Kerala Flood 2018: Flood Mapping by Participatory GIS approach, Meloor Panchayat

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ABSTRACT: This study formulates a new method for flood mapping, while remote sensing technology and flood modelling methods areirrelevant due to unavailability of data. Bad weather and temporal resolution (Revisit time)affect the availability of satellite imagery in peak flood hour and for flood modelling, discharge data are required. Mapping the flood is very important for future references and planning. In Kerala, a major flood occurred was on 1924, which is almost 100 years back and we cannot predict the future events also so that a flood map is essential for the future references. By taking Meloor Panchayat, Kerala as study area we have designed a methodology for calculating the flood inundated area using GIS and PGIS technologies. Flood depth was surveyed using a participatory GIS approach and this paper demonstrates the capability of GIS technology to accurately map the flood inundated area.By this method, we found that the flood height of some regions was up to 7.6 M, which is more than a double storied building and 53% of the study area was flood inundated.

Keywords: Kerala flood, Participatory GIS, Flood mapping, ODK, GIS

I. INTRODUCTION

All over the world, floods are the most common disaster; their frequency, magnitude and the cost of damage are very high. Flooding is a temporary condition where sudden water is accumulated from inland or tidal or from rapid runoff due to rain, causing complete inundation (Jeb and Aggarwal, 2008). The Disasters resulting due to various weather conditions affected many countries which caused the loss of many Lives; several properties were damaged above all overall economic activities were disrupted. Weather-related disasters that happened from the year 1995 to 2015, 47% among them were due to flooding in which 2.3 billion people were suffered were from Asia [1]. The most flood-affected country in the World is Bangladesh and then comes the position of India and one-fifth of the global death rate is happening due to flood. Twenty-three states in the nation are liable to floods and hectares of about 40 million lands, around one-eighth of the nation's topographical region, is inclined to floods. India counts almost one-fifth of worldwide death rate because of floods. Around four Lakh square km or about one-eighth of India's topographical territory is flooding inclined [2].

From 1 June 2018 to 19 Aug 2018 Kerala experienced an intensely high rainfall, which resulted in severe flooding in 13 districts of Kerala [3]. Only one district was out of this tragic flood. As per IMD data, from June 1st, 2018 to Aug 19th, 2018 Kerala received rainfall of about 2346.6mm was only expected rainfall of 1649.5 mm [4]. The resulted rainfall was 42% above the expected value [5]. Above than normal rainfall experienced in Kerala during June, July and August, June faced 15% more, July 18% more and from August 1st to August 19th it

was 164% more. Heavy rainfall started from the 14th Aug and ended in 19th of August, which resulted in a flood in which 13 among 14 districts were affected [6]. 5.4 million people were affected and 1.4 million people left their home and displaced, saddening is 433 people loss their life (22 May–29 August 2018) during the destructive flood [7,27]. Our study area Meloor panchayat was severely flooded from 14th to 16th of August and peak flood was on 16th morning.

The problem faced by officials was the unavailability of flood prone area maps for reference. Because of that they faced difficulties in evacuation and selecting camp locations, two relief camp locations selected were flooded during the peak flood hours and people were stranded there. This makes the necessity of a Flood map for future reference. When considering the previous major flood in Kerala was on 1924 [7,20, 23], which is around 100 years back, shows the importance to map the current flood events for the future generation. Otherwise, the same disaster will be repeated.

There are several GIS and Remote sensing flood mapping techniques, GIS gives enabling technology by providing a feasible solution. GIS also have suitable tools and methods assisting each stage of flood management. GIS helps in the various processes such as locating, planning, mitigation actions, aiding in response, helps in recovery management [8,21]. By remote sensing, data for GIS analysis are acquired, there are several research on Remote sensing for flood mapping, most of the works were on optical remote sensing, using several optical satellites like Landsat Thematic Mapper (TM) data in North America [9]and Landsat Multispectral Scanner (MSS) remote sensing of

West Africa [10], Many studies using Landsat MSS band 7 [11], TM bands 4 and 7 [12-13]. NDWI was used in water delineation [14], Flood monitoring was done using NOAA AVHRR sensor [15]. [16] Found a method using IRS-D and DEM to evaluate safe areas for Tapi Basin, Surat District.

