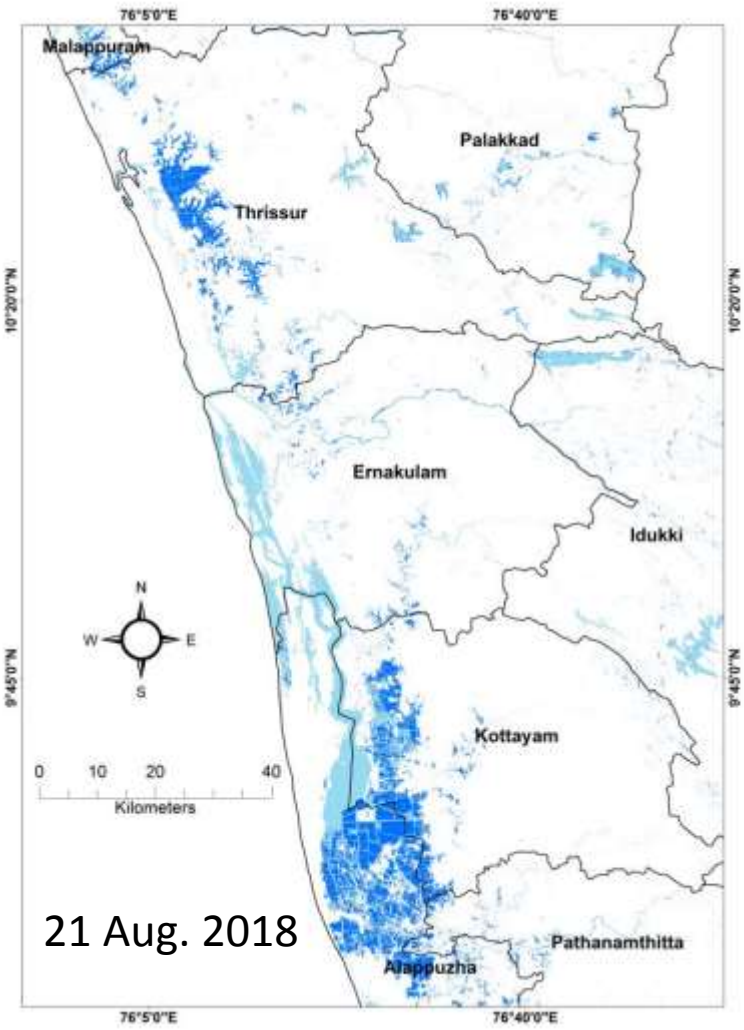
Inundation Area: 379 km^2

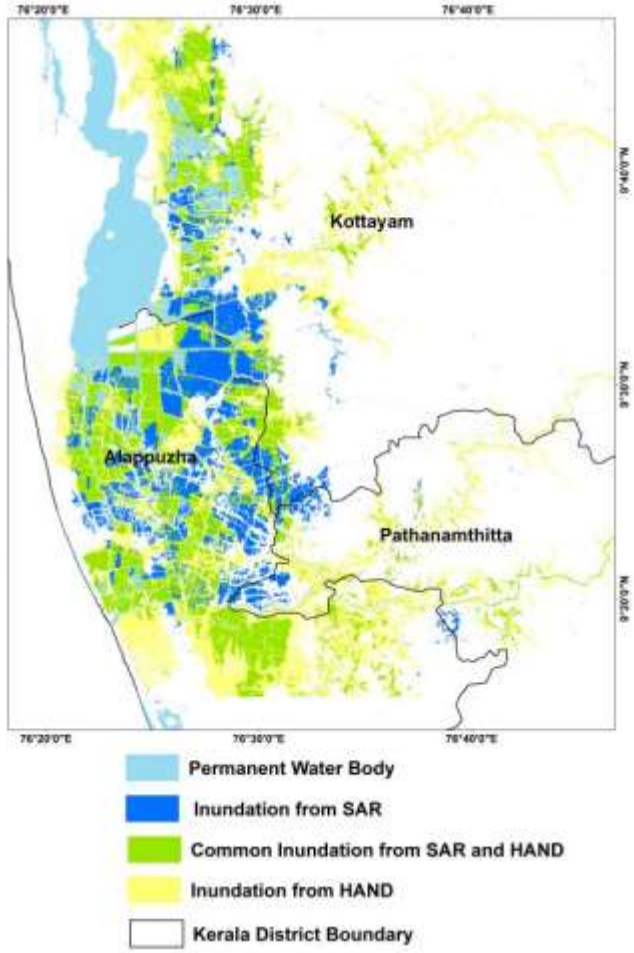
District	Flood inundation Aug 21 2018 (km^2)
Alappuzha	272
Kottayam	136
Patahanamthitta	48

Flood inundation maps from Sentinel-1, 2 data using Google Earth Engine & GIS tools

Pre flood water body maps generated using Sentinel-2 data(2017-18) in Google Earth Engine

