Flood Mapping and Vulnerability Assessment Using Geospatial Techniques: A Case Study of Lower Periyar River Basin, Kerala

S. Suresh Kumar and K. Jayarajan

Abstract The flood can strike anywhere without warning. Flooding is a very common environmental hazard. Due to this natural disaster, infrastructure damages and human life losses occur every year. In August 2018, because of a low-pressure framework close to the start of the month, the Indian territory of Kerala got an all-inclusive time of substantial precipitation, joined by storm wretchedness a few days after the fact. About 400 people were killed by the ensuing floods and a million more were displaced. Here, delineation of the spatial extent of flooding is of great importance for the dynamic monitoring of flood evolution and corresponding emergency strategies. An interest for satellite-based immersion planning in close to constant has been shown by late flood occasions. Simulating and forecasting the magnitude of floods is critical for risk mitigation. Flood mapping is a process used during the flood for damage assessment and risk evaluation and to assist rescues. The purpose of the analysis is to identify the magnitude of the flood, the damage to the built environment, by mapping the vulnerable areas of the flood, based on different analytical techniques. To classify the affected areas based on variations between the two images, the applied approach is to examine and compare two images (one before and one after the disaster). This study shows that SAR data and Landsat images alongside GIS can be utilized adequately to map, track, and evaluate the distribution of floodwater in flood-prone areas of the lower reaches of the Periyar river basin.

Keywords Flood extent · Flood mapping · Risk assessment · GIS · Synthetic aperture radar (SAR)

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P. K. Rai et al. (eds.), *Recent Technologies for Disaster Management and Risk Reduction*, Earth and Environmental Sciences Library,
https://doi.org/10.1007/978-3-030-76116-5_7

1 Introduction

Floods represent the most generous natural disaster that may occur at different levels, having an impact on environment, ecology, agriculture, and infrastructure (Dadhich et al. 2019). Rainfall extremes cause flooding. Increased surface run-off and rainfall are greater than the outgoing discharge potential which cause the level of water to increase, leading to area submergence, landslide, debris flow, water-related health disaster, etc (Ray et al. 2019). By damaging ecosystems, disrupting lives, harming infrastructure, etc., floods impact the environment and community. Remote sensing and, in particular, synthetic aperture radar (SAR) sensors are ideal for data gaining under conditions of dense precipitation and provide quick assessment and long-term flood zone monitoring. Due to specular reflection, the synthetic aperture radar (SAR) system is sensitive to water and capable of acquiring images both day and night, giving it a characteristic specification.

Flood mapping gives an idea about the change in the existing scenario and possible future area likely to be affected by floods. Remote sensing and, in particular, SAR sensors are ideal for flood cloud conditions and quick assessment and long-term flood area monitoring (Megha et al. 2019). Due to specular reflection, SAR sensors are sensitive to moisture and are capable of acquiring day and night imagery. In rapid disaster response preparation and management, the rapid generation of flood extent maps from SAR data provides access to useful data and in the management of disaster situations, monitoring of impacted areas by flooding and damage to agriculture and infrastructure evaluation is an important activity.

The definition of vulnerability reflects the multidimensionality of calamities by concentrating on the totality of experiences in a particular social situation, which is a circumstance that creates a catastrophe in conjunction with environmental forces. In knowing the true degree of risk, exposure to natural hazards is an integral factor. Vulnerability factors can be separated into three main areas physical vulnerability, social vulnerability, and economic vulnerability (Rakib et al. 2018). In the 1990s, in the sense of disasters, the term 'vulnerability' was first used, but vulnerability quantification is a complex one, there are four dimensions of vulnerability evaluation, i.e., physical, economic, social, and environmental (Ahmed and Kranthi 2018). Among them, in this article, only the physical dimension of vulnerability is discussed.

For future references and scheduling, mapping the flood is very critical. In Kerala, there was a big flood in 1924, almost 100 years ago. We cannot predict future events and thus a flood map becomes essential for future references. Kerala encountered a strongly elevated level of precipitation from June 1, 2018, to Aug 19, 2018, bringing about unusual flooding in 13 districts of Kerala (Sankar 2018). The rainfall resulting from this was 42% above the expected value (G.O.I. Centre water commission 2018). During the monsoon months of June, July, and August, June faced 15% more than average rainfall in Kerala, July 18% more and 164% more from August 1 to August 19. Intensive rain began on the 14th of August and ended on the 19th of August, resulting in a flood that affected 13 of the 14 districts. 5.4 million people were affected, 1.4 million people left their home and displaced, and saddening is 433 people lost their lives during the destructive flood (Joy et al. 2019).