But weather conditions during the peak flood restrict the usage of an optical sensor because cloud cover will hinder the view [17]. In that condition, [18], [19], [21], [22], [24] and [25], they believe that Radar Sensors work better than Optical Sensors because it can penetrate the clouds and can work during the night and dark conditions. The Radar sensors available during the flood events are ALOS 2 PALSAR, Dated August 17, 15:30Hrs, Radarsat-2, Dated August 18, 19:00Hrs, TerraSAR-X, Dated August 18: 04Hrs [26], Sentinel 1A, Dated 21 August. [27] They used Sentinel 1A for studying flood, 2018 for entire Kerala state. But specifically for this study area, Meloor Panchayat, peak flood hours was on 16th August and after that, it receded immediately, so satellite remote sensing was not a good option here.

So field survey is sometimes the only choice, availability of sensors and temporal resolution may reduce the options to field survey only [17, 29], Werner had proposed a method for calculating the flood inundated area. The flood depth raster was created using the IDW interpolation technique from flood depth points and was subtracted from DEM. To remove low lying areas, which were not connected to the river, he used a cost distance algorithm. He concluded that to find better interpolation techniques, IDW tends to show some variations. Then [17] had done works on using ancillary information from digital elevation for removing the difficulties of unavailability of satellite data during the peak flood event. 'Least accumulative cost – distance' matrix is derived from digital topography. The least accumulative cost distance matrix was integrated with the flood inundated area extracted from SAR imagery processing. This method can solve the problem of the unavailability of satellites during the peak flood event.

Flood depth data collections from the field using traditional survey methods are costly and time-consuming due to skilled manpower requirement and sophisticated equipment. So another approach was followed, and it was able to generate data with the help of the local community and to integrate that information in GIS and it is called PGIS, Participatory GIS [30]. To calculate the flood inundated area [28]. When data of flood discharge is not available flood modelling techniques using software like HEC-RAS, MIKE II, LISFLOOD etc. are irrelevant [29]. A good example of using PGIS due to unavailability of data showed in research carried in New Orleans in the USA, where difficulties were faced while surveying neighbourhood needs [32]. PGIS is a technology which was upheld as the perfect platform for adding the power of information from local communities of the nation and can be used in natural resource management [33]. PGIS can be simplified to collectively include many groups for mapping purpose. Mobile applications can be used in PGIS to make the mapping simple and efficient. [34].

ODK (Open Data Kit) is the perfect open source mobile platform for PGIS because of the facilities of making a questionnaire and storing the data in the server. Every mobile phone is connected to the server and final surveyed results can be downloaded from a single platform [30]. Volunteers are trained on ODK to collect application and were divided into groups; each group contains local members or panchayat officials, which increased the data quality due to local knowledge.

II. MATERIAL AND METHIODS

A.Study Area

Meloor panchayat is the study area selected, which lies in Thrissur district, Kerala State and comes under Chalakkudy blockMeloor. It is 246 KM away from state capital Thiruvananthapuram, its situated 36 KM from district headquarters Thrissur and only 1 KM away from Chalakkudy town. Meloorlies on the banks of Chalakkudy River, northern side boundary is completely facingthe Chalakkudy River, and this exactly measures 15.52 Km². Just opposite side of the Chalakkudy river is Pariyaram panchayat and Chalakkudy municipality. Southern side boundary is Koratty panchayat and eastern side boundary is Karukutty panchayat, which is also a district boundary, it shares a boundary with Ernakulam district. Western side boundary is Kadukutty panchayat. The total area of panchayat is 23 sq.km and Spatial Extent is from 10.317321˚& 76.326424˚to 10.277273˚& 76.417582˚ (Latitude / Longitude in Decimal Degree). There are17 Wards in the panchayat as showed in Fig. 1.

Meloor panchayat was flood affected from 14 August 2018 to 16 August 2018, Peak flood height was in 16 August morning and after that water receded quickly afternoon.

B. Methodology

Participatory GIS. Since no satellite images were available for peak hours of a flood, the best option is to ask the affected people, do a post-flood survey. It was very important to survey the affected area immediately after the flood event because people tend to forget the flood level and also the flood marks which is useful for verification will also become disappear during the post-flood rehabilitation. Participatory GIS is an effective technique in which we can extract information from people itself and can be used to model flood event and study about it.