Flood inundation mapping using topography based index HAND (Height Above Nearest Drainage)



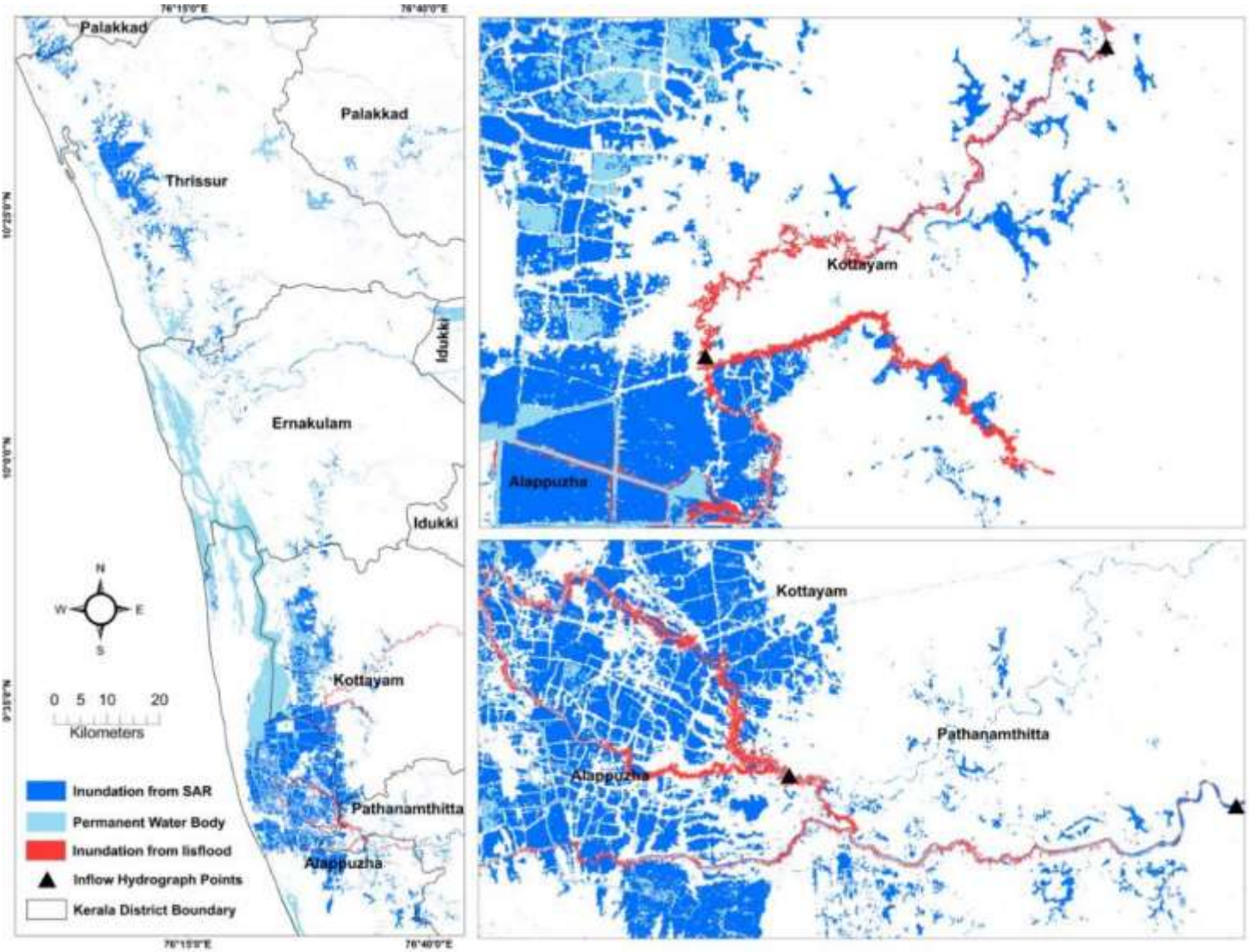


Attempt has been made to capture probable flood inundation areas using topography based flood inundation tool HAND (Height Above Nearest Drainage tool)

Thresholding (ranging between 0 to 12 m) was given with respect to Kodoor and Pamba basins topography, results showed good match at middle and downstream area of the respective basins, while over/under estimated for some parts of the upstream/other/lower basin areas.

The flood inundation from HAND tool can be improved by better DEM and multiple/variable thresholds for various streams. The SAR data Based flood gives low flooded area as it is taken 3 days after peak flood

Flood inundation mapping using 2-D open source hydrodynamic (HD) modelling – Lissflood



Application of 2D hydrodynamic model Lissflood has been tested to simulate flood inundation.

Flood Hydrographs from using HEC-HMS were used as boundary conditions.

It was found that model was able simulate flood inundation in main river reach, but has limited its application in low lying flat area.

More dense stream network, calibrated or actual inflow flood hydrographs and high resolution DEM needed for better flood inundation using 2-D flood models