This study aims to demonstrate the adequacy of Sentinel-1 SAR to estimate the extent of flooding and built-up areas at risk due to flooding based on data availability. In this respect, data on the rainfall rate was used to know the severity and length of the study area's rainfall rate. Based on this, Sentinel-1 SAR data acquired on August 21, 2018, pertaining heavy rainfall period were used to estimate the coverage of the flooding around Lower reaches of Periyar River basin. This was followed by extraction of the built-up land which was affected by inundation during the flood using Open Street Map (OSM). This exercise is an operational method for providing critical inputs for evaluating and mitigating flood risk. This study aims to examine the vulnerability of floods along the Lower Periyar River basin to provide more options for flood risk management and control.

2 Materials and Methods

2.1 Site Description

The study area extend from 9° 49′ 35″ N to 10° 17′ 07″ N latitude and 76° 08′ 34″ E to 77° 33′ 32″ E longitude (Fig. 1). The longest river (244 km) in Kerala is Periyar with a drainage area of 5398 km^2 (Chattopadhyay 2007; Chattopadhyay and Sureshkumar 2013) of which 114 square kilometers are located in Tamil Nadu. Periyar, being an eighth order stream, originates at an elevation of 1560 m from

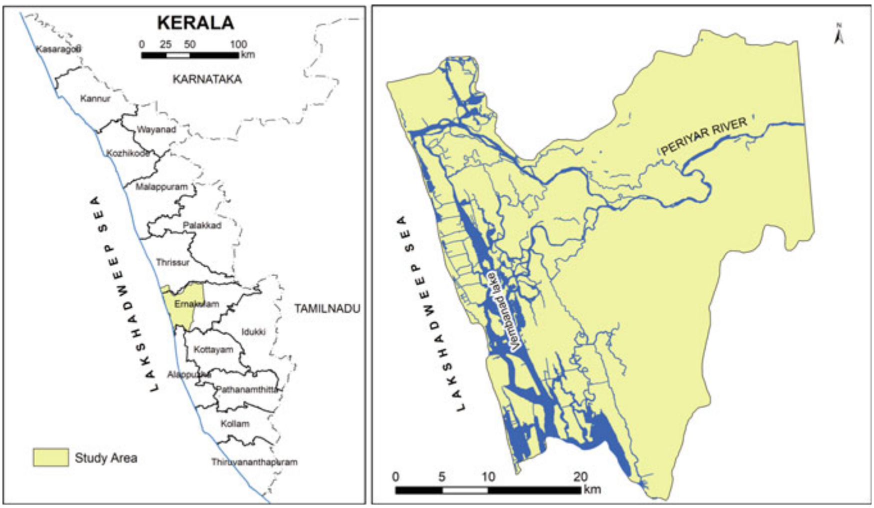

Fig. 1 Lower reaches of Periyar River basin

the high hills of the Western Ghats toward the southeast corner of the basin and initially follows a northward course. Major reservoirs like Periyar Lake, Idukki, Anairangal, Idamalayar, Mattupetty, and Sethuparvathipuram are within the basin area. Periyar River debouches in the Lakshadweep sea through Vembanad lake in the West. Mathirapuzha and Idamalayar are two among several important tributaries of the river. Drainage pattern is primarily dendritic to trellis and parallel in some places. The study area occupies 1282.74 km^2. There are two different forms of topography in the river basin, the mountainous upper region, and the flat coastal regions. The study area is very much vulnerable to flooding because of the comparatively low-lying areas. The vegetation of this area is a combination of coconut, rubber, tapioca, paddy, marshy lands, and grass.

2.2 Data and Methods

The extensive list of study area data, needed for informed interpretations and decision making, is required for mapping of flood and vulnerability assessment.