The questionnaire was prepared and uploaded to an open source mobile application "ODK Collect". Open Data Kit is a package of open source tools used to collect and manage data. The ODK tools used was

1. ODK Build
2. ODK Aggregate
3. ODK Collect

ODK Build. ODK Build is a website form designer, which is having a very easy drag and drop user interface. Simple forms can be designed using this web application. To build forms you have to sign in to website "http://build.opendatakit.org".
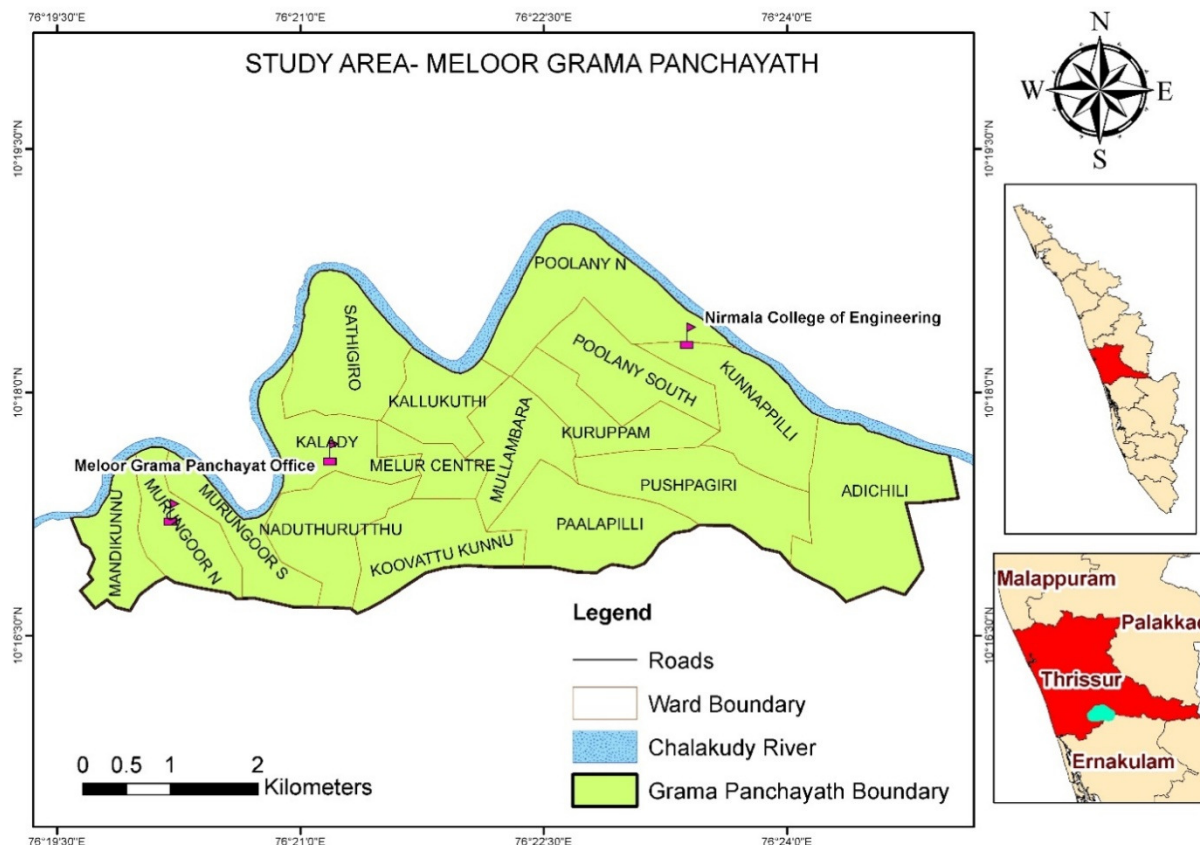
Fig. 1. Study area.

Then Survey forms are prepared using the drag and drop facility available and questions are typed. Questions for data collection are:

Location Details: GPS Latitude, Longitude, Altitude & Accuracy.

Basic Details: Name, Ward number, Building number, Contact.

Flood Details: Flood level, Time, Sudden or Gradual, Rate(Height/ hour), Flood duration, Rescued or Evacuated, Rescue method, Time of rescue, Water level during rescue time,the Evacuation route, Route name, Relief Camp name.

This Questionnaire is uploaded to ODK Aggregate server.

ODK Aggregate. ODK Aggregate is an application used to store survey data collected using ODK collects [31]. Aggregate need to be hosted in local or cloud servers, google cloud server was used for this purpose. Forms are uploaded to ODK Aggregate server and using android app ODK collect we can conduct the survey.

ODK Collect.ODK Collect is an open source Android app. This app is capable to replace paper forms and questionnaire used in mobile survey data collection. It supports many formats and a wide range of forms and is constructed to work well without network connectivity [31].

ODK Collect is an android app available in google play store which can replace paper forms for the mass survey. It has the ability to collect multiple types of questions with the help of facilities in a smartphone. It supports location, images, audio, video, signatures, and barcodes, free text multiple-choice and numeric answers. It also has the ability to accept the answers from other apps in the smartphone (Fig. 2). The final data can be downloaded in a single excel file. So it was decided to form a team and conduct the field survey using mobile phones.Participatory Survey. A team of 40 members consist of students and panchayat personnel were formed. Flood affected area was visited and by interacting with people and observing the site condition data was collected. All mobile phones were connected via the internet to save the filled questionnaire to ODK Aggregate server and after completion of 3 days of a survey; it was downloaded as a CSV file to work with MS Excel.

