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Comprehensive Flood Risk and Inundation Mapping in the Thamirabarani River Basin Through GIS-AHP and Remote Sensing Techniques

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Abstract:- Flooding poses significant risks to communities and infrastructure in vulnerable regions, requiring robust assessment methods for effective mitigation. This study aims to assess flood risk in the Thamirabarani River Basin using a GIS-based Analytical Hierarchy Process (AHP) model, combined with remote sensing techniques. The model incorporates factors such as population density, proximity to rivers, slope, land use, and precipitation patterns to evaluate flood vulnerability and hazard. Sentinel-1 imagery from the European Space Agency's Copernicus Portal was used for flood inundation analysis, detecting changes in land cover due to flooding on December 18, 2023. The findings reveal that 94 villages in Tirunelveli, Tenkasi, and Thoothukudi districts are high-risk zones, with areas near rivers and densely populated regions showing the greatest vulnerability. The combination of AHP modeling and remote sensing offers a detailed assessment of flood risk, aiding policymakers in developing targeted strategies for flood mitigation and preparedness. This research highlights the importance of integrated approaches for managing flood risks in susceptible regions.

***Keywords**:- Flood Risk, GIS, AHP, Remote Sensing, Flood Inundation Analysis.*

I. INTRODUCTION

Flooding represents one of the most frequent and destructive natural disasters globally, with profound impacts on ecosystems, economies, and human livelihoods. The increasing incidence and severity of flooding events, driven by climate change, land-use changes, and urbanization, emphasize the urgent need for effective flood risk management strategies. Comprehensive understanding of flood hazards, vulnerability, and risk is vital for developing targeted mitigation and preparedness initiatives, especially in flood-prone areas [1][2].

Recent advancements in geospatial technologies have significantly enhanced flood risk assessment methodologies. The integration of Geographic Information Systems (GIS) with multi-criteria decision-making (MCDM) approaches, such as the Analytical Hierarchy Process (AHP), has emerged as a robust framework for evaluating flood risk. These techniques facilitate the incorporation of diverse datasets and stakeholder perspectives, enabling researchers to identify high-risk zones effectively [3][4]. For instance, studies have demonstrated the utility of GIS-AHP in various regional contexts, revealing its potential for improving flood risk management practices [5][6].

However, there remains ongoing debate regarding the optimal methodologies for flood risk assessment, with differing opinions on the importance of incorporating socio-economic factors alongside environmental variables. Some scholars advocate for a holistic approach that considers both physical and socio-economic dimensions, while others emphasize the need for precise hydrological modeling to inform flood risk assessments [7][8]. This divergence highlights the complexity of the field and the necessity for further investigation into frameworks that effectively balance technical accuracy with contextual relevance.

This study aims to assess flood risk in the Thamirabarani River Basin by employing a GIS-based AHP model. The research incorporates critical factors such as population density, proximity to water bodies, land use, slope characteristics, and precipitation patterns to generate a comprehensive flood risk map. The findings reveal that 94 villages within the Tirunelveli, Tenkasi, and Thoothukudi districts face elevated flood risks due to their geographical and socio-economic conditions. These insights are intended to inform policymakers and stakeholders, facilitating the implementation of effective flood mitigation strategies in the region.

II. STUDY AREA

The Thamirabarani River originates in the Western Ghats of Tamil Nadu, at an elevation of 1,725 meters (5,659 feet) above sea level, specifically from the peak of Agasthyakoodam Hill. Flowing through the Tirunelveli and Tuticorin districts, the river eventually meets the Bay of Bengal. As it descends from the mountains near Papanasam, it creates notable waterfalls, including Kalyanatheertham and Agasthiar Falls. The river's perennial flow is sustained by the abundant rainfall received in the Western Ghats during both monsoon seasons, ensuring that the river and its tributaries remain consistently active throughout the year.