2.3 Datasets

SAR Data: We use a wide collection of SAR images acquired by land observation with progressive scans acquisition mode C-band Sentinel-1A and B satellites and revisit the period six days before and during the flood event to map and compare the flood extent. Using a collection of SAR images acquired before the flood event, a flood-free reference amplitude image is also produced (Cian et al. 2018; Sherpa et al. 2020). Apart from its all-weather ability, one of the key advantages of using SAR imagery is its ability to discriminate against water from other categories. Radio detection and ranging (RADAR) synthetic aperture is a strong active remote sensing technology used for many applications, especially in flood monitoring. RADAR is an active device that illuminates the Earth's surface and, thus, without sunlight, images can be obtained by day during any lighting conditions or at night. These images are also not impacted by cloud cover, fog, or smoke as these covers can be penetrated by the RADAR signals (Carreño Conde and Matta 2019). Water characteristics function as a surface mirror, their responses are low (low coefficient of backscatter in SAR image) and thus appears as a dark area. Owing to the surface roughness, the landmass, for its part, gives a large amount of radar energy, and this produces high contrast between surfaces: soil and water. The satellite images were acquired sequentially by satellite Sentinel 1A, before and after the flood took place. Sentinel 1 SAR (VV) Polarization data, Vertically Transmitted Vertically Receive was the satellite dataset used in the analysis. Therefore, Sentinel-1 SAR data acquired on August 21, 2018, of this event are selected based on the availability.

Landsat: Landsat-8 OLI imagery acquired on February 3 2017, data were downloaded from the open-source repository of USGS's EarthExplorer in GeoTIFF format. During the pre-flooded time, Landsat-8 OLI data from the study area were analyzed using geospatial techniques, particularly for calculating the normalized difference water index (NDWI) using the spatial analyst tool.

Open Street Map (OSM) data: OSM has provided the cheapest source of geographic information from a web service. They have been imported in QGIS through the QuickOSM plugin (Pasi et al. 2015; Suthakaran et al. 2018).

2.4 Method

The workflow of the current investigation has four components: (1) delineating extent of non-flooded surface in and around the major flood zone; (2) extracting the landuse category from the OSM data; (3) extracting the buildings and transport network from OSM web service; (4) importing the above three layers into a vector GIS environment and performing spatial analysis to obtain relevant results.

A. Flood Extent Mapping.

Synthetic aperture radar (SAR) data has played an important role for decades, enabling flood extent maps to be extracted during disasters. One of the main barriers to using optical remote sensing in flood control is the predominance of cloud cover during the flooding season (Mohanty et al. 2019). The approach suggested is based on variations in the physical relationship between standing water and rough ground. In both polarizations, the returned signal intensity to the side-looking antenna is negligible as long as the water surface is still, due to the specular reflection over standing water. The rough land surface, in contrast, has a huge amount of signal return to the radar (Jo et al. 2018). Delineation of the non-flooded area is particularly important because these areas can serve as a temporary shelter for the nearby settlements. Such data is important for the identification of settlements that are extremely vulnerable to flooding. Settlements having no immediate access to dry regions would be considered highly vulnerable to flooding (Sanyal and Lu 2004).

The method is based on the statistical analysis of SAR images: one containing only images before the flood, i.e., reference images, and another one containing reference images and images of the event. The images were preprocessed and analyzed using Arc GIS software, ASF Custom Toolbox developed by Alaska Satellite Facility. It is accompanied by the generation of the backscatter coefficient histogram, and it has been used to set a value that most accurately represents the threshold between non-water and water characteristics. Finally, the resulting binary raster data has been transformed for analysis into a vector file. For damage estimation, these vector datasets are superimposed on the built-up region (Armenakis et al. 2017).

2.5 Processing Sentinel-1 Image

In this study, the Sentinel-1A data acquired in August 21, 2018, during the flood event was used to develop flood inundation map. ASF tools that used to perform geoprocessing tasks useful for working with synthetic aperture radar (SAR) data. The analyzing procedures are including unzip compressed files, scale conversion method, reclassify RTC, and calculate log difference.

Unzip compressed files

Unzip Files Tool assists in file management when downloading.zip files from Alaskan Satellite Facility. This tool offers a quick and easy way to extract multiple zip files to the desired destination folder. It extracts the contents of the downloaded zip files to the desired destination folder and then deletes the original zip files from the download folder.