Total of 293 points was collected from flood affected area and random sampling method was used.

B. Flood Mapping
The flood boundaries were mapped using Flood depth points collected and SRTM DEM. SRTM DEM was downloaded from "https://search.earthdata.nasa.gov". Registration is required in this website; this website is an initiative by NASA for sharing and archiving earth data from multiple missions worldwide.
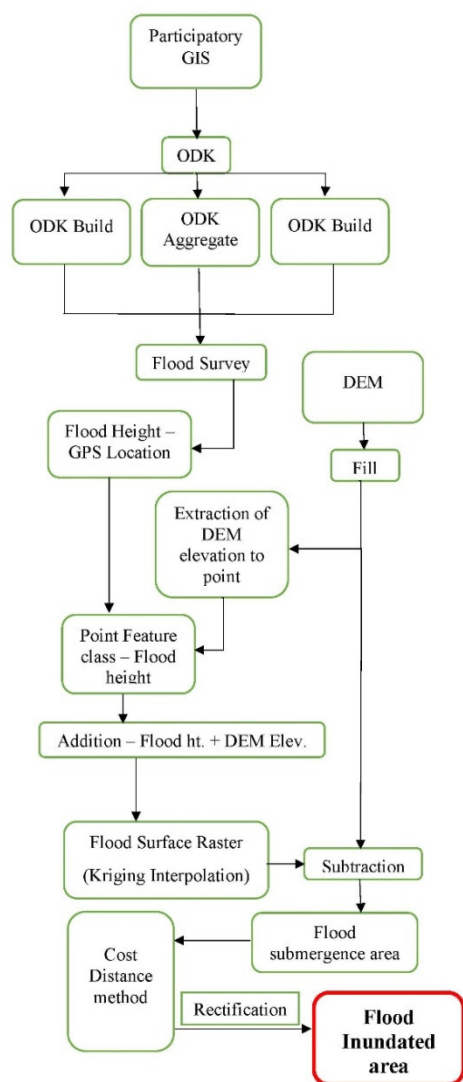
Fig. 2. Methodology adopted.

Flood surface Raster. The surveyed data was downloaded from the ODK Aggregate server as Tabular format (.csv). This Table contains the Latitude (Y) and Longitude (X) collected using mobile GPS. This table is added to the "ArcCatalog" GIS software. Using create feature class from "X-Y table" tool, the point feature class with entire survey details were created (Fig. 4). In "X-Y table" tool dialogue box the X Field is selected as Longitude column and Y field is selected as Latitude value. The coordinate system is set as Geographic coordinate system "WGS1984" because the GPS collects coordinates in "WGS1984". This Point has the survey results in its attribute table, which is useful in using for further analysis.

Project Geo-database was created and DEM and Survey point feature class was imported to it. For analysis and manipulation, the data must be in a projected coordinate system. According to the standards, the UTM Projection was chosen and for the study area the UTM zone is "UTM 43 North zone". SRTM DEM was projected using the "Project Raster" tool in ArcGIS and Survey Point feature class projected using "Project (Data management)" tool. Small imperfections and sinks are removed using the "Fill" tool in the "Hydrology" toolset. This will remove the error pixels in DEM.

The Flood depth collected is from ground level and for finding out the inundated area, Flood level above sea level is needed. In that case, SRTM DEM was used; the elevation values in SRTM DEM are above sea level. The Ground elevation is added with surveyed flood depth to get the flood height above sea level. The Elevation values from DEM is extracted and added to survey Point feature class using the "Extract by points" tool in ArcGIS. This tool captures the elevation values from pixels, where the points are located. A new field was added to the attribute table, prior to the running of the tool. So the DEM elevation and Flood depth values were added using the "Field calculator" in attribute, to get the Flood level above sea level. These Flood level points are interpolated to get the flood surface raster. Interpolation method used was "Kriging".
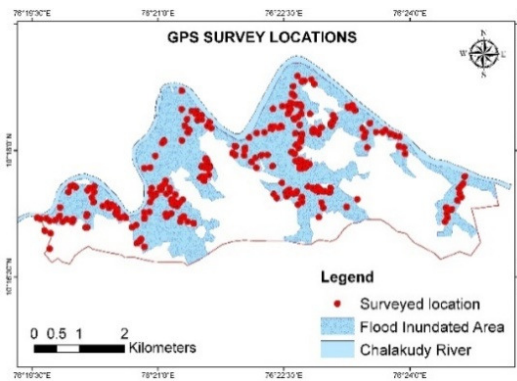

Fig. 3. ODK Collect Questionnaire format.