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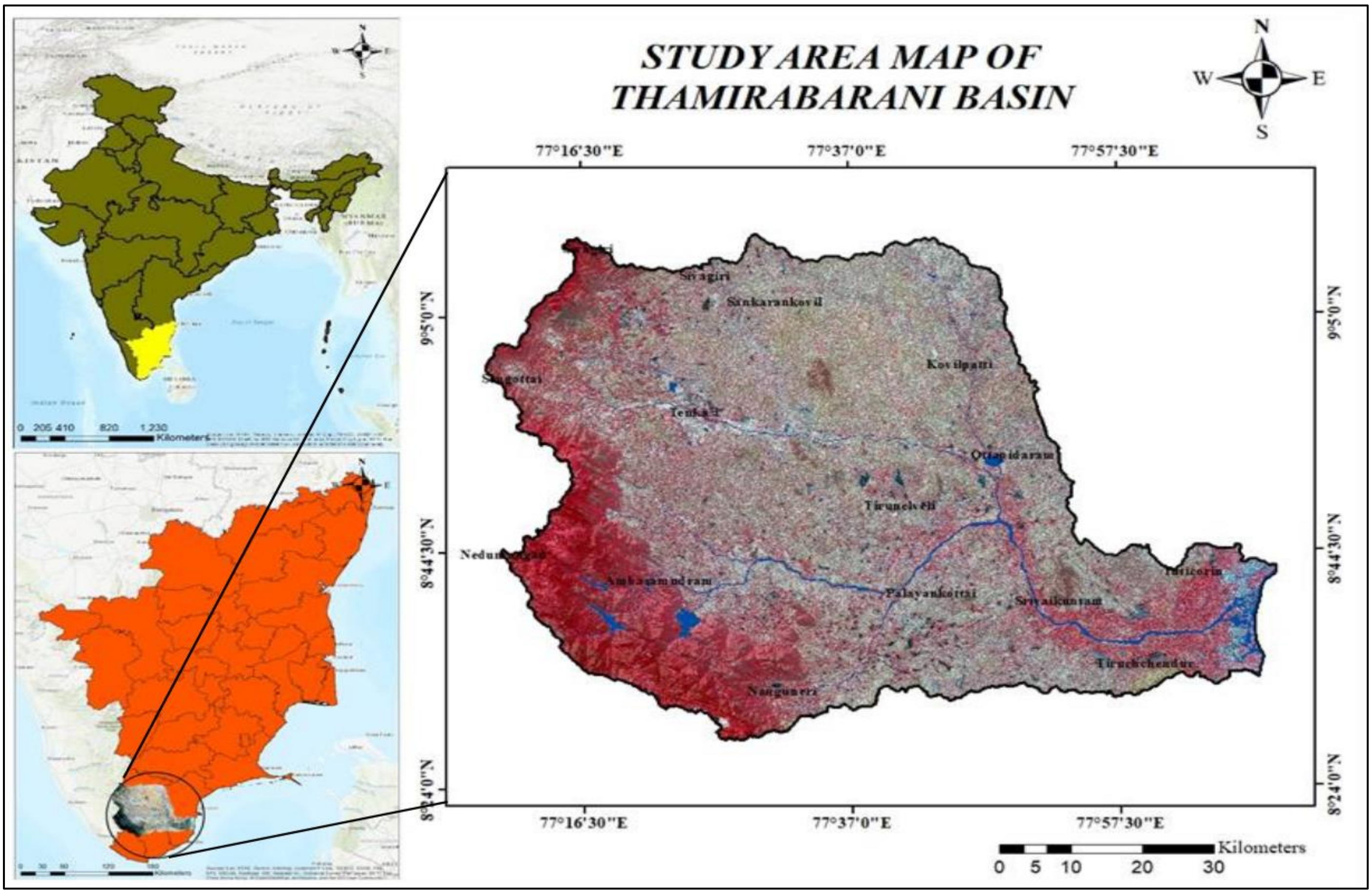

Fig 1 Study Area Map

A significant portion of the study area encompasses the rugged western hilly terrain, which exhibits greater geological complexity compared to the Eastern Ghats. In contrast, the central part of the basin features the Pedi Plain, characterized by agricultural lands and numerous villages. The local population is intricately linked to the river, relying on it for various livelihoods. Moreover, industrial development has occurred in several urbanized areas along the river, further highlighting the Thamirabarani's importance as one of the major rivers in South India. The river's dual role as a monsoon-fed and perennial watercourse is critical to the socio-economic activities in the region.

III. MATERIALS AND METHODS

➢ *Source of Data*

The study utilized open-source spatial data from Sentinel-2A, Sentinel-1 SAR, ASTER GDEM, TNAU Soil Data, and Census of India. These datasets provided crucial insights into land use, soil characteristics, elevation, slope, population, and household density, forming the basis for flood risk and vulnerability mapping in the Thamirabarani River Basin.