Scale conversion

Scale conversion tool converts SAR imagery from one scale into another. The scales most commonly used with SAR data are power, amplitude, and dB. The output is a new raster dataset, with the pixel values in the designated output scale.

Reclassify RTC

A reclassified raster based on a threshold value is generated by the reclassify RTC tool. It is designed to use for identifying water, which has very low radiometric returns when the surface of the water is calm. Water is often best delineated using dB values, which offers better differentiation between very dark pixels and the rest of the image. VV polarization often offers the best value delineation, but is sensitive to the wind; on windy days, the radar backscatter is higher, and water may be difficult to differentiate from other surfaces. VH is less susceptible to changes in surface roughness, so over various wind conditions, the values would be more stable. Consider thresholding all available polarizations and combining the outputs, or selecting the polarization that gives the best results for a specific application. This tool produces a raster that contains only those pixels below a threshold value specified by the user and is intended to identify water pixels. (Fig. 2).

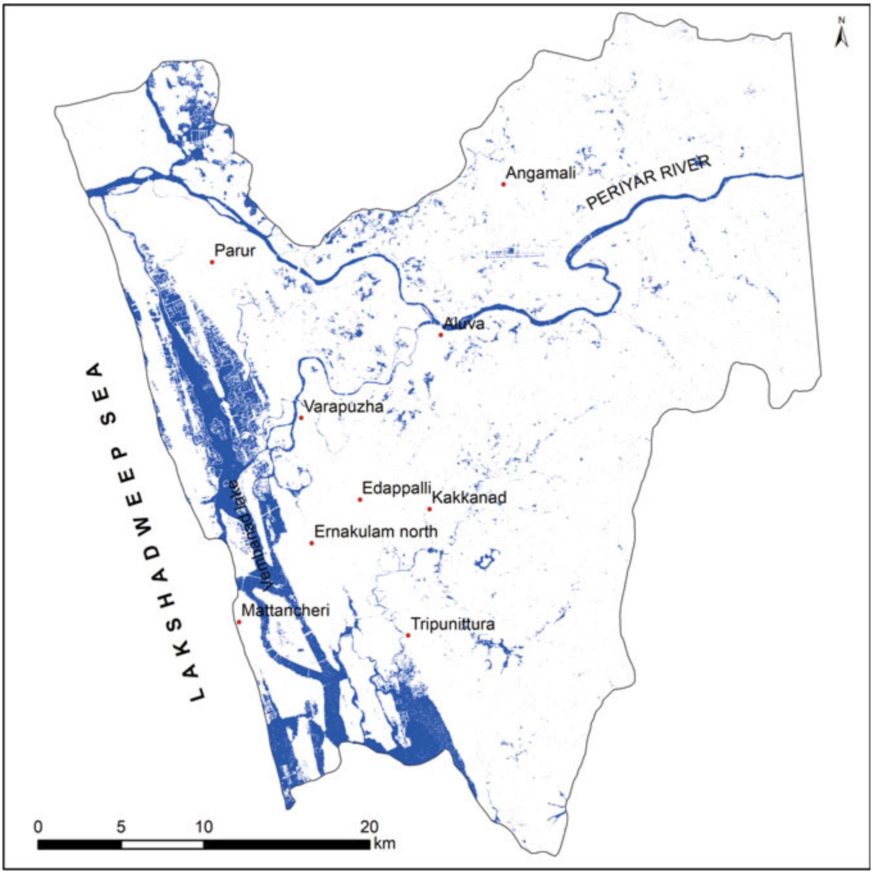

Fig. 2 Reclassified raster showing water pixels

Calculate Log difference

Log difference tool calculates the log difference between the two rasters. It was designed to work with a 2-point time series of radiometric terrain corrected (RTC) SAR products in amplitude scale, but can be used to look for differences between any two rasters.

The four tools mentioned above can be effectively utilized to identify flood-affected areas. Flood-affected areas were identified using the VV Polarization in the SAR image which offers the best result. The black pixels in the processed SAR image represent water and, the gray and white color indicate rough land surfaces.

B. Delineate open water features

Landsat-8 OLI has been used to delineate and refine the characteristics of open water. By implementing the following proven geospatial procedures, open water features of the study area were extracted. The measurement of the NDWI (Normalized Difference Water Index) was used: (Green-NIR)/ (Green + NIR), where band 3 and band 5 respectively corresponds to Green and NIR (Near Infra-Red). For this, NIR and green channels of Landsat-8 OLI were used to delineate and enhance open water features. NDWI results computed from Landsat-8 OLI (February 03, 2017) detected the region of the water bodies.