Fig. 4. GPS location of the flooded area.

Kriging Interpolation

Kriging is an interpolation method where the surface is created using advanced geo-statistical procedure, Height values are used for this. Other interpolation tools like IDW and spline are deterministic interpolation technique were measured surrounding values and mathematical formulas are used to determine the smoothness of the surface. A geo-statistical method like kriging is using statistical relationships between the measured points. Due to this geo-statistical method produces prediction surfaces with a good accurate prediction. Variation in the surface can be explained using the spatial correlation of the sample points.

Formula:

$$Z(S_o) = \sum_{i=1}^{N} \lambda_i Z(S_i) [32]$$

Where:

$Z(S_i)$ = measured value at the Ith location.

λ_i = an unknown weight for the measured value at the Ith location.

S_o = the prediction location

N = No: of measured values.

So the Flood surface was predicted using the surveyed GPS locations.

Delineating the Flood boundary

Flood boundary was delineated using Raster calculation. SRTM DEM and Flood surface raster (created in the last step) were used in the "Raster calculator" tool.

In "Raster Calculator", the following equation was done.

"*Flood inundated area = Flood surface raster – DEM*"

In resultant raster, all Positive values are flood inundated area and negative values should be removed for extracting flood inundated area raster. See Fig. 4, this is the result when subtracting the flood level with DEM, flood inundated area were found. Blue coloured area with positively valued pixels represents the flood inundated area and red coloured area represents the pixel with negative values. Fig. 5 represents the cross-section from Fig. 4, it is visible that low lying area which is not connected to the river in any manner is also found flooded (Fig. 5), which is wrong. This is due to the technique we used, subtraction method will always show flood in low lying regions below flood level, but there could be barriers, dams or natural hills which prevent direct entry of flood water.
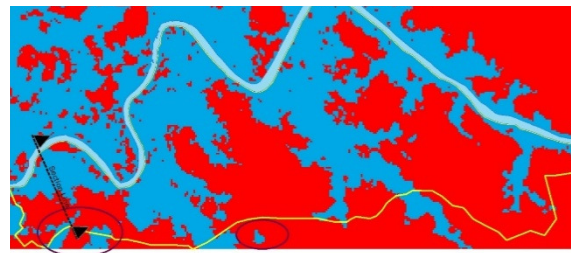

Fig. 5. Flood Inundated area raster with cross-section line with wrong flood information.
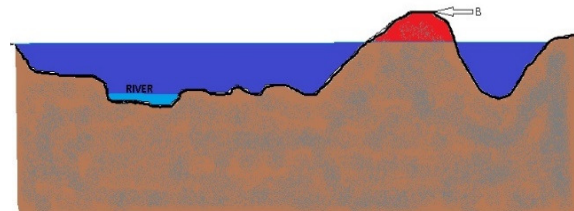

Fig. 6. Representation of cross-section of flood surface raster with DEM.

Cost Distance Method

So to remove the error in raster calculation, Cost distance method was used. This tool calculates least accumulated cost distance for a single pixel from the source over a cost surface. Here the source is a river, so river polygon was converted to raster using "polygon to raster" tool to get the source raster. The Cost raster to be input into the tool is the Flood inundated area raster with positive values as flooded area and negative values as the non-flooded area.

Cost raster is showed in Fig. 4, this raster has the cost or impedance to move horizontally through each pixel i.e. here the value is flood depth as impedance.

Each cell value is multiplied by the resolution of the cell to obtain the cost of movement through the cell. The values in the cost raster should be zero or a positive value, negatives values are avoided in the result.

The output cost distance raster shows the least accumulative cost distance for each cell over a cost raster [33]. Cost distance output avoids the pixels which are not connected to source raster.

See Fig. 6 and Fig. 7 the area which was not connected with the river due to some barriers or topographic undulations, were removed from flooded area results, because that area won't get flooded from the river source.
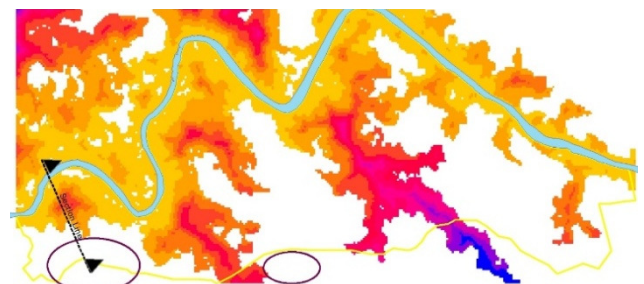

Fig. 7. Cost Distance raster (Inundated area).

