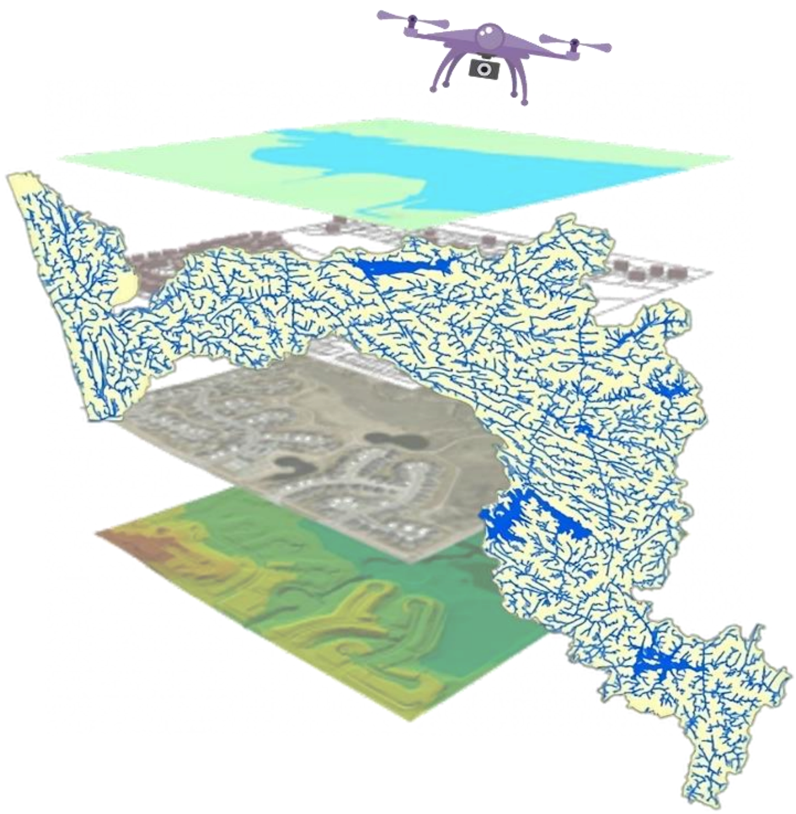
National River Conservation Directorate
Department of Water Resources,
River Development & Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

STATUS OF AERIAL/DRONE SURVEY OF PERIYAR RIVER BASIN



September 2024

STATUS OF AERIAL/DRONE SURVEY OF PERIYAR RIVER BASIN

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.
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The Center for Periyar River Basin Management and Studies (cPeriyar) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IIT Palakkad and NIT Calicut, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cPeriyar is committed to restoring and conserving the Periyar River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.
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cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.
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Acknowledgment

This report is a comprehensive outcome of the project jointly executed by IIT Palakkad (Lead Institute) and NIT Calicut (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

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Preface

Rivers have a very major environmental and societal role on this planet as they provide water, the elixir of life, and render incredibly invaluable ecosystem services including facilitating production of food and nutrients, flood and drought mitigation, transport, power generation, recreation etc as well as providing habitat and supporting biodiversity. River corridors, which include river channels, riparian zones, floodplains etc play a major role in enabling rivers to render the services mentioned above. Many of these corridors are susceptible to natural hazards to different degrees, and hence constant and close monitoring is extremely important to improve our understanding of the various processes and mechanisms at work and to protect people. Aerial surveying and remote sensing offers a rapidly growing technologically superior suite of methods to perform river corridor monitoring even under challenging and difficult topographical and environmental settings over a wide range of spatial and temporal scales.

In this document, the potential for use of drones/ UAVs/ aerial surveys for condition assessment of river basins, in general, and its scope and limitations are presented. The status of aerial surveys performed in the Periyar River Basin is reviewed. Also, an attempt has been made to identify critical zones within the Periyar River Basin where aerial surveys are required to be performed from the perspective of susceptibility to natural hazards of relevance to the area such as landslides, soli piping, floods etc. This exercise has been carried out using medium/ high resolution satellite imageries that are easily accessible. Constraints to performing high resolution aerial surveys in the Periyar River Basin using drones eqipped with LiDAR are identified.

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Abbreviations and Acronyms

AAI	Airports Authority of India
CIAL	Cochin International Airport Limited
DEM	Digital Elevation Model
DGCA	Directorate General of Civil Aviation
DTM	Digital Terrain Model
GIS	Geographic Information System
HAL	Hindustan Aeronautics Limited
IAF	Indian Air Force
KSREC	Kerala State Remote Sensing and Environment Centre
LiDAR	Light Detection and Ranging
LSGD	Local Self Government Department
LULC	Land Use and Land Cover
MoPR	Ministry of Panchayati Raj
NCESS	National Centre for Earth Science Studies
RGB	Red, Green, and Blue (referring to imagery)
SfM	Structure from Motion
SVAMITVA	Survey of Villages and Mapping with Improvised Technology in Village Areas
UAV	Unmanned Aerial Vehicle

1.0 Introduction

Advancements in technologies and methods in surveying have significantly improved the accuracy of mapping products. The digital era has transformed surveying methods with several innovations such as satellite remote sensing, and advancements in aerial surveying including the use of drones and Light Detection and Ranging (LiDAR). When combined with modern image processing techniques and software, these technologies have revolutionized 3D mapping and terrain modelling of the Earth (Chaudhry, 2020). Technologies like drones and Unmanned Aerial Vehicles (UAVs) are rapidly transforming the way in which environmental assessments and land surveys are conducted. These technologies offer innovative solutions for accessing remote and inaccessible areas, providing high-resolution data for mapping, monitoring, and analyzing landscapes. In the context of river basin studies, drones have proven its capability and efficiency in capturing topographic data in great detail, tracking changes in landuse, river course, erosion etc, monitoring vegetation health, and even assessing water quality.

Aerial and drone surveys find application in river basin studies due to its ability to provide detailed, high-resolution data in a cost-effective and efficient manner. These techniques are widely used to monitor river basins, reservoirs, canopy cover, landuse etc and facilitate tracking water levels, detecting erosion, and assessing flood risks, thereby enabling better water resource management and disaster preparedness. The use of drones for performing aerial surveys in river basin assessments offers several key benefits. Drones can easily access disaster-prone areas, making them ideal for surveying challenging terrain. It is possible to acquire real-time data which is especially valuable in the event of occurrence of natural disasters such as floods, landslides etc. It offers high-precision mapping and analysis through advanced technologies such as photogrammetry and LiDAR, thereby facilitating much better and accurate assessments.

Analyses of aerial photographs enable the use of a consistent classification system across different time periods. In contrast, maps often face thematic inconsistencies, such as the lack of clear definitions for specific landscape features, posing a challenge in evaluation (Vuorela et al., 2002). Analyses of aerial photographs help to identify changes in land use over time. By applying a uniform classification system, it becomes easier to track and compare how land use evolves across different time periods.

Drones equipped with cameras and LiDAR sensors can capture high-resolution images, which in turn can be used to generate digital elevation models (DEMs)/ digital terrain models (DTMs) to understand and assess the topographic features in a river basin. Also, these data products are key inputs to hydrologic models used for performing studies on water and sediment related problems in river basins. By performing drone surveys, it is possible to monitor sediment accumulation within the river channels, which is critical for maintaining the channel capacity and preventing floods. UAVs provide an efficient and precise method for surveying riverbanks that are prone to erosion/ change at regular intervals. By capturing high-resolution images and data over time, UAVs can track changes in the landscape, helping to monitor the rate and extent of erosion.

Aerial surveys play a crucial role in monitoring vegetation health in river basins, thereby enabling the identification of stressed areas that may need restoration or conservation efforts. LiDAR surveys are useful for developing high-resolution Digital Terrain Models (DTMs). In a river basin with relatively dense canopy cover as in the case of the Periyar River Basin, LiDAR surveys are required to be performed to enable development of digital terrain models (DTMs). DTMs provide vital information on areas prone to inundation during heavy rainfall or flooding and are a key resource in exercised on floodplain mapping. During flood events, aerial surveys can be performed in real-time to assess the spread, depth, and impact of flooding, thereby assisting emergency response teams and aiding in post-disaster recovery efforts in the river basin. Monitoring vegetation health in the upper reaches of the river basin and floodplains and sediment accumulation in the river channels and mapping the floodplains of rivers enable development of effective strategies to manage several problems and enhances the overall resilience of the community to natural disasters.

Integrating various technologies in aerial surveying to perform condition assessment in a river basin yields significant benefits in terms of efficiency, accuracy, and cost-effectiveness. By leveraging these technologies, Authorities can monitor and manage river basins much better, thereby moving towards facilitating sustainable water and land management in terms of water use, water conservation, recycling and reuse of water, flood prevention, mitigation of the adverse effects of floods, conservation of the landscape, monitoring changes in land use-land cover, preventing encroachment of flood plains of rivers, enforcing appropriate land use, monitoring erosion and sediment accumulation in rivers etc.

2.0. Potential Use of Drone/ UAV/ Aerial Surveys in the Condition Assessment of Rivers and River Basins

Aerial and drone surveys are crucial tools in river basin studies, offering several advantages over traditional methods. They provide high-resolution, real-time data on topography, vegetation, and water flow, which are vital for accurate hydrological modelling and environmental monitoring. Unlike ground-based surveys, aerial and drone surveys can cover large and inaccessible areas quickly and in a cost-effective manner. This makes them particularly useful in monitoring dynamic environments such as rivers and floodplains, where conditions change rapidly. Additionally, drone-based surveys can capture data at any desired altitude and angle, offering detailed insights into geomorphological features and changes in the landscape.

In the context of the Periyar River Basin, a relatively small and ecologically sensitive region, aerial and drone surveys offer unique advantages. They enable precise mapping of the intricate topography, dense vegetation, and large number of water bodies, which would be difficult to achieve through traditional ground-based methods due to the rugged terrain. However, there are several challenges specific to river basins located in the humid tropical belt adjoining the Western Ghats, the Periyar River Basin being one among these, including the relatively long monsoon period when heavy rainfall and dense cloud cover interfere with flight stability and limit aerial visibility, resulting in difficulties in performing aerial surveys during this period. Additionally, the dense vegetation, particularly in the upper and middle reaches of the river basin, limit ground visibility, necessitating complementary data sources for improved accuracy. LiDAR-based surveys are particularly useful in overcoming the limitations associated with conventional RGB photography. While effective for surface-level visuals, RGB images provide little or no information on variations in topography where the ground is covered with dense vegetation. LiDAR, however, can penetrate vegetation and produce precise, high-resolution Digital Terrain Models (DTMs) essential for understanding the topography, sediment transport, and riverbank dynamics. Teresa Gracchi et al. (2021), in their work on UAV photogrammetry, stated that high-resolution terrain models are invaluable for detecting geomorphic processes like important processes such as erosion and sedimentation in a river basin. This is more relevant in the case of river basins with complex hydrological and geomorphological features as in the case of the Periyar River.

Literature review reveals that while RGB imagery combined with photogrammetric techniques like Structure from Motion (SfM) has been successfully employed to monitor flooding and riverine features (La Salandra et al., 2023), this approach might not offer the level of sub-canopy detail needed for a river basin with dense vegetation. However, LiDAR surveys provide a more comprehensive view of the area surveyed and facilitate both surface and below-canopy terrain mapping, which is critical for flood risk and landslide susceptibility assessments.