C. Extract built-up areas and transport network

Detailed data collection of the built-up area is essential for conducting a vulnerability assessment. For this purpose, various types of information have been collected using the web services of OSM. The information needed for this study was collected using the Quick OSM plugin of QGIS software. OSM data provides information about residential buildings, public facilities (houses, police stations, schools and universities), commercial buildings; cultural heritage sites (museums, theaters, historic buildings). Various kinds of transport network data have also been collected using OSM.

3 Results and Discussion

The susceptibility to flooding is not limited to existing structures but also includes the basin's numerous landuse patterns. Particularly, vulnerable buildings such as hospitals, schools, university, houses, parking, industrial, college, as well as transportation networks are taken into account with a corresponding vulnerability for potential damages. The land transportation networks include highway service, highway secondary, highway residential, highway construction, highway tertiary, highway primary, highway unclassified, road, footway, and trunk. OSM web service helps to acquire various spatial information such as residential buildings, public facilities

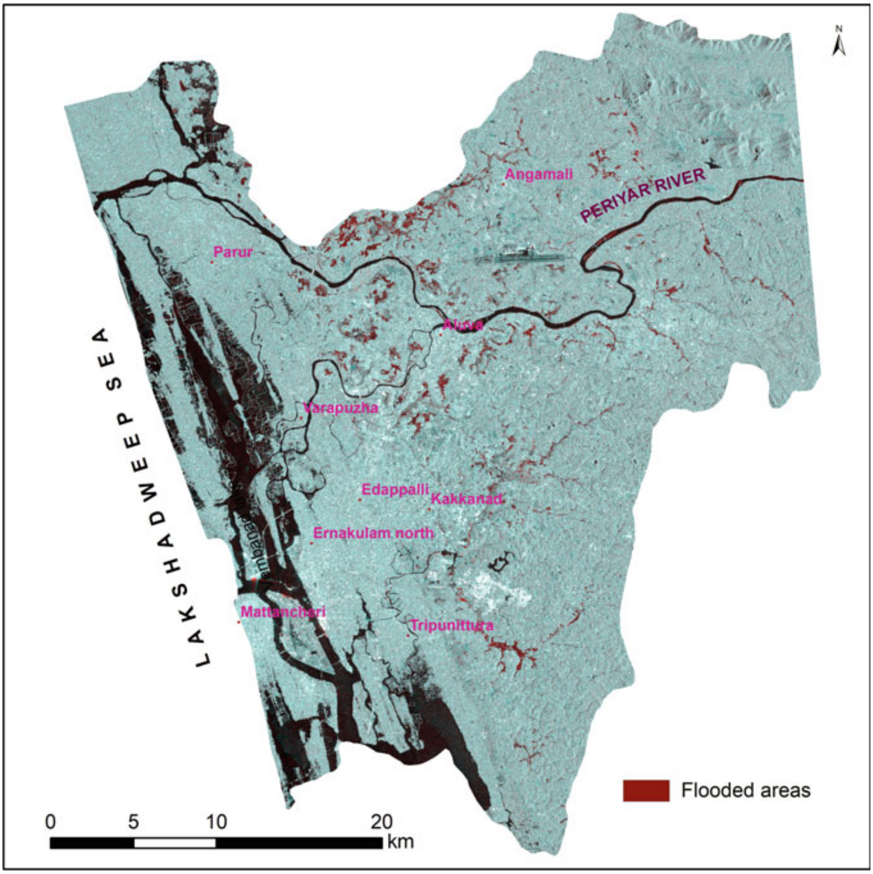

Fig. 3 Flooded areas in radar image

(schools, hospitals, police stations, and universities), commercial activities (industrial and parking), and transportation networks. An overlying flood inundation map was used to carry out the damage analysis over the land cover map, and the flooded area was estimated for each class category. It has been observed that the majority of the area affected was settlement with mixed tree crops and farmland.