Table 1 Source of Data

S. No	Dataset Name	Dataset Provider
1	Sentinel-1 SAR Imagery	ESA(European Space Agency)
2	Sentinel -2A	ESA(European Space Agency)
3	Population Data	Census Handbook of India
4	Household Data	Census Handbook of India
5	DEM	ASTER GDEM
6	Rainfall Data	IMD Pune
7	Soil	TNAU Soil Data

➢ *GIS-Based Analytical Hierarchy Process (AHP)*

The Analytical Hierarchy Process (AHP) is a widely recognized decision-making tool, developed by Thomas L. Saaty in 1970, designed to handle complex multi-criteria decision problems by breaking them down into a hierarchical structure [9]. This method is particularly effective in various fields, including flood risk management, as it allows for the systematic evaluation of multiple factors that contribute to flood vulnerability and hazard levels.

The first step in the AHP process is to establish a hierarchy that decomposes the decision problem in this case, flood risk assessment into its essential components. For the Thamirabarani River Basin, the goal is to assess flood risk, and the hierarchy consists of relevant criteria and sub-criteria influencing this goal. The primary factors include population density, proximity to water bodies, land use, slope characteristics, and precipitation patterns. Each of these factors is further analyzed to determine its contribution to the overall flood risk.

After identifying the criteria, a pairwise comparison matrix (Pij) is created, where each criterion is compared against the others based on its relative importance toward the overall goal. The scale for comparison, as introduced by Saaty, ranges from 1 to 9, where 1 indicates equal importance, and 9 signifies extreme importance of one factor over another [10]. This comparison matrix quantifies the preferences between criteria, facilitating the determination of the weight for each factor in the decision-making process.

The pairwise comparison matrix is used to calculate scale weights (SW) for each criterion. The columns of the matrix are summed, and a normalized pairwise matrix is created by dividing each element by its respective column sum. Next, the row averages are computed to derive the Geometric Mean (GM) for each criterion. These values represent the relative weights of the criteria in the context of flood risk assessment.

It is essential to ensure the consistency of the pairwise comparisons to validate the AHP model's reliability. The consistency ratio (CR) is computed using the formula:

CR=CI/RI

Where **CI = λmax - n/n-1** is the principal eigenvalue of the matrix, and **RI** is the Random Consistency Index [11]. A CR value below 0.1 is considered acceptable, indicating that the judgments made in the pairwise comparisons are consistent.

Table 2 Pairwise Comparison Matrix (Flood Vulnerability)

Factors	Population Density	Household Density	Distance From River	LULC
Population Density	1	3	5	2
Household Density	1/3	1	4	1
Distance From River	1/5	1/4	1	1/3
LULC	1/2	1	3	1

Table 3 Normalized Pairwise Comparison Matrix (Flood Vulnerability)

Factors	Population Density	Household Density	Distance From River	LULC	Sum	Criteria Weights	Criteria weight (%)
Population Density	0.49	0.57	0.38	0.46	1.91	0.48	48
Household Density	0.16	0.19	0.31	0.23	0.89	0.22	22
Distance From River	0.10	0.05	0.08	0.08	0.30	0.07	7
LULC	0.25	0.19	0.23	0.23	0.90	0.22	22
Factors						1	100

Table 4 Consistency Ratio (Flood Vulnerability)

Factors	Population Density	Household Density	Distance From River	LULC	Weighted sum value	Criteria Weight	WSV/CW
Population Density	0.48	0.67	0.37	0.45	1.97	0.48	4.13
Household Density	0.16	0.22	0.30	0.22	0.91	0.22	4.06
Distance From River	0.10	0.06	0.07	0.07	0.30	0.07	4.02
LULC	0.24	0.22	0.22	0.22	0.91	0.22	4.06
Factors						L.max=	**4.07**

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Table 5 Pairwise Comparison Matrix (Flood Hazard)

Factors	CN Runoff	Distance From River	Slope	Pervious/ Impervious	Precipitation
CN Number	1	3	2	5	3
Distance From River	1/3	1	1/3	3	2
Slope	1/2	3	1	4	3
Pervious/Impervious	1/5	1/3	1/4	1	1/2
Precipitation	1/3	1/2	1/3	2	1

Table 6 Normalized Pairwise Comparison Matrix (Flood Hazard)