3.0 Drone Survey

3.1 Flying zones under the Drone Rules, 2021

The Drone Airspace Map is an interactive tool that demarcates the Yellow and Red Zones across India, as outlined by the Drone Rules, 2021. The airspace is classified into three zones:

Green Zone: Airspace up to 400 feet in areas that have not been classified as Yellow or Red. It also includes airspace up to 200 feet in areas located 8-12 km from the perimeter of an operational airport. In the Green Zone, no permissions are required to operate drones with an all-up weight of up to 500 kg.

Yellow Zone: It refers to the airspace above 400 feet in Green Zones, above 200 feet in areas 8-12 km from the perimeter of airports, and the airspace within 5-8 km of an airport. Depending on the jurisdiction, drone operations in the Yellow Zone require clearance from the relevant air traffic control authorities, such as AAI, IAF, Navy, or HAL.

Red Zone: It is a no-fly area where drone operations are strictly prohibited without explicit permission from the Central Government. Drones can be flown in the Red Zones only under exceptional circumstances, ensuring heightened security and regulatory compliance in these sensitive areas.

3.2 Zones restricted for operation of drones in the Periyar River Basin

The portion of the Periyar River Basin within Kerala faces specific geographical, strategic, and security challenges, leading to the establishment of zones restricted for drone operations under the Drone Rules, 2021. These restricted zones are typically classified into several categories, including areas near critical infrastructure, industrial zones, and certain protected natural areas. The Digital Sky platform hosted by the Directorate General of Civil Aviation (DGCA) provides detailed maps of these no-fly zones, ensuring that drone operators comply with regulations to maintain safety and security in the region. Zones restricted for drone operations in the Periyar River Basin are depicted in Figure 1. These zones primarily fall into the following categories:

Airport Zone

An area of about 12 km radius from the perimeter of the Cochin International Airport Limited (CIAL), is a restricted zone for drone operations.

Industrial Zone

The areas near Kochi, particularly around its industrial hubs, are designated as restricted zones for drone operations under the Drone Rules, 2021. These restrictions are in place to safeguard industrial infrastructure, prevent accidents, and ensure compliance with safety regulations.

Critical Infrastructure Zone

Drone operations are restricted around the Lower Periyar, Idukki, and Mullaperiyar dams due to its strategic importance. Special permission is required for any drone activity, including surveys, in these areas to ensure security and protect critical infrastructure.

3.3 Drone surveys performed in the Periyar River Basin

The SVAMITVA Yojana (Survey of Villages Abadi and Mapping with Improvised Technology in Village Areas) launched on 24th April 2021 is a Central Sector Scheme of the Ministry of Panchayati Raj aimed at creating accurate property records in rural India. . The Ministry of Panchayati Raj (MoPR) is the Nodal Ministry for implementation of the scheme. In the States, the Revenue Department/ Land Records Department is the Nodal Department for carrying out the scheme with support of State Panchayati Raj Department. Survey of India is the technology partner for implementation of the scheme. Under this scheme, inhabited areas in villages, traditionally not covered in conventional land surveys, are to be mapped using drone technology. The scheme envisages enabling rural residents to use their property as a financial asset, facilitating access to loans and promoting economic stability. Additionally, SVAMITVA aims to reduce property disputes, improve local planning, and support accurate tax assessments by producing detailed GIS maps.

The SVAMITVA scheme has made some progress in the State of Kerala, including areas within the Periyar basin. As part of the initiative, drone surveys have been completed in 596 out of the 1415 notified villages in the State (https://svamitva.nic.in/), out of which 25 (out of a total of 154 villages) fall within the Periyar River Basin. The status of drone survey performed under the SVAMITVA Yojana is presented in Figures 2 and 3.

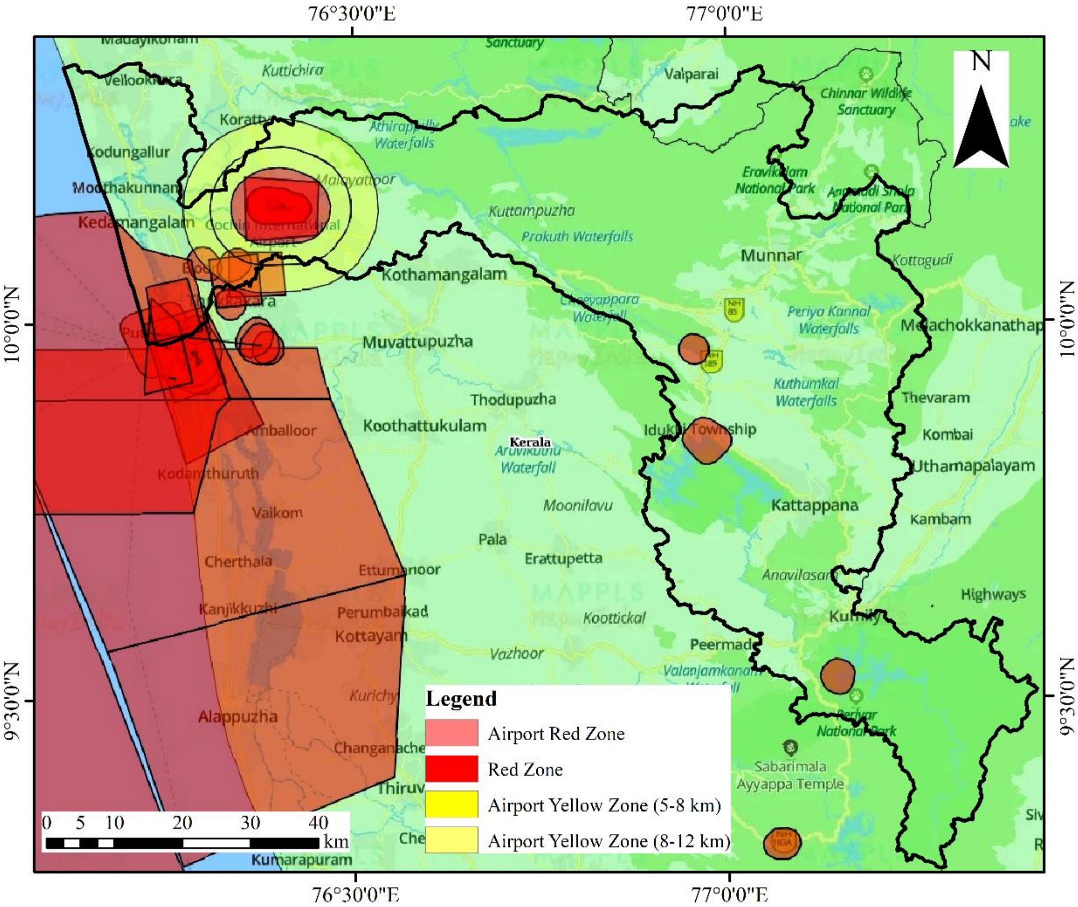


Figure 1: Restricted zones for drone operations under the Drone Rules, 2021

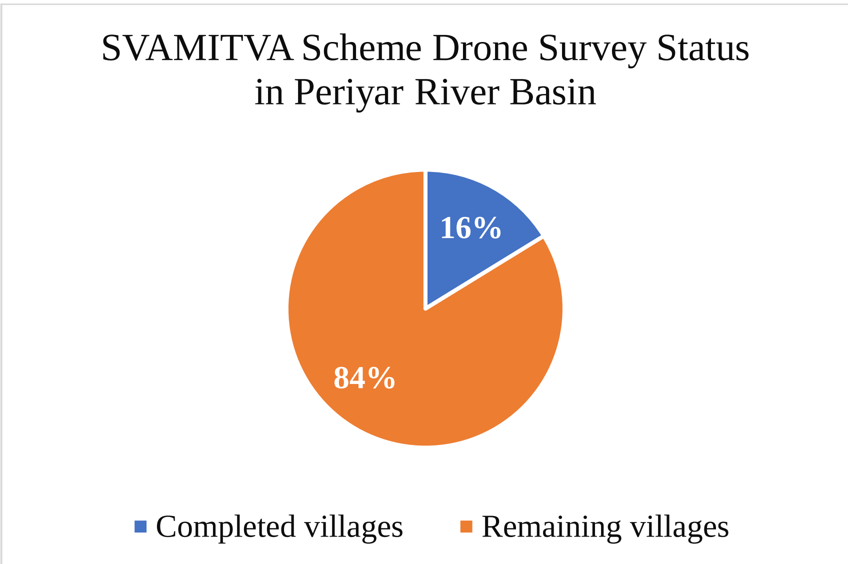


Figure 2: Status of drone survey under the SVAMITVA Yojana - Periyar River Basin

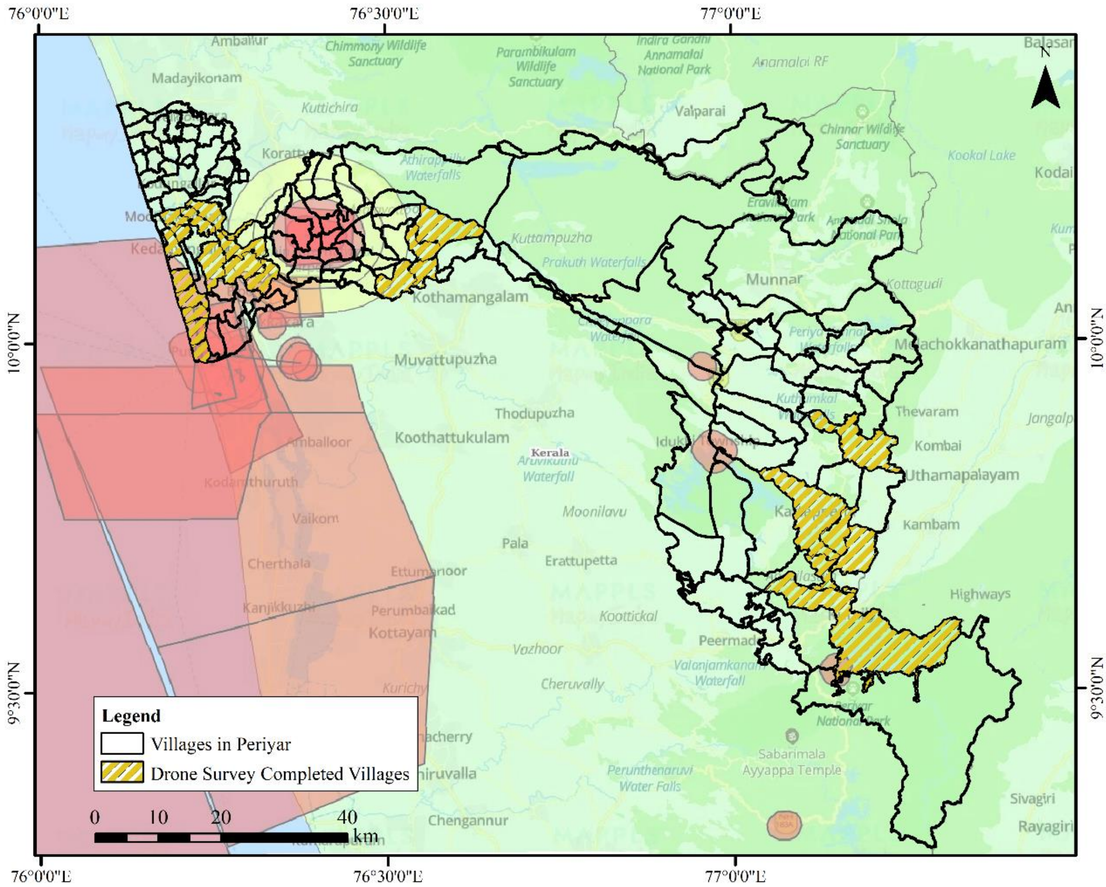


Figure 3: Villages in the Periyar River basin where drone survey has been completed

Enquiries were made with the Dept. of Irrigation, Govt. of Kerala, the Kerala State Remote Sensing and Environment Centre (KSREC), and the Department of Local Self Government (LSGD), Govt. of Kerala, regarding availability of aerial survey data. There is no response yet from the LSGD where as the other two informed that they have not performed any. Private agencies such as the Uralungal Labour Co-operative Society (ULCCS) and Dronimagination Solutions Pvt. Ltd. have performed drone surveys for very limited areas.