Flood-affected areas were extracted from the radar image (Fig. 3). An area of 28 sq km of the study area was submerged underwater. Frequent floods are affecting these areas the most. Analyzing the landuse in the Lower Periyar area, 2842.40 ha area was found to be flooded. Of these, the settlement with mixed tree crop category

Table 1 Flood-inundated landuse categories

Landuse	Area (ha)
Settlement with mixed tree crops	2429.70
Aquaculture	2.16
Commercial	0.03
Farmland	297.26
Forest	0.25
Grass	98.73
Greenfield	3.11
Industrial	5.98
Landfill	1.81
Military	0.21
Quarry	0.89
Railway	0.80
Recreation ground	0.02
Residential	0.27
Village green	1.18
Total	2842.40

had the highest flood threat. It is 2429 ha area of settlement with mixed tree crops submerged underwater (Table 1). 297 ha of farmland was flooded. Elsewhere, the grass land 98 ha area and the industrial area 5.98 ha area were inundated (Fig. 4). These flood-prone areas need to be effectively maintained. Of course, such flood threats will continue in the future.

The highway unclassified road network was the most flooded when it came to analyzing flood-affected transportation systems. It was submerged in several places for a distance of about 12 km. The highest level of flooding was on the highway residential road. It flooded 151 places at a distance of about 10 km (Table 2). Through such analyses, it is possible to understand the extent of the flood threat and intensity in the region. When submerged buildings and land transport networks were identified, 21 large and small buildings were completely and partially submerged, and 32 km of transport networks were completely submerged. Considering the transportation network alone, 357 places were flooded in 2018 (Fig. 5). OSM data was used for such findings.

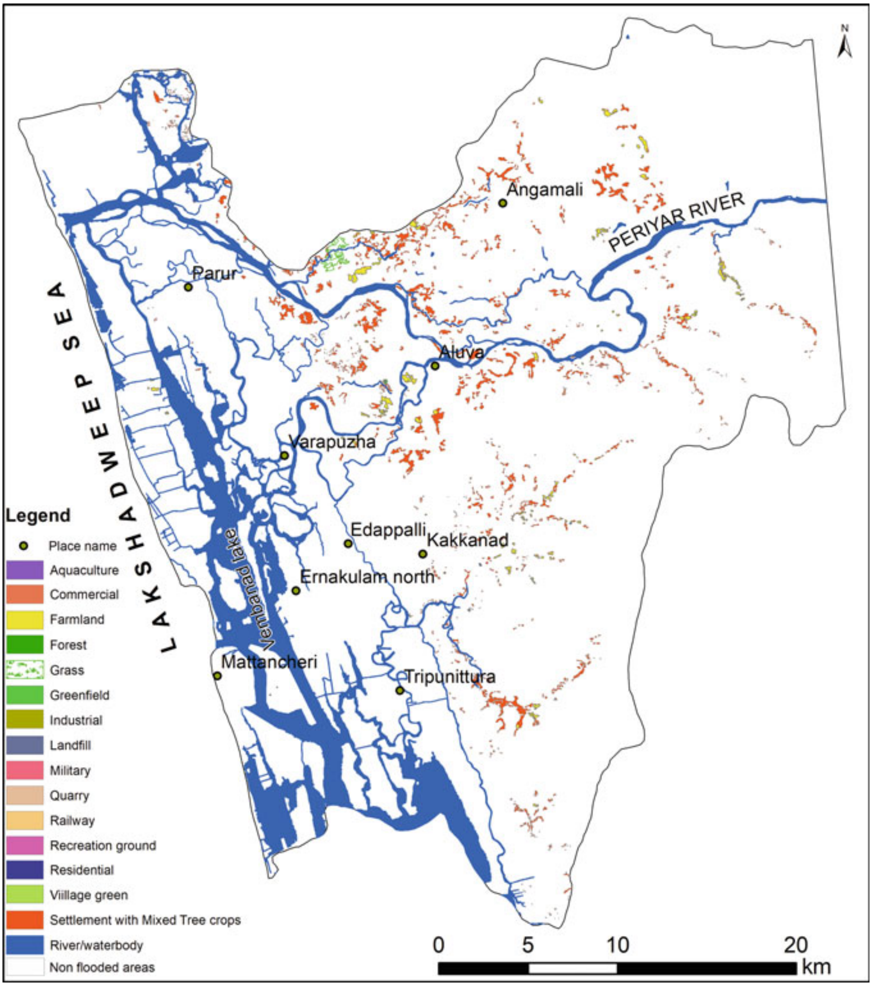

Fig. 4 Landuse categories submerged under water

In the study area, eleven houses, three school buildings, two colleges, and a hospital were flooded in 2018 (Table 3). Such buildings will be flooded again in the future. This type of study shows that it is possible to identify which buildings are most at risk of flooding. Analysis of the landuse, transport network, and buildings in the lower course region of the Periyar River has revealed the intensity of flooding in the area. It is a fact that mitigation measures can be taken only if such flood-prone areas are identified.