Thus the inundated area was found from the cost distance raster output. For the purpose of converting the raster to polygon feature, it was reclassified into one class using the "Reclassify" tool. Pixel values in cost distance raster range from 0 to 6300, which was reclassified to one class and value was given as "1". Inundated area polygon was created using "Raster to Polygon" tool, thus reclassified raster was converted into polygon feature class and Inundated area polygon was made.
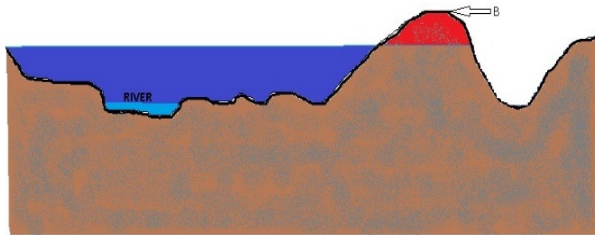

Fig. 8. Cross section of Cost distance raster (Inundated area).

III. RESULT AND DISCUSSION

The method used was very effective in mapping the flood inundated area. By ground-trothing it was observed that the same area was inundated during the flood event. The total flooded area is 12.22sq.km, which was calculated from flood inundated polygon. The total area of panchayat is 23sq. km and it was founded that 53% of the study area was flooded. Water entered directly from river to the watershed area through the streams and canals, it was observed that low lying land like paddy fields and agricultural lands was severely flood affected. Also observed that newly build settlements were more affected during the flood and it is clear that land encroachments in the flood plain were in rising during the recent years. According to senior residents of Meloor, in past, during every monsoon, flood events used to happen in low lying regions. But after the construction of dams along the river basin flood events was stopped and people started to build settlements in low lying regions, which was the major reason for this kind of destructions.

From surveyed 293 GPS locations, the highest flood height recorded was 7.6 M, which is more than double storied building.116 locations were recorded height more than 3 M and from that data, it was clear that flood height was severe and destructive.
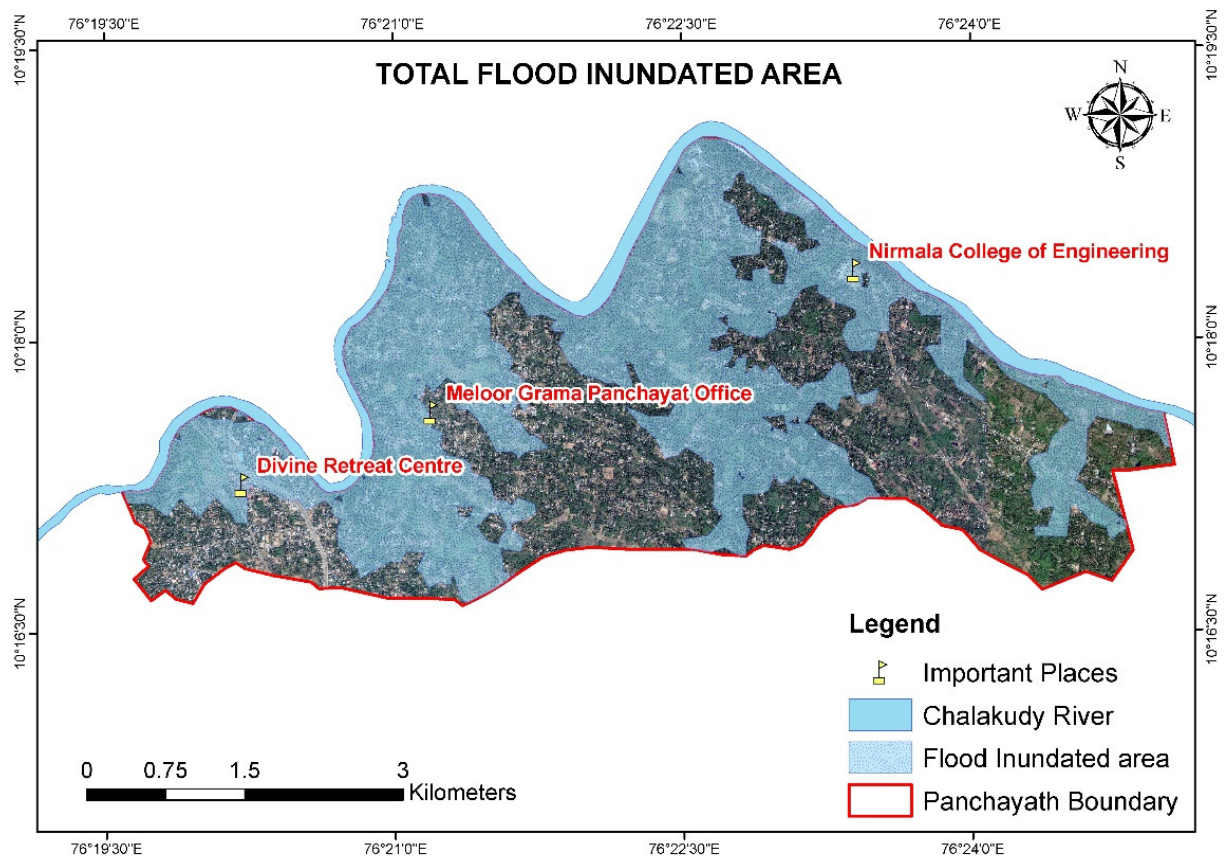