The objective of the SVAMITVA scheme explicitly states that it is not intended for geospatial analysis. Rather, it is for maintaining an accurate record of property. Therefore, the data collected under this initiative does not align with the objectives of our current project and will not be, in general, useful for hydrologic modelling to be performed under this project. It may not be of much use for floodplain delineation and zoning in view of the limitations mentioned previously. Additionally, the spatial coverage of this scheme in the Periyar River Basin to date is limited and significantly small compared to its areal extent, making the drone survey data deficient for our analysis. The same conclusion applies to the drone surveys performed by other agencies mentioned herein as well.

4.0 Analysis of Temporal Changes in the River Basin

4.1 Identification of temporal changes in the river course

As the availability of aerial survey data for the river basin is very limited, it was decided to use moderate and high-resolution satellite imageries for detecting changes in the river basin, and providing long-term macro level insights into the river morphology, land use, and environmental impacts. Multi-temporal Landsat and other high-resolution satellite imageries and historical imageries from the Google Earth, depending on its availability, clarity etc can be utilized to track changes/ shifts in the riverbanks, alterations in the floodplains and derive information pertaining to sediment dynamics over time. The Landsat program, with its multi-decadal archive of images, is particularly useful for monitoring changes in the river regime. Hossain et al. (2013) used eight dry season satellite images of Landsat MSS (1973–1984), Landsat TM (1993–2003), and IRS LISS (2009), to assess morphological changes of the River Ganga within Bangladesh. The study revealed significant erosion and accretion in several stretches of the river. A similar approach could be applied in the Periyar River Basin also to detect changes in bank erosion, sediment deposition, and channel migration. These are influenced by rainfall patterns and magnitudes, and anthropogenic activities such as the construction of hydraulic structures across streams.

Historical imageries in Google Earth are a readily accessible tool for change detection, especially for smaller river basins like the Periyar. However, studies such as those by Alqahtani (2024) and Nwilo et al. (2022) caution about the positional accuracy of Google Earth imageries. Discrepancies in the Northing and Easting of points have been reported affecting the overall accuracy of exercises employing this data product.. Despite this limitation, the Google Earth platform remains a cost-effective option for preliminary assessment of morphological changes and shifts in the riverbanks. Aung and Tint (2018) employed Google Earth imageries for detecting river corridors and sandbanks. They demonstrated its utility in flood modelling and morphological studies, achieving relatively high accuracy when combined with machine learning techniques such as Support Vector Machines (SVMs). The use of remote sensing and GIS techniques in several related studies, such as those of Maurya and Yadav (2016) on the Ramganga River, demonstrated the utility of Landsat and other satellite imageries in tracking changes in the river course over decades. For the Periyar River, a similar approach could provide insights into how the river course has shifted during natural events and/ or in the event of human interventions such as the construction of hydraulic structures, and land-use changes.

In larger river systems like the Mekong, satellite imageries have proven indispensable for understanding the geomorphological behaviour across vast areas. Gupta et al. (2002) highlighted the challenges of studying such large systems and demonstrated the utility of satellite images in monitoring sediment transport and environmental degradation. It may be noted that the Periyar River Basin is relatively small when compared to the other river basins under the CAMP Project. Remote Sensing and GIS techniques can be scaled down to address local geomorphological changes, such as identifying areas prone to erosion or changes in riparian vegetation, which are critical for sustainable river management.

4.2 Detection of changes in LULC in the Periyar River Basin

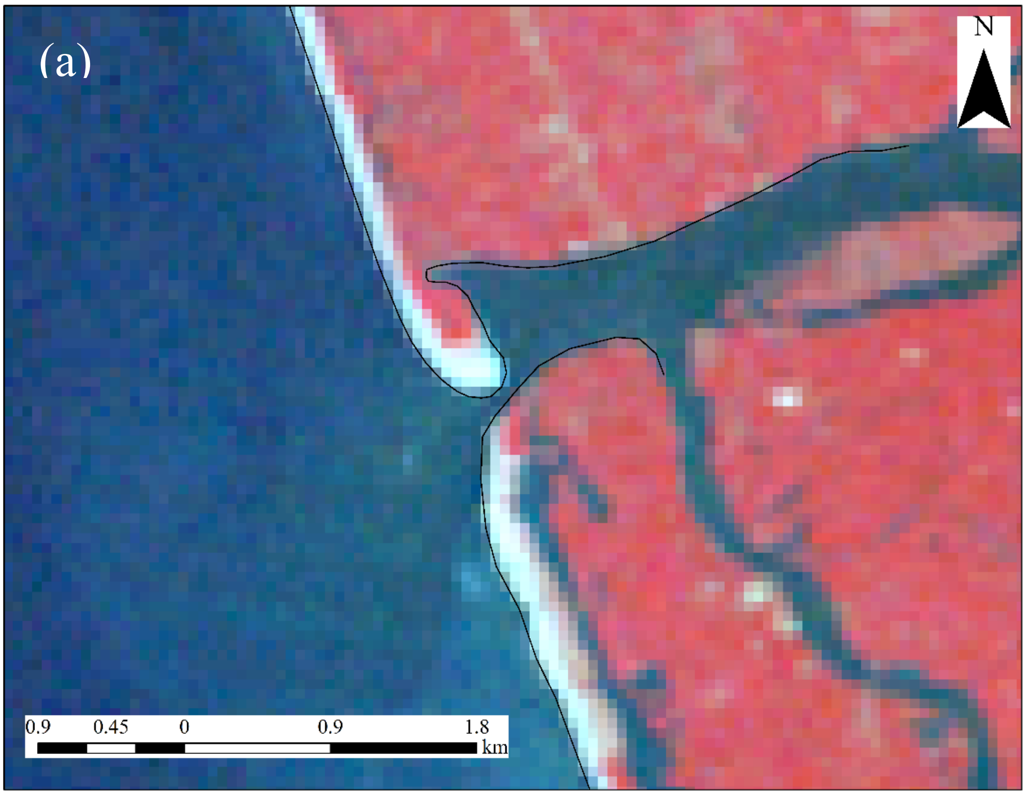
The Periyar River Basin (PRB) has undergone land use-land cover (LULC) changes over the years. This is expected to impact surface runoff, streamflows, and sediment yield, particularly at the sub-watershed scale. Sadhwani et al. (2022) reported that, between 1988 and 2016, urban areas in the basin increased by 4.13%, while plantation and forest areas decreased by 1.5%. Projections indicate that by the year 2100, urban areas may increase by about 16.45%, whereas areas with forest and plantation cover may decrease by about 13.7%. Although the impact of these changes on the overall watershed may be very small, the changes in streamflow and sediment yield at sub-watershed level may be significant. Key factors contributing to these changes include urbanization, slope of the terrain, and LULC transitions. The study emphasized the need for performing a detailed LULC analysis to enable devising appropriate strategies to mitigate potential enhancement in flooding and sedimentation. Understanding these changes is essential for developing appropriate plans and strategies for sustainable river basin management.

Dipson et al. (2022) investigated changes in the estuarine region of the Vembanad-Kol wetlands from 1944 to 2009 with the help of multi-temporal satellite data. The estuarine areas were identified in the Landsat MSS (1973), Landsat ETM (1990) and IRS LISS-III (1998 and 2009) imageries by visual interpretation and using digitization techniques in the ArcGIS 9.3 environment. The study revealed a progressive decrease in the estuarine area. This estuary, into which one segment of the Periyar River drains, is part of a Ramsar site. Over the past seven decades, this critical ecological zone has experienced rapid urbanization and significant land use/ land cover changes. In this study, an attempt was made to identify the key factors contributing to reduction in the estuarine area and provide crucial insights to facilitate sustainable management of the estuary. The study underscored the importance of satellite-based monitoring in conserving riverine and estuarine systems.

4.3 Temporal changes in the coastal zone of the Periyar River Basin

The coastal zone of the Periyar River Basin has experienced significant changes over the years due to a combination of natural processes and anthropogenic activities. The dynamic nature of coastal processes have resulted in considerable changes in the shoreline, particularly due to erosion and sedimentation (Selvan et al., 2019). The interaction of the Periyar River with the Arabian Sea and the presence of backwaters contribute to sediment transport, affecting coastal stability. Additionally, human activities, such as port construction, dredging and land reclamation, have intensified coastal erosion in certain parts of Ernakulam. The construction of coastal structures like sea walls and groynes has altered natural sediment flows, leading to accretion in some areas and erosion in the others.