Factors	CN Runoff	Distance From River	Slope	Pervious/ Impervious	Precipitation	Sum	Criteria Weights	Criteria weight (%)
CN Number	0.42	0.38	0.51	0.33	0.32	1.97	0.39	39
Distance From River	0.14	0.13	0.09	0.20	0.21	0.76	0.15	15
Slope	0.21	0.38	0.26	0.27	0.32	1.43	0.29	29
Pervious/Impervious	0.08	0.04	0.06	0.07	0.05	0.31	0.06	6
Precipitation	0.14	0.06	0.09	0.13	0.11	0.53	0.11	11
							1	100

Table 7 Consistency Ratio (Flood Hazard)

Factors	CN Runoff	Distance From River	Slope	Pervious/ Impervious	Precipitation	Weighted sum value	Criteria Weight	WSV/CW
CN Number	0.39	0.46	0.57	0.31	0.32	2.05	0.39	5.22
Distance From River	0.13	0.15	0.10	0.19	0.21	0.78	0.15	5.08
Slope	0.20	0.46	0.29	0.25	0.32	1.51	0.29	5.26
Pervious/Impervious	0.08	0.05	0.07	0.06	0.05	0.32	0.06	5.09
Precipitation	0.13	0.08	0.10	0.12	0.11	0.53	0.11	5.04
							L.max	5.14

➢ *Flood Inundation Mapping and Flood Risk Evaluation*

The methodology for flood risk assessment in the Thamirabarani River Basin was designed based on multiple critical factors, drawing from established research and geospatial data [10][12]. The primary criteria were categorized into four major groups, each playing a pivotal role in influencing flood susceptibility. Key hydrological components such as precipitation patterns and proximity to water bodies were extracted from remote sensing data, primarily utilizing Sentinel-2A imagery. This provided insights into surface water distribution and potential areas vulnerable to runoff. Soil data, including soil type and hydrological soil group, were derived from TNAU Soil Data and incorporated using the Curve Number (CN) method to assess infiltration rates and water retention capacities. The soil group classification helped evaluate the permeability and drainage capacity of different land types. Elevation and slope data were obtained from ASTER GDEM to account for terrain variations that influence water flow and accumulation. Morphometric parameters, such as distance from rivers and slope characteristics, were considered essential for assessing the movement of floodwaters across the landscape. Land use and land cover (LULC) were identified from Sentinel-2A, capturing the impacts of human activities such as settlement expansion and deforestation. Population density data from the Census of India were also integrated to examine the risk to populated areas. Sentinel-1 SAR imagery was employed to process refined flood pixels, which contributed to the flood inundation mapping.

Each dataset was pre-processed and standardized, ensuring a consistent spatial resolution for raster data analysis. Using the Analytical Hierarchy Process (AHP), a pairwise comparison of these criteria was conducted to derive the relative importance of each factor. Expert input from hydrology, soil science, and disaster management professionals informed this comparison, which resulted in a weighted matrix of criteria.

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A consistency ratio (CR) check was performed to ensure the reliability of the pairwise comparisons. The AHP-derived weights were applied within a GIS environment (ArcGIS 10.8), where spatial analysis tools were used to generate flood vulnerability and hazard maps. The final flood risk map was produced by combining these layers, highlighting areas at varying levels of susceptibility ranging from low to high.

This multi-criteria analysis approach, as outlined in the methodology flowchart, provided a robust framework for identifying flood-prone zones in the Thamirabarani River Basin.