Table 2 Transportation network submerged under water

Land transportation network (OSM)	Flooded (Length in m)	Total number of segments flooded
Railway	1560.39	11
Highway trunk	54.63	1
Highway service	2380.9	10
Highway secondary	634.69	15
Highway residential	10,590.95	151
Highway construction	409.03	1
Highway tertiary	2379.81	36
Highway primary	289.63	7
Highway unclassified	12,628.29	107
Road	666.77	11
Footway	41.55	1
Trunk	600.51	6
Total	32,237.15	357

Frequent floods in Kerala will put low-lying areas in crisis. Proper management and planning can help reduce the severity of floods. Identifying flood-affected areas and finding out which areas will adversely affect buildings and transportation networks will help mitigate future flood damage. Creating flood maps can help with a variety of planning and safety activities.

4 Conclusion

The frequent flood inundated the study area regularly. Many houses, schools, industrial, and colleges of Periyar lower reaches are under flood affected. Many infrastructures of this study area are also destroyed by the flood. Riverine floods in the state are not a recent phenomenon. The low-lying areas of the Periyar River, which is close to the coast, are depositional area. These areas are most prone to floods. In the low-lying areas, the height of the levee is low in some places, causing flooding in flood plains and back swamp areas. The increase in construction areas and reclamation of wetlands increased the intensity of flooding in these areas. As the slope of the hilly region gradually increases, the intensity of river flow increases and as a result deposits in low-lying regions increase. Deposit accumulation has also contributed to a rise in the severity of floods. Flooding can occur regularly, but people in the area should be accustomed to the flood, and adequate measures should be taken by the government to reduce the vulnerability of the flood.