The coastal regions of Munambam and Vypin in Ernakulam district, Kerala, are highly dynamic, facing substantial coastal erosion and accretion due to natural processes and human interventions. Munambam, located at the northern tip of Vypin Island, where one segment of the Periyar River meets the Arabian Sea, experiences significant erosion, particularly during the monsoon season. Strong tidal currents and wave action during the southwest monsoon cause severe shoreline retreats, as evidenced in various studies on the coastal dynamics of Kerala (Thodi et al., 2023; Noujas et al., 2013). Our preliminary analysis using satellite imageries of the area for the period between 1973 and 2024 clearly depict changes in the shoreline at Munambam (Figure 4). Sentinel-2 imageries of 10-m spatial resolution for the period 2016-2024 also clearly indicate changes in the shoreline (Figure 5). The breakwater at Munambam-Azhimugham has caused accretion, with significant sand deposition on both sides of the structure and reshaped the coastline. A depositional feature has developed in the river near Munambam due to sediment accumulation. It was initially noticed in 2015 and over the years it had increased in size. Overall, the changes in the coastal zone were identified by comparing multispectral data from the LANDSAT images of the years 1973 (Landsat 1 MSS), 1988 (Landsat 5 TM), 2001 (Landsat 5 TM), 2008 (Landsat 5 TM) 2017 (Landsat 8 OLI/TIRS) and 2024 (Landsat 9 OLI-2/TIRS-2). Sediment accumulation at this site is influenced by tides, changes in the tidal pattern and human interventions along the coastline, causing alterations in the natural flow of sediments.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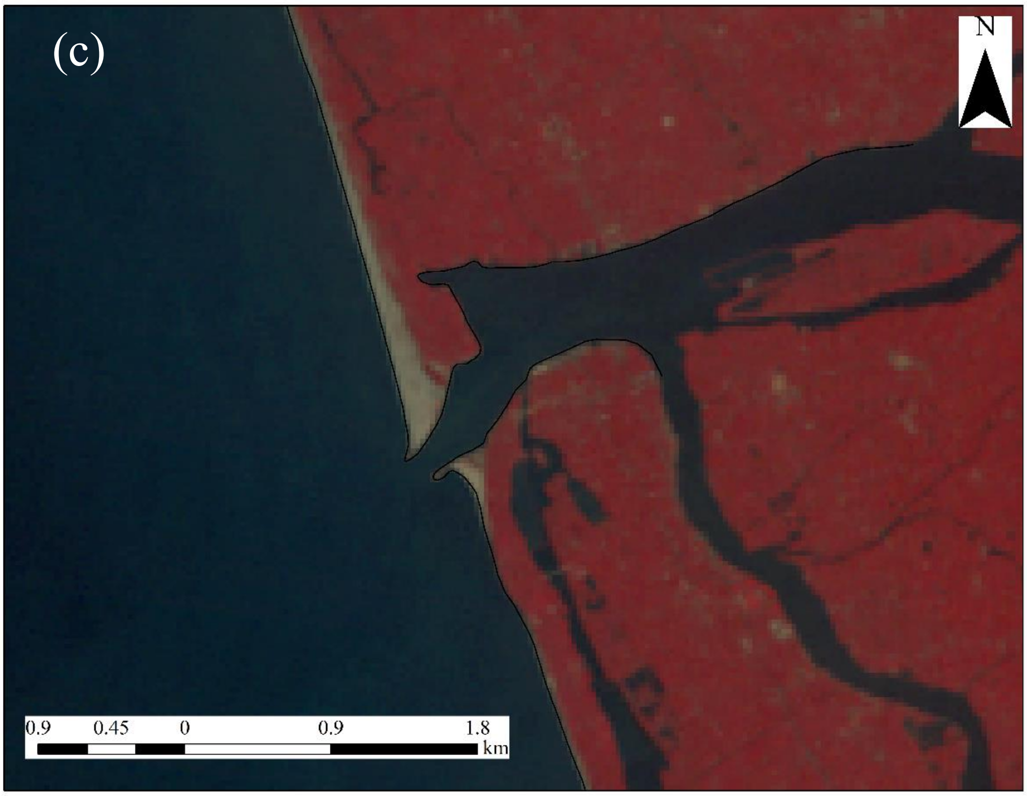
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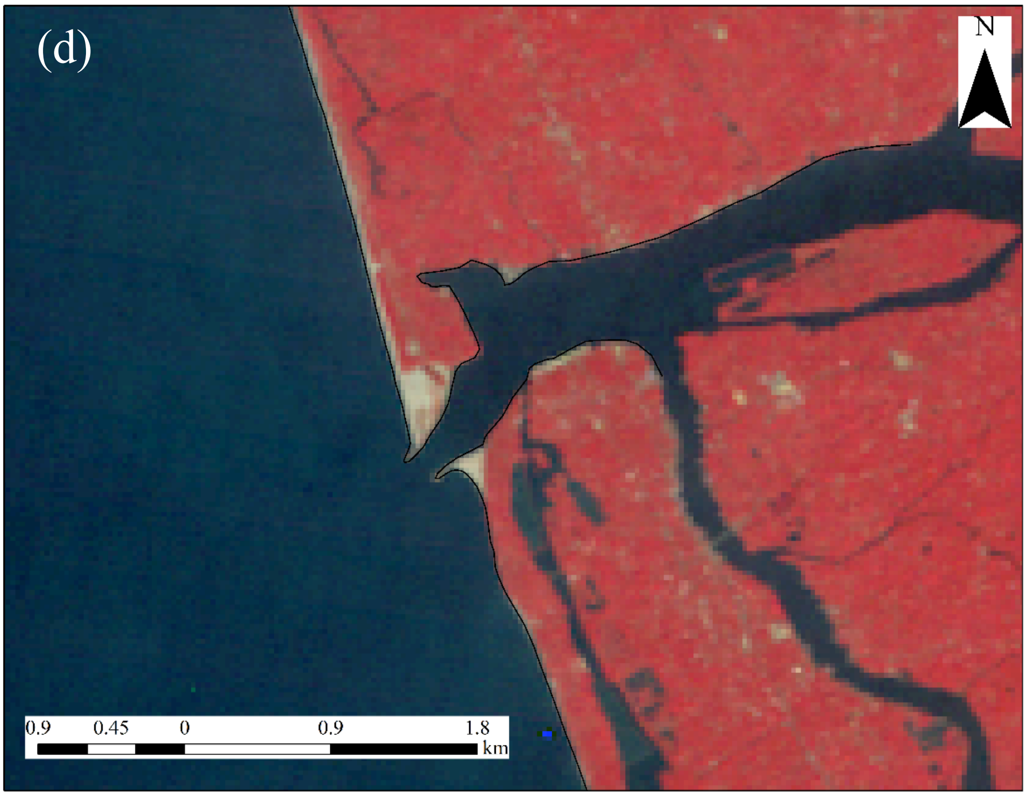
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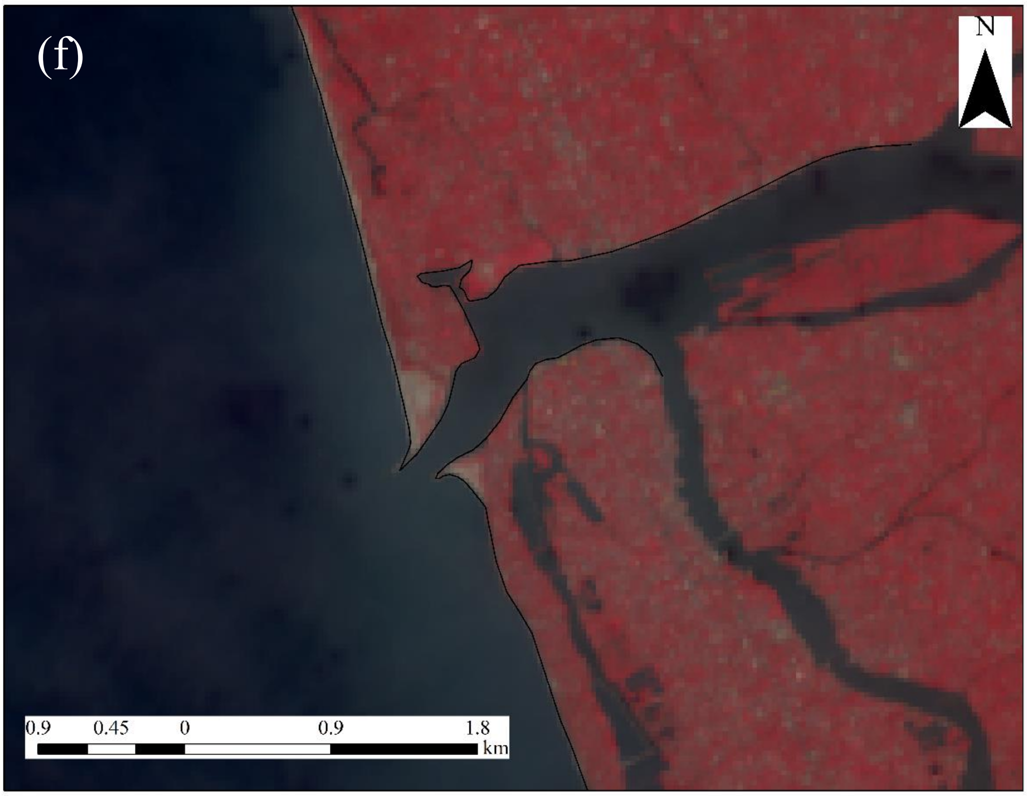

Figure 4: Landsat Satellite images of Munambam (a) 1973 (b) 1988 (c) 2001 (d) 2008 (e) 2017 (f) 2024

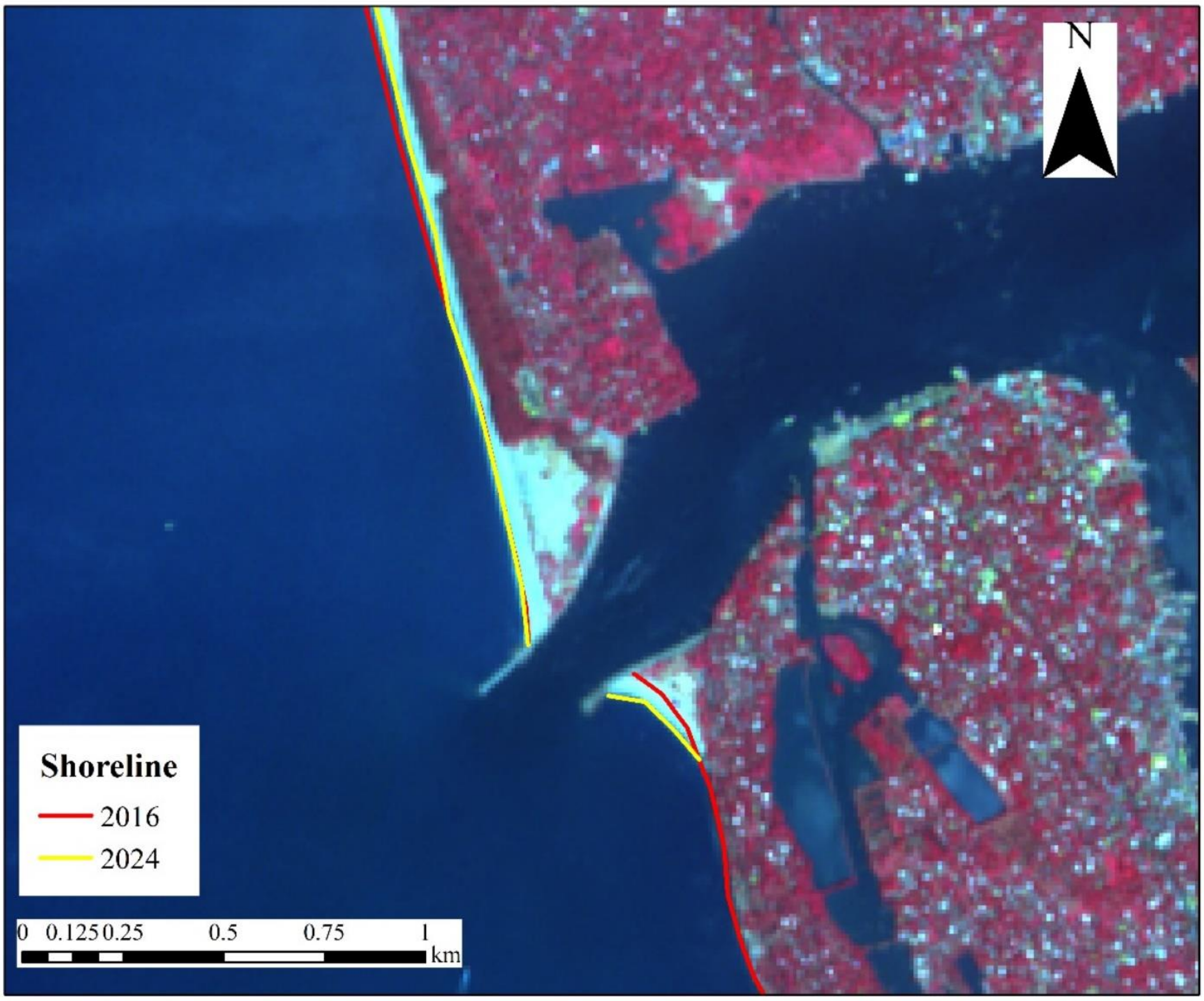

Figure 5: Shoreline change at Munambam observed using Sentinel-2 satellite imagery

It is also observed that coastal defence structures such as breakwaters and groynes have altered the natural sediment distribution in different parts of the Vypin island, leading to localized erosion in some stretches, and accretion in some others. This is clearly evident from Figure 6 that a significant change in the shoreline at Vypin has occurred. Construction of breakwaters and groynes has accelerated the accretion process, leading to the deposition of sand along both sides of these structures, reshaping the coastline over time. Also, the construction of a port at Vypin has intensified the shoreline change (Figure 7). Also, sediment influx from the Periyar River along with wave action contributed to accretion in some areas leading to an expansion in the land area, whereas some other stretches lost land to the sea.