Fig. 9. Flood inundation map.

Ward wise flooded area
There are 17 wards total and all wards in the panchayat were flood affected, to calculate flood affected area in each ward, "Intersect" tool was used. Flood inundated area polygon and Ward boundary polygon was intersected and the area was calculated using "Calculate Geometry" tool. All wards were flooded during the event and highest flooded area was in Santhigiri Ward, 1.613

sq.km and lowest was in the ward named Melur centre, 0.098 sq.km. Santhigiri was 94.47 % flooded and Melur centre was 18.12% flooded. All wards near to river were severely flooded. Melur centre and Koovattukunnu was situated away from the river and elevation was also high, so flooded area was less. Fig. 10, Fig. 11 and Table 1 shows the details of each ward.

Table 1: Flood inundated area per Ward.

| No:	WARD NAME	Ward Area (Sq.Km)	INUNDATED AREA (Sq.Km)	% Flooded Area
1	SATHIGIRI	1.707	1.613	94.473
2	KALLUKUTHI	0.939	0.388	41.338
3	POOLANY N	2.009	1.566	77.921
4	KURUPPAM	1.060	0.694	65.473
5	POOLANY SOUTH	1.332	0.543	40.771
6	KUNNAPPILLI	1.554	0.554	35.657
7	ADICHILI	2.479	0.759	30.619
8	PUSHPAGIRI	1.758	0.471	26.774
9	PAALAPILLI	1.629	0.604	37.081
10	MULLAMBARA	1.112	0.597	53.739
11	MELUR CENTRE	0.541	0.098	18.125
12	KOOVATTU KUNNU	1.419	0.314	22.092
13	NADUTHURUTTHU	1.374	1.001	72.865
14	MURUNGOOR S	0.931	0.494	53.087
15	MURUNGOOR N	1.086	0.434	39.940
16	MANDIKUNNU	0.921	0.431	46.755
17	KALADY	1.161	0.858	73.910
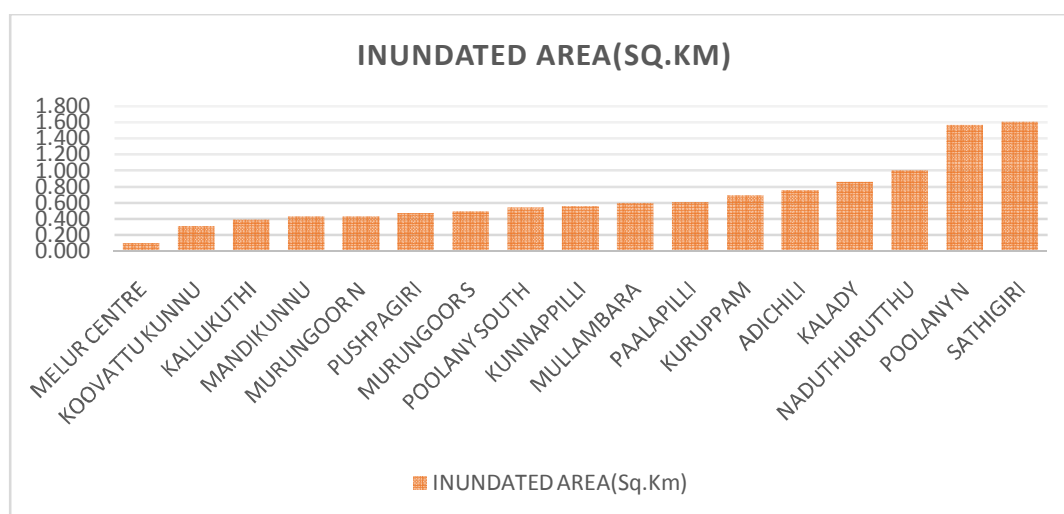
Fig. 10. Graph showing the flooded area.