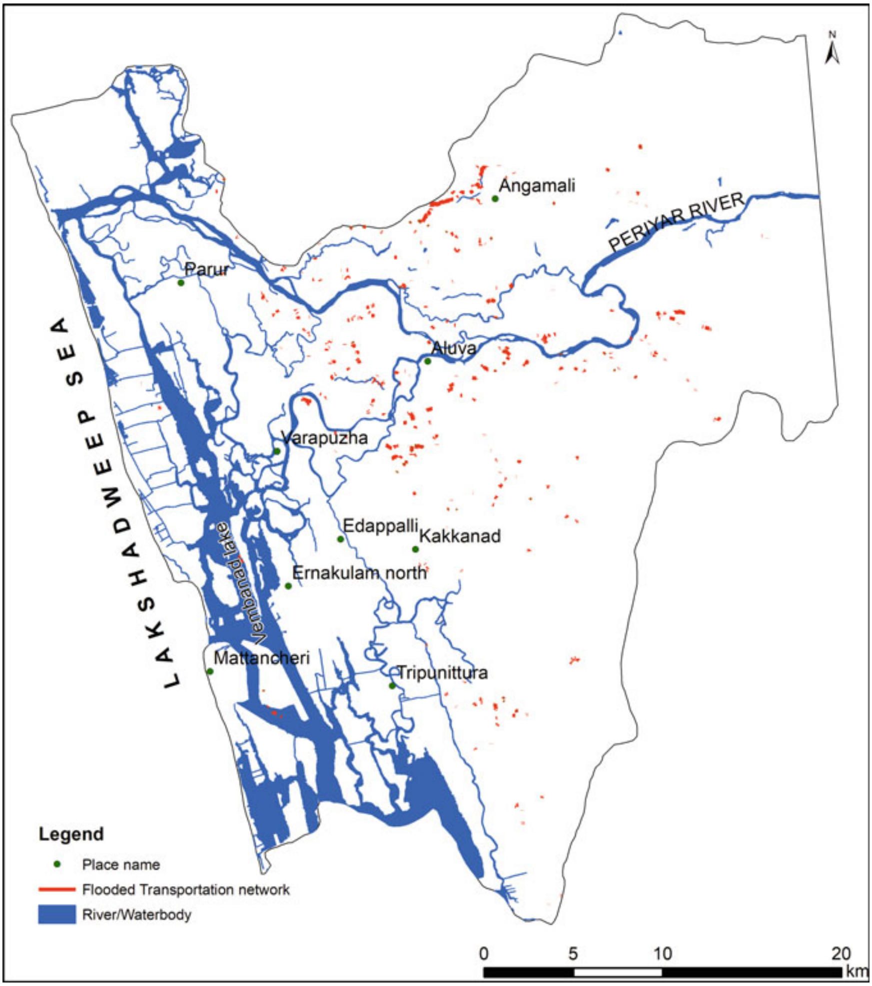

Fig. 5 Transporatation network submerged under water

Table 3 Buildings and amenities submerged under water

Buildings and amenities	No. of building flooded
House	11
Industrial	2
Hospital	1
University	1
School	3
College	2
Parking	1
Total	21

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മാർച്ച് 2022

ഇശൽ പൈതൃകം

ത്രൈമാസിക

Volume 28
March 2022

മഹാകവി മോയിൻകുട്ടി വൈദ്യർ
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ISSN:2582-550X

ISSN:2582-550X

Islam and Gender: From Islamic Feminism to Queer Islamic Studies

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Abstract

The revival of religions in the second half of the twentieth century and the changing geopolitics of the period have led to new readings of the experiences of believing women and their gendered lives. This interest in the lives of religious women forms part of a continuum which comprises black feminism and various other forms of feminisms and it also brings to fore the experiences of those women who were hitherto considered outside the feminist discourse. This complex theoretical turn, with its interdisciplinarity, is an outcome of various influences. Euro- American feminism's disregard for the experiences of the dalits, blacks and Middle East women, and its thrust on a universal feminist discourse make it a rather incompatible methodological tool to analyse religion as a category that genders women's lives in myriad ways. The gender turn taken by Islamic studies and the interest in religion by feminists now borders on a broader theoretical paradigm that includes the sexual minorities and their engagement with religion. This has its twin focus on how the LGBTQ communities experience religion and the Islamic reading of queerness. This paper attempts to trace this shift in the critical approaches to the study of religion and gender.

Keywords: Gender, Islam, Sexuality, Queer, Islamic Feminism.

Islam and Gender: From Islamic Feminism to Queer Islamic studies

Islamic Feminism is both a critical approach and a mode of activism. Islamic Feminism as a critical tool for analysis became increasingly discernible in the 1990's, though its roots can be traced back to the late 19th century. This phenomenon has given rise to some of the boldest discursive articulations on the relationship between gender and religion. In the 1990's attempts were made to analyse Muslim women's negotiations with religion as well as their lived experiences. Women started negotiating and marking their experiences of gender-struggle within and outside their religious spaces. This accounts for the emergence of new trends in Islamic Feminism. They placed themselves within the larger context of Islam without negating the plurality and uniqueness of their socio political contexts. This focus on the experiences of women in Islam gradually led to the emergence of methodological approaches that foregrounded issues of 'women' and later 'gender',an inclusive term for women, men and other sexual minoritie. Islamic feminism has evolved and is recently emerging as an inclusive methodological approach that can be used to study issues of women, masculinity and sexual minorities. It can be argued that the contours of Islamic feminism, as an analytical discipline, is expanded to encompass the question of gender and thus makes analyses of gendered experiences more holistic.

The complexity and inherent contradiction in the term 'Islamic Feminism' is often a matter of debate. Yet the significance of this discipline and the impact of its readings remain unquestioned. Islamic feminism combines in its analysis aspects of secularization with that of Islamization and thus brings out its political, social and cultural complexity. Islamic feminists are simultaneously waging a struggle against the patriarchal manifestations of Islam and also the Islamophobic manifestations of feminism. Thus they de-traditionalize Islam by re-reading relations between genders. In the past few decades this mode of critical inquiry that combines feminism with religious studies has created new ways of perceiving gender relations. This has its impact on religious practices, judiciary and even policy making bodies in various parts of the world.