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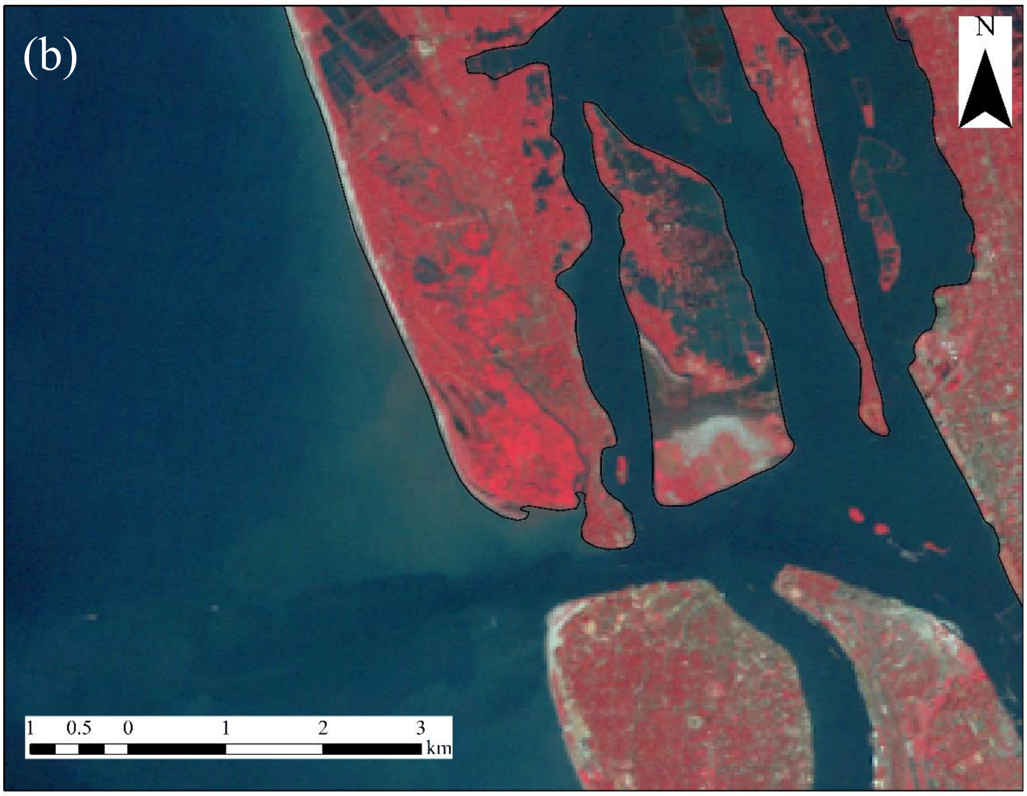
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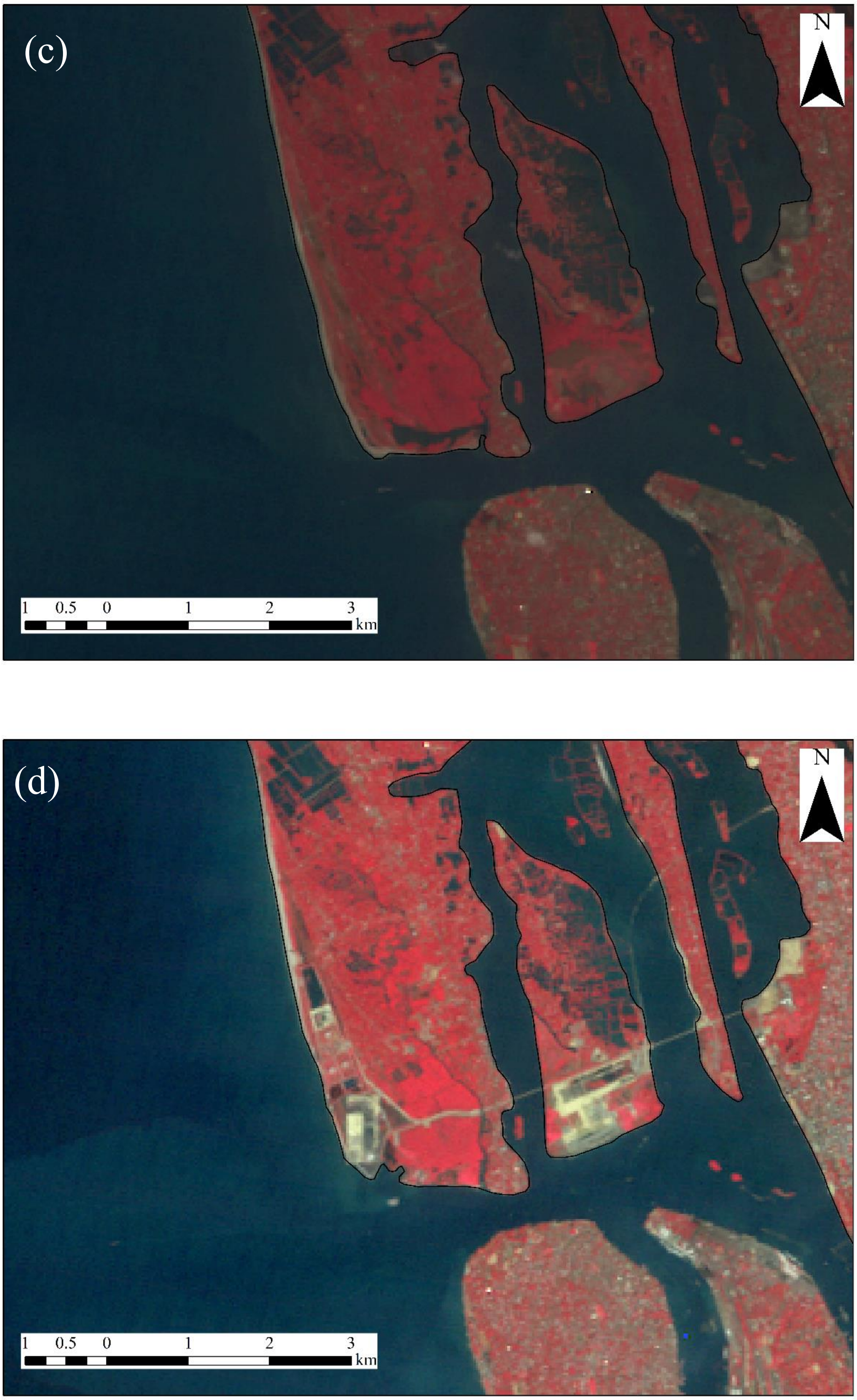
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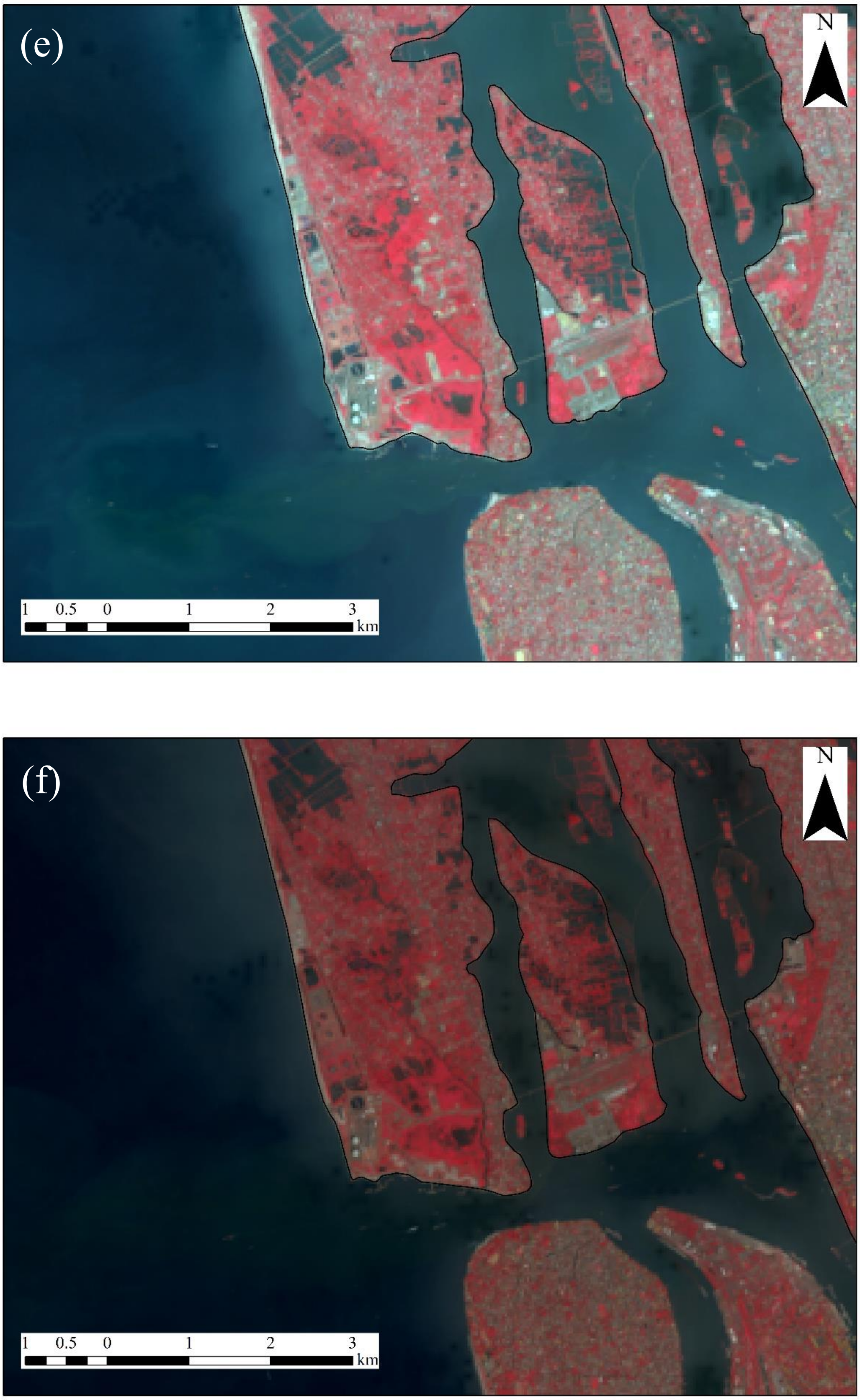


Figure 6: Landsat Satellite images of Vypin (a) 1973 (b) 1988 (c) 2001 (d) 2008 (e) 2017 (f) 2024