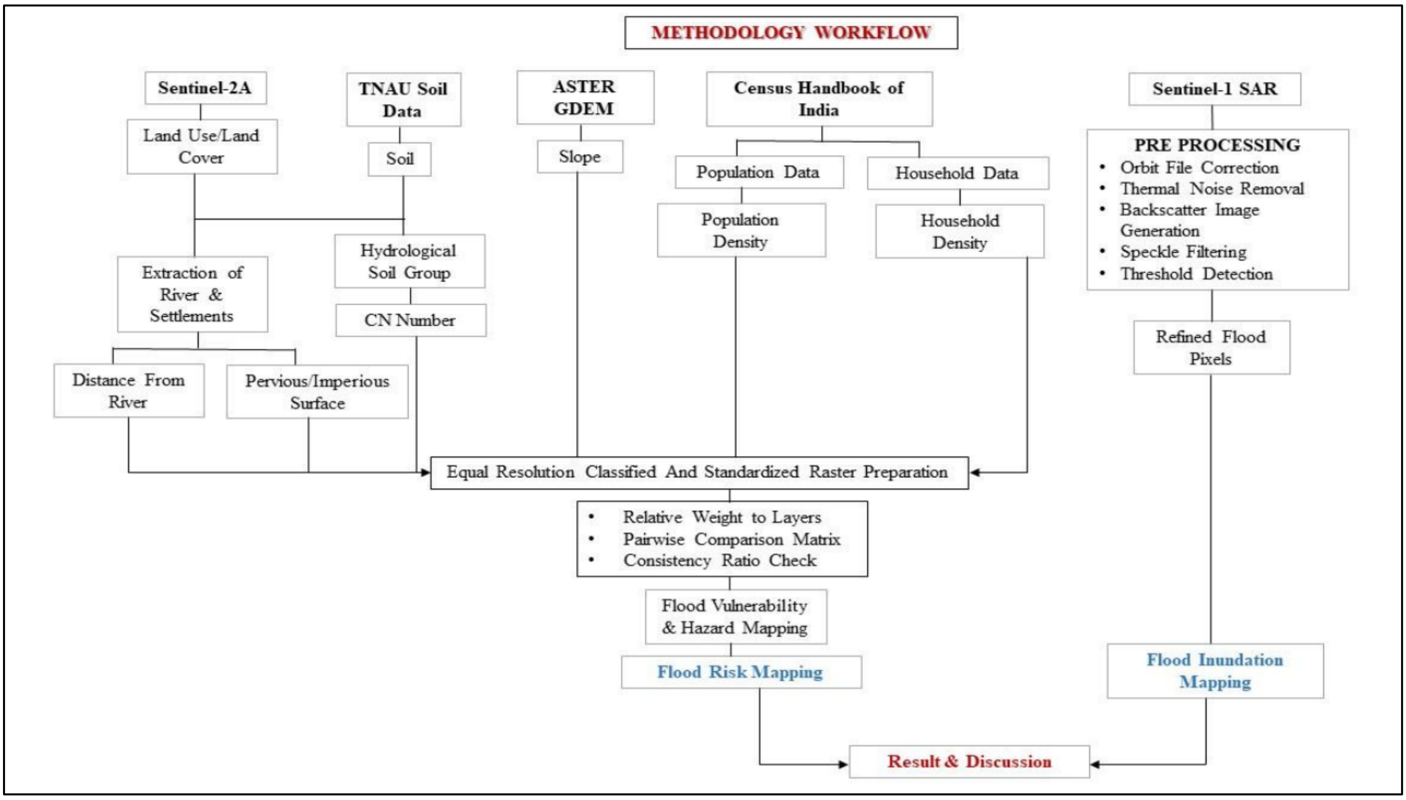

Fig 2 Methodology Flowchart

IV. RESULTS

➢ *Flood Vulnerability Assessment*

The flood vulnerability assessment identifies the susceptibility of regions to the adverse impacts of flooding, factoring in variables such as population density, proximity to water bodies, land use, and socio-economic indicators. This study employed a Geographic Information System (GIS)-based Analytical Hierarchy Process (AHP) technique, as proposed by Saaty (1970), to conduct a multi-parameter analysis of flood vulnerability within the Thamirabarani River Basin. The AHP methodology, detailed in Section 3.2, utilized a preference scale ranging from 1 to 5 in a pairwise comparison matrix to ascertain the relative importance of various criteria influencing flood vulnerability.

- *Population Density*

Population density emerged as a critical indicator in assessing flood vulnerability. Data obtained from the 2011 Census of India were utilized to derive population statistics for the Thamirabarani River Basin. Employing the point density tool within ArcGIS version 10.8.1, a detailed population density map was generated, illustrating areas of high inhabitance that may experience greater flood risks.

- *Household Density*

The analysis also included the generation of a household density map, which depicted the spatial distribution of households across the Thamirabarani River Basin. This map highlighted regions with elevated household densities, signaling areas that may be more vulnerable to flooding. The insights gleaned from this information are invaluable for flood risk assessment and planning mitigation strategies.

- *River Proximity Analysis*

The river networks within the Thamirabarani River Basin were mapped using vector layers representing river polygons. Buffer zones were established at specified distance thresholds (less than 100 m, 100-200 m, 200-300 m, 300-400 m, and 400-500 m) from the riverbanks. This buffer analysis enabled the identification of areas at varying proximities to the river, enhancing our understanding of the dynamics of flood vulnerability.

- *Land Use and Land Cover (LULC)*

A Land Use and Land Cover (LULC) map was developed based on Landsat 9 imagery from April 2023. This map categorized various features in the study area, including agricultural land, forests, water bodies, and urban settlements. The analysis revealed that land cover comprises

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