IV. CONCLUSION

This research paved the way to found the flood inundated area and the preparation of the map. This map will facilitate future uses in disaster preparedness and land use planning, for effectively using the flood plain. The participatory survey conducted was very effective in collecting required data and it strengthens the community involvement in decision making, which will empower them. It was observed that several landfilling are occurred in low lying paddy fields and agricultural lands for the construction of houses, religious buildings and commercial establishments. This unscientific way of the landfill will increase the destructions in future flood events.Due to the usage of comparatively low-resolution DEM (30M), there will be small variations in the results.

Due to the low 30 M resolution, small barriers like roads and manmade structures won't count and this will cause

errors in the final flood map. But for this study area, flood height was very high, which reduced the errors due to DEM shortcomings, it should be noted that, during scenarios of low flood height, SRTM DEM could cause disparities while flood mapping with this technique.
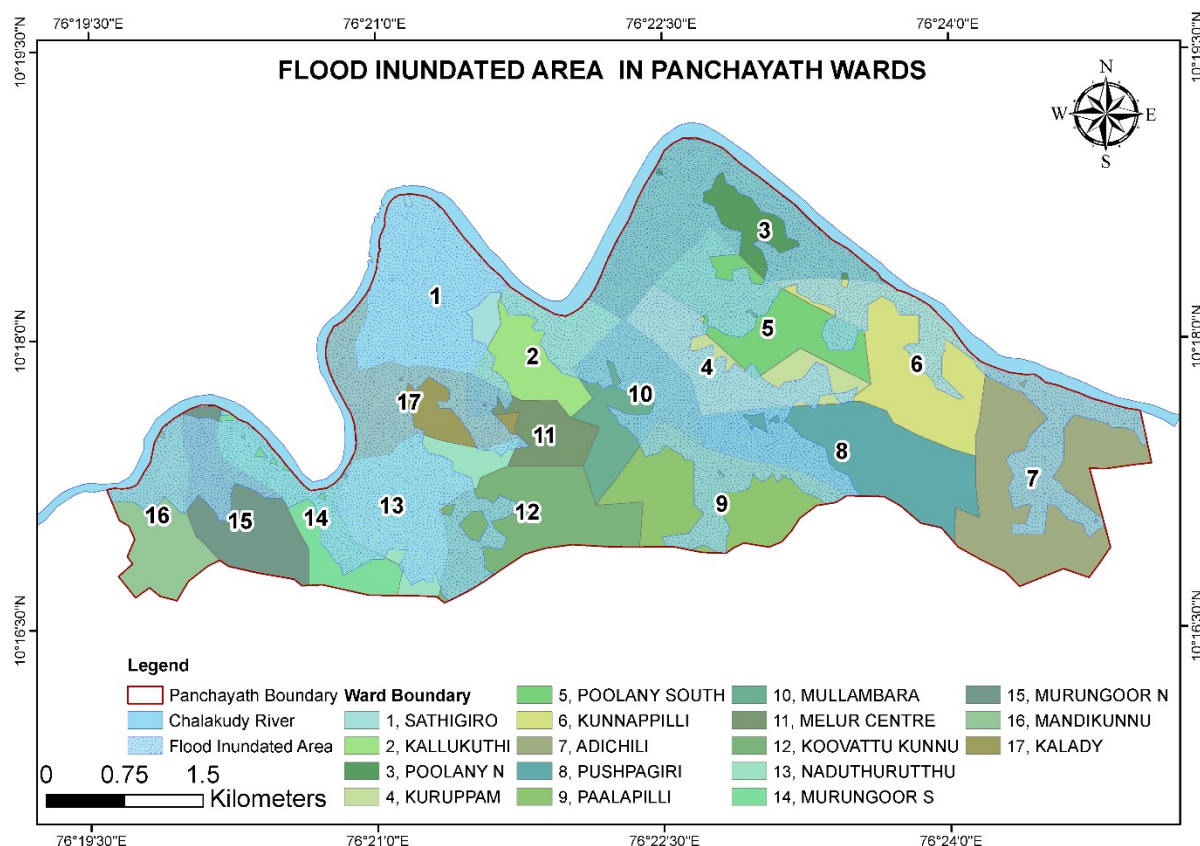

Fig. 11. Ward wise flood inundated area.

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