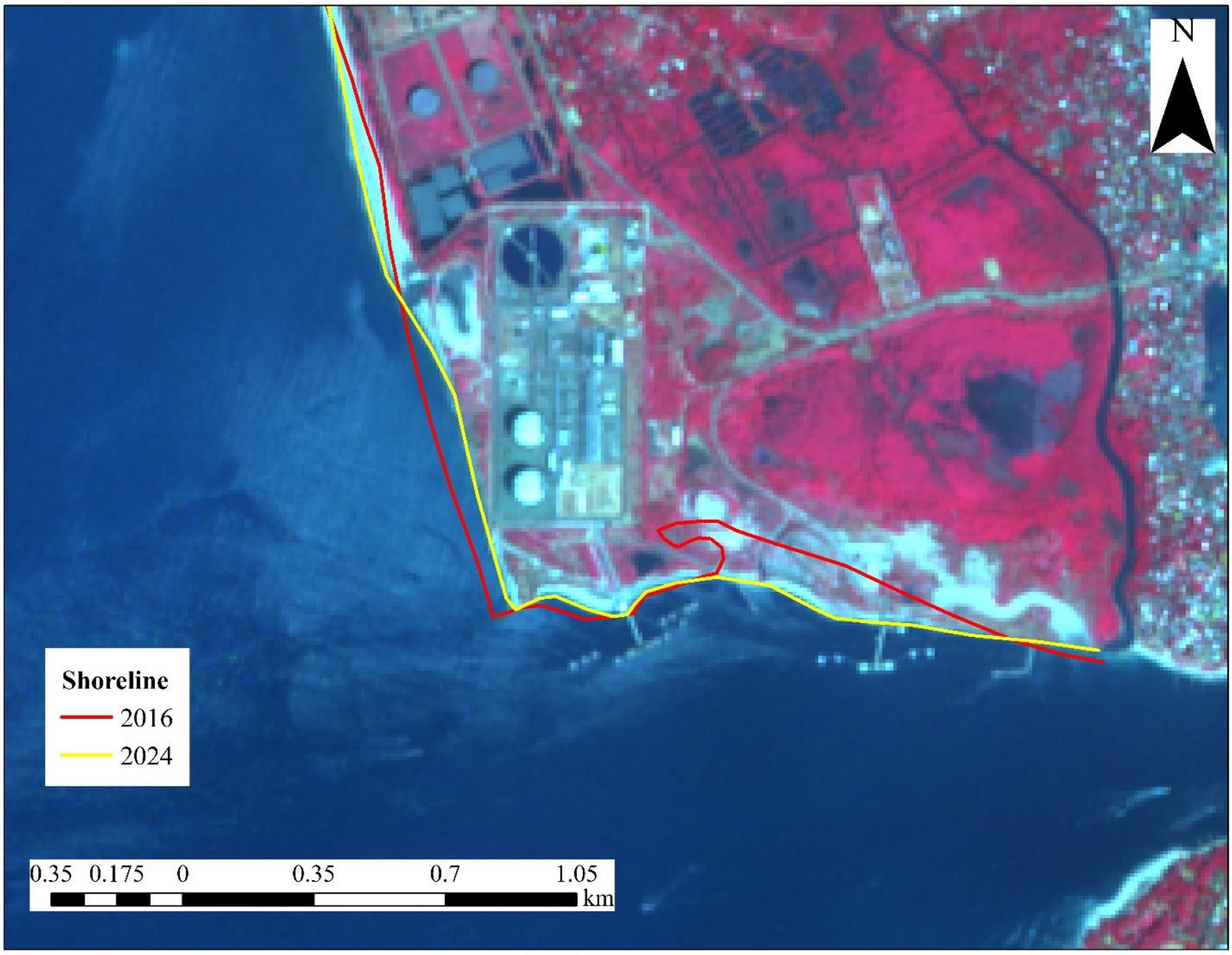


Figure 7: Shoreline change at Vypin observed using 10 m Sentinel-2 satellite imagery

Analysis of temporal changes in the coastline of the river basin clearly indicates significant erosion and deposition due to natural and anthropogenic activities between 1973 and 2024. The shoreline at Munambam and Vypin during the years 1973, 1988, 2001, 2008, 2017 and 2024 are presented in Figures 8 and 9.

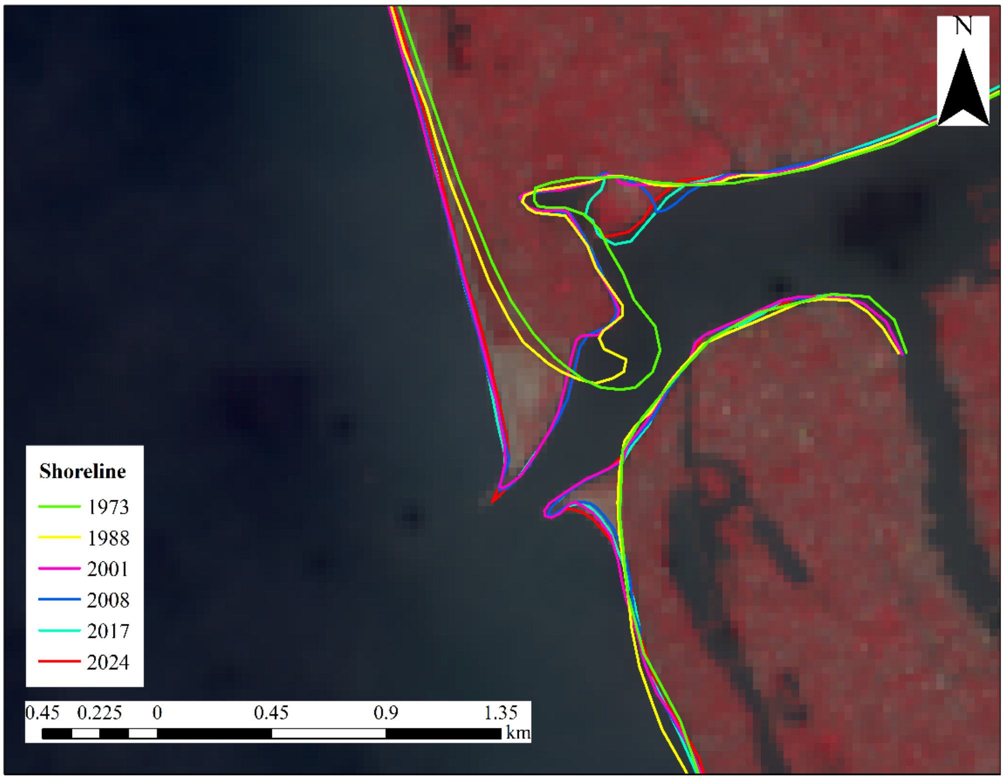


Figure 8: Shoreline line change at Munambam in the period 1973-2024

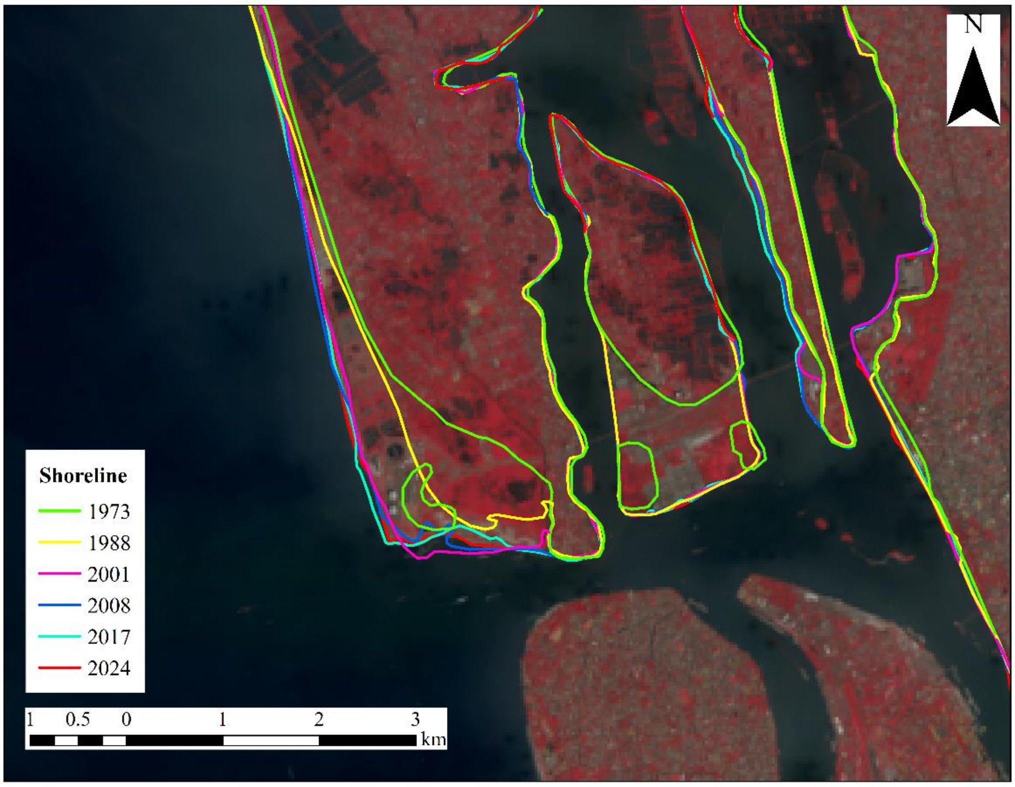
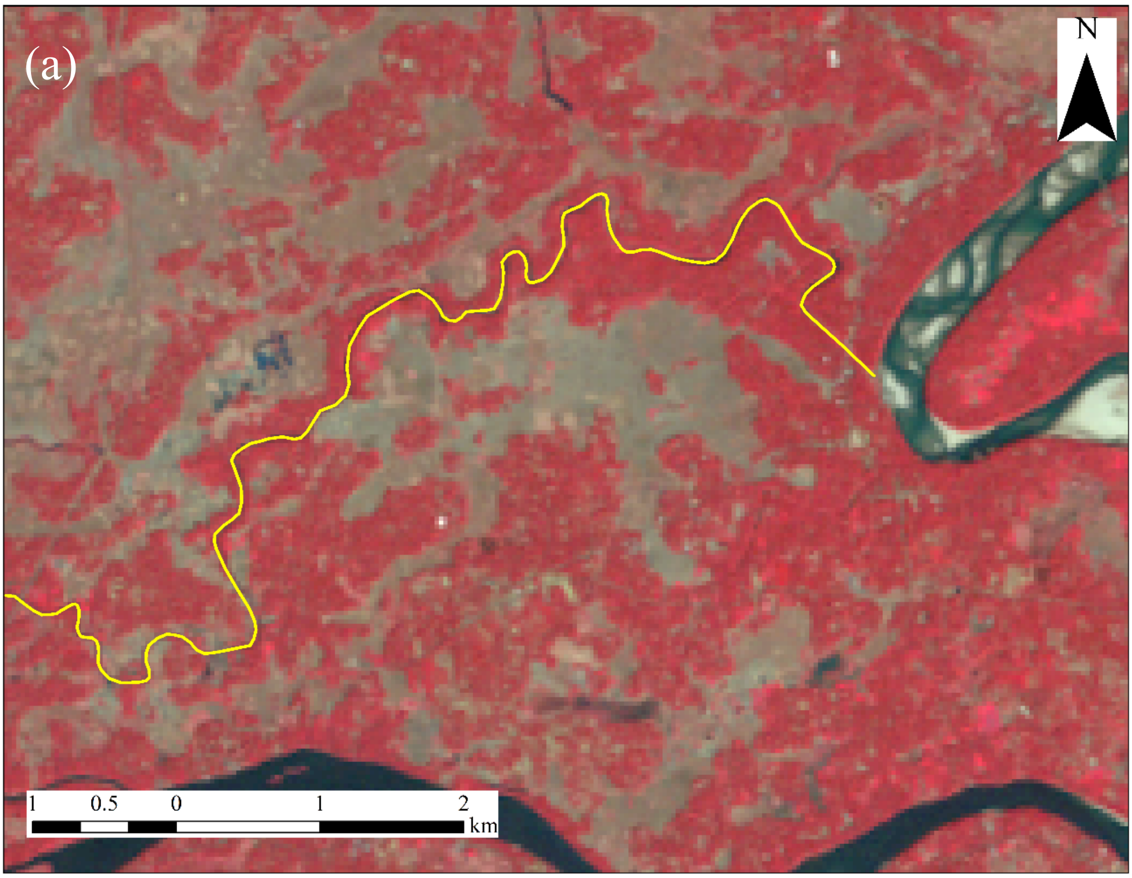


Figure 9: Shoreline line change at Vypin in the period 1973-2024

4.4 Temporal changes in the lower floodplains of the Periyar River Basin

Comparison of the satellite images of 1988 and 2024 revealed that the Chengal Thodu, a creek that served as a distributary from the Periyar River, has been blocked post-construction of the Cochin International Airport. Figure 10 shows the satellite images of Aluva before and after the construction of the Cochin International Airport. The runway of the airport, which was built on the lower floodplains of the river basin by reclaiming paddy fields, obstructs the natural flow of the Chengal Thodu. It is reported that the realignment carried out to facilitate the construction of the runway narrowed the creek. Prior to the construction of the Idukki Reservoir, approximately one-fourth of the water in the Periyar River flowed through the Chengal Thodu. Now, it is a degraded waterway with stagnant water during the normal season.



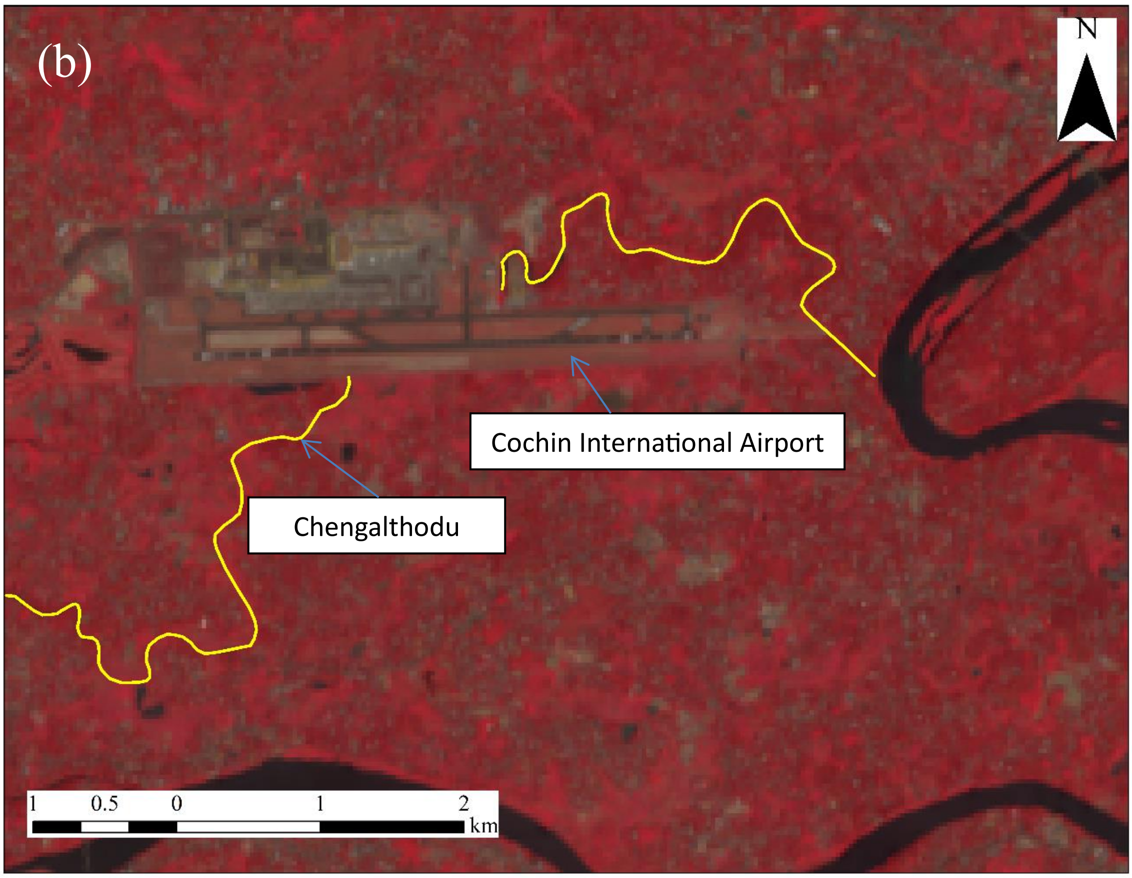


Figure 10: Satellite images of Aluva before and after construction of the Cochin International Airport (a) Landsat-5 TM (1988) (b) Landsat-9 OLI-2/TIRS-2 (2024)

5.0 Hazard Zonation Mapping of the Periyar River Basin

5.1 Landslide susceptibility

The landslide susceptibility map (LSM) prepared by the National Landslide Susceptibility Mapping (NLSM) Program of the Geological Survey of India (GSI) is a very useful tool for identifying landslide-prone regions. High, moderate, and low susceptibility zones have been demarcated based on various geospatial factors such as slope, geology, land use, and rainfall. In the Periyar River Basin, 13.21% of the area falls in the high susceptibility zone, 33.24% of the area in the moderate susceptibility zone and the remaining 53.55% area in the low susceptibility zone. The high and moderate susceptibility zones lie in the Taluks of Peerumedu, Udumbanchola, Idukki, Devikulam, Kothamangalam, and Aluva (eastern parts). These zones represent areas with a significantly high risk of occurrence of landslides and should be prioritized when planning drone surveys for detailed assessments.

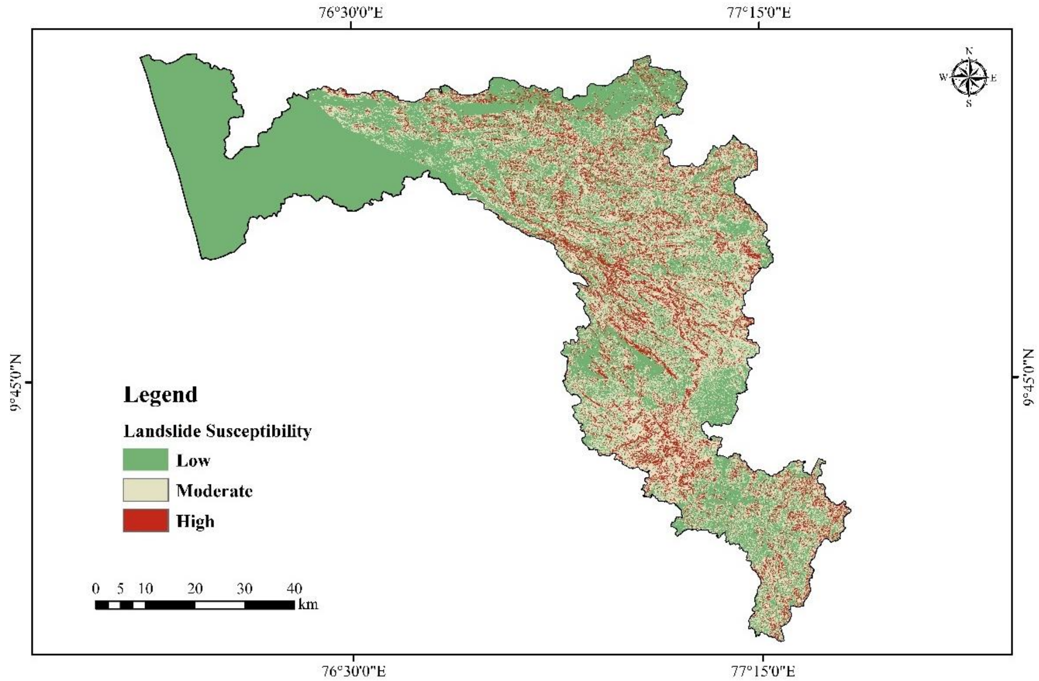


Figure 11: Landslide susceptibility map of the Periyar River Basin

5.2 Susceptibility to soil piping

Soil piping, also known as tunnel erosion, is an erosional process in which subsurface water flow gradually removes soil material, leading to the formation of underground tunnels or pipes. These tunnels/ pipes weaken the soil structure, causing the surface layer to collapse, leading to land subsidence and creation of sinkholes or gullies. This phenomenon is particularly hazardous in areas with specific soil types, such as loose, non-cohesive soils, and is often exacerbated by factors like high rainfall, deforestation, and improper land use. Bhagyalekshmi et al. (2015) reported that the factors contributing to soil piping include rainfall intensity exceeding 5 cm/h, a high concentration of sodium and low concentrations of calcium and magnesium in the soil, sandy texture at shallow depths, and vicinity to lineaments in regions of tectonic stress development and deforestation. The report by NCESS (2020) on soil piping highlights the vulnerability of several areas in the Western Ghats, particularly in the Periyar River Basin and within the Idukki District, to landslides. The study demarcates affected zones covering significant portions of Idukki, including parts of Devikulam and Udumbanchola Taluks, both of which are critical regions in the Periyar River Basin (https://sdma.kerala.gov.in/). The location of places in the Periyar River basin where soil piping has been reported are presented in Fig. 12. This signals underlying vulnerabilities in these regions, which are often characterized by steep slopes and high rainfall. Soil piping events can lead to severe land degradation and contribute to landslides, making these areas prone to further environmental hazards. Proper monitoring and preventive measures, such as controlled land use and good drainage systems, are critical to mitigate the risks associated with soil piping in the vulnerable zones.

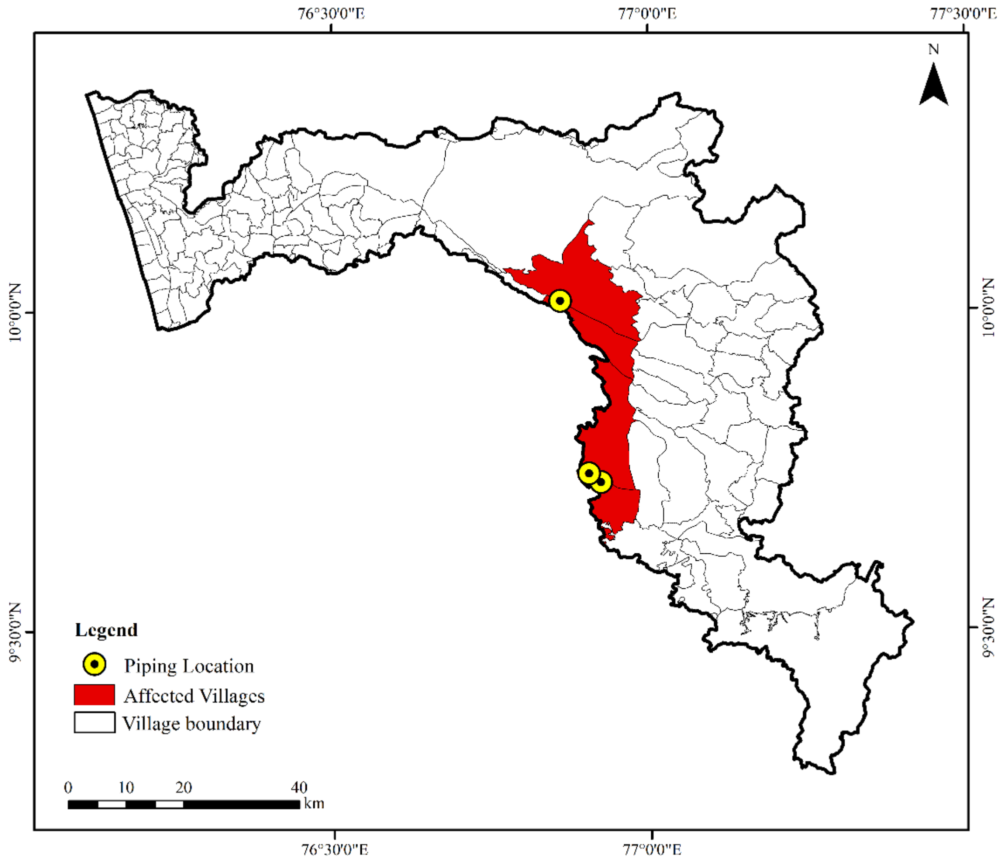


Figure 12: Soil piping locations in the Periyar River Basin

5.3 Susceptibility to floods

A map of areas prone to flood hazards in the Periyar River Basin was prepared using the information available on the website of the Kerala State Disaster Management Authority (https://sdma.kerala.gov.in/hazard-maps/). Areas within the river basin prone to different levels/ severity of flooding are depicted in Figure 13. The analysis was for a 10-year return period flood. A detailed sub-district-wise map showing the spatial distribution of flood prone areas (Figure 14) was also prepared from the data published on the KSDMA website (KSDMA, 2022). It is observed that Mukundapuram, Chalakudy, Aluva and Paravur sub-districts are susceptible to flooding.

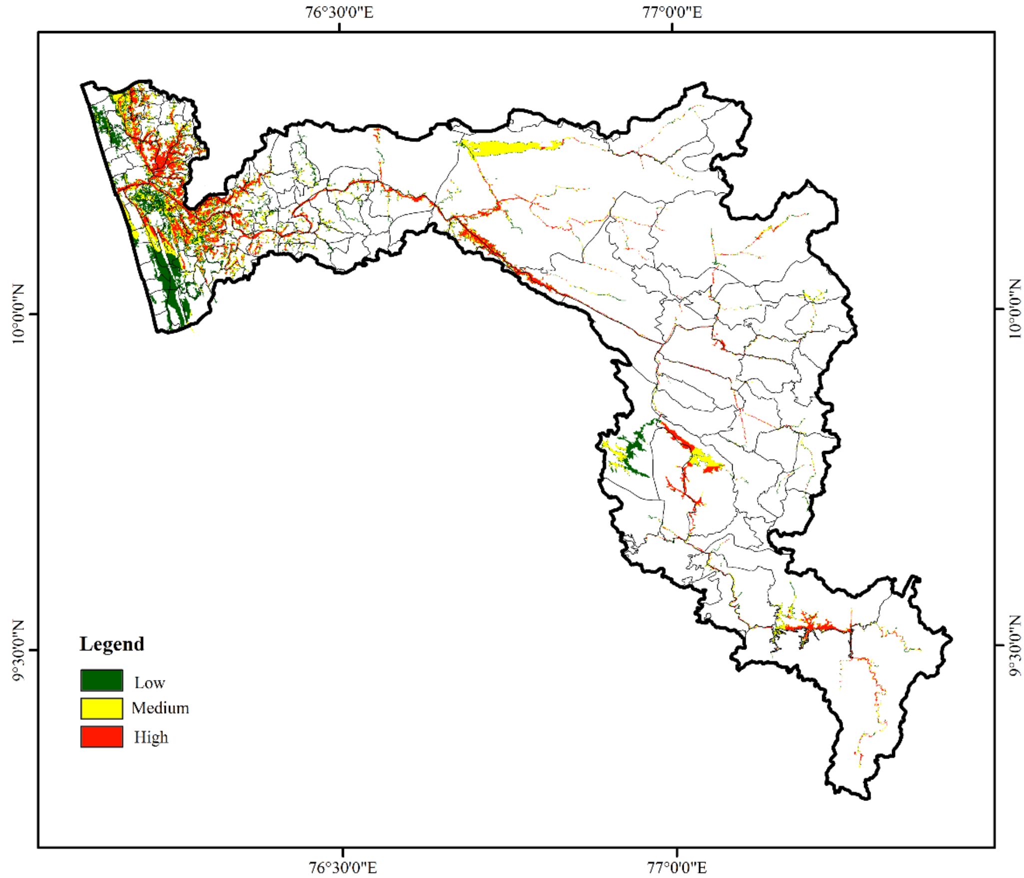


Figure 13: Flood hazard map of the Periyar River Basin (Source: KSDMA, 2022)

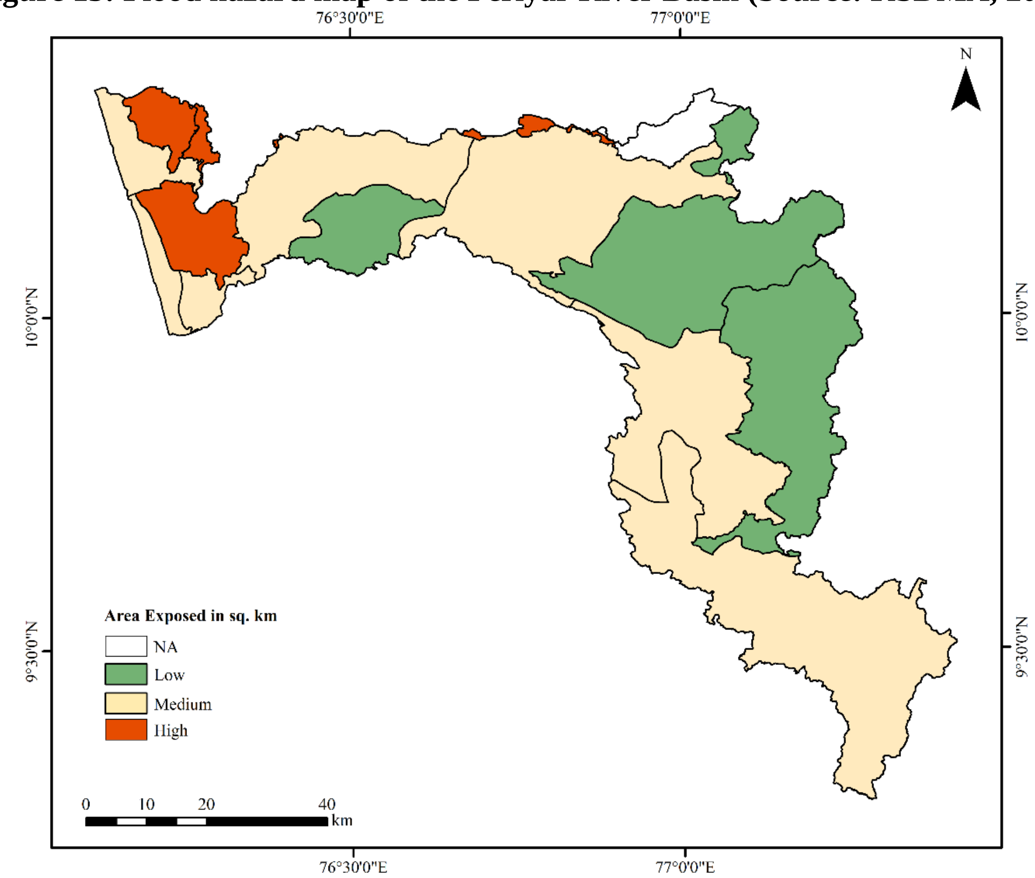


Figure 14: Flood prone sub-districts in the Periyar River Basin (Source: KSDMA, 2022)

5.4 Historically hazard-prone areas

A report on the Natural Hazard Zonation Map of Kerala, published by the Kerala State Disaster Management Authority (KSDMA) in 2014 (https://sdma.kerala.gov.in/hazard-maps/), provides an in-depth analysis of the vulnerability of the State to a variety of natural hazards including coastal erosion, landslides, and floods. In the Periyar River Basin, the report underscores the susceptibility of the areas along the coast, including densely populated urban regions within the Kochi Corporation, to coastal erosion.

In August 2018, Kerala experienced unprecedented rainfall that led to the worst flooding since 1924. The State received an abnormally high rainfall from 1st June 2018 to 19th August 2018, resulting in severe flooding in 13 out of the 14 Districts. According to the IMD, the rainfall of Kerala from 1st June 2018 to 19th August 2018 was about 2346.6 mm, as against the normal, which was about 1649.5 mm (about 42% above the normal). Overall, the rainfall during 15-17 August 2018 was comparable to that of 16-18 July 1924. The State encountered tremendous economic losses due to the extreme flood event, reducing its GDP growth by 1% (Tripathi, et al. (2020)). In addition to the tragic loss of human and animal lives, the floods severely damaged buildings, roads, and essential infrastructure, including water and sanitation systems, underscoring the magnitude of the disaster (Tripathi, 2020). Understanding the human and natural factors contributing to extreme flood events is vital for future disaster preparedness. During the 2018 flood event, about 26.14% of the geographical area of Aluva Taluk, one of the most affected regions in Kerala, experienced severe inundation, resulting in extensive damage to infrastructure, agricultural land, and residential areas, displacement of thousands of people and significant economic losses. Several other areas within the river basin also experienced severe flooding in 2018, of a magnitude comparable or even graver than that experienced during the previously reported severe flood of 1924.

6.0 Nature of Aerial Surveys and Datasets Required

From the preliminary analysis, it is understood that anthropogenic activities combined with extreme events are the root cause of the various calamities occurring in the Periyar River Basin over the years. Therefore, it is necessary to carry out a detailed analysis of the changes in the overall landscape of the river basin, including land use/ land cover, and the influence of hydraulic structures on the hydrology of the river basin. A proper Digital Terrain Model

(DTM) of the river basin is essential to prepare hazard/ risk maps for floods, landslides and other disasters to which the river basin, in general, is vulnerable.

6.1 Landscape change analysis

Temporal change in the basin landscape can be analyzed using aerial photographs and satellite imageries. At present, the availability of this data for the river basin is very limited. Under this circumstance, moderate and high-resolution satellite datasets may be utilized to map the changes that have occurred over the past 50 years in the overall landscape. However, to understand the influence of the hydraulic structures on riverine hydrology and landscape, it is necessary to use aerial photographs or CORONA satellite data acquired before the construction of these structures.

6.2 Development of Digital Terrain Models (DTMs)

Satellite-based DEMs are primarily Digital Surface Models (DSMs). Large deviations are observed between the actual ground elevations and the corresponding elevations obtained from DSMs for densely vegetated regions. Therefore, it is recommended to use DTMs for those analyses in which terrain elevations are crucial. LiDAR-based drone surveys are currently employed to produce high-resolution DTMs, which are essential for micro-level analysis and preparation of landslide susceptibility maps and flood inundation maps.

6.3 Prioritization for aerial surveys

Aerial surveys shall be conducted in critical locations susceptible to landslides and other geotechnical/ geological hazards and regions prone to frequent flooding. LiDAR-based drone surveys are to be conducted in the upper reaches of the basin, where landslide susceptibility is high (Figure 10). It will enable us to identify the exact nature of the slope and will provide crucial input for mesoscale landslide susceptibility zonation. Similarly, the lower reaches of the Periyar River Basin are subjected to frequent floods (Figure 13). It is recommended that LiDAR-based drone surveys may be conducted in this part of the River Basin as well.

6.4 Constraints for conducting aerial surveys

Most parts in the lower reaches of the Periyar River Basin are designated as red zones and yellow zones by DGCA due to the strategic location of Cochin International Airport in the Aluva Taluk. Apart from this, large areas lying within the limits of the Kochi Municipal Corporation and the neighbouring Municipalities and Grama Panchayats also fall under the red zone due to the presence of industries and the Cochin Harbor (Figure 1). Flying drones for data acquisition in these regions is prohibited. Moreover, the data acquisition costs using LiDAR surveys are very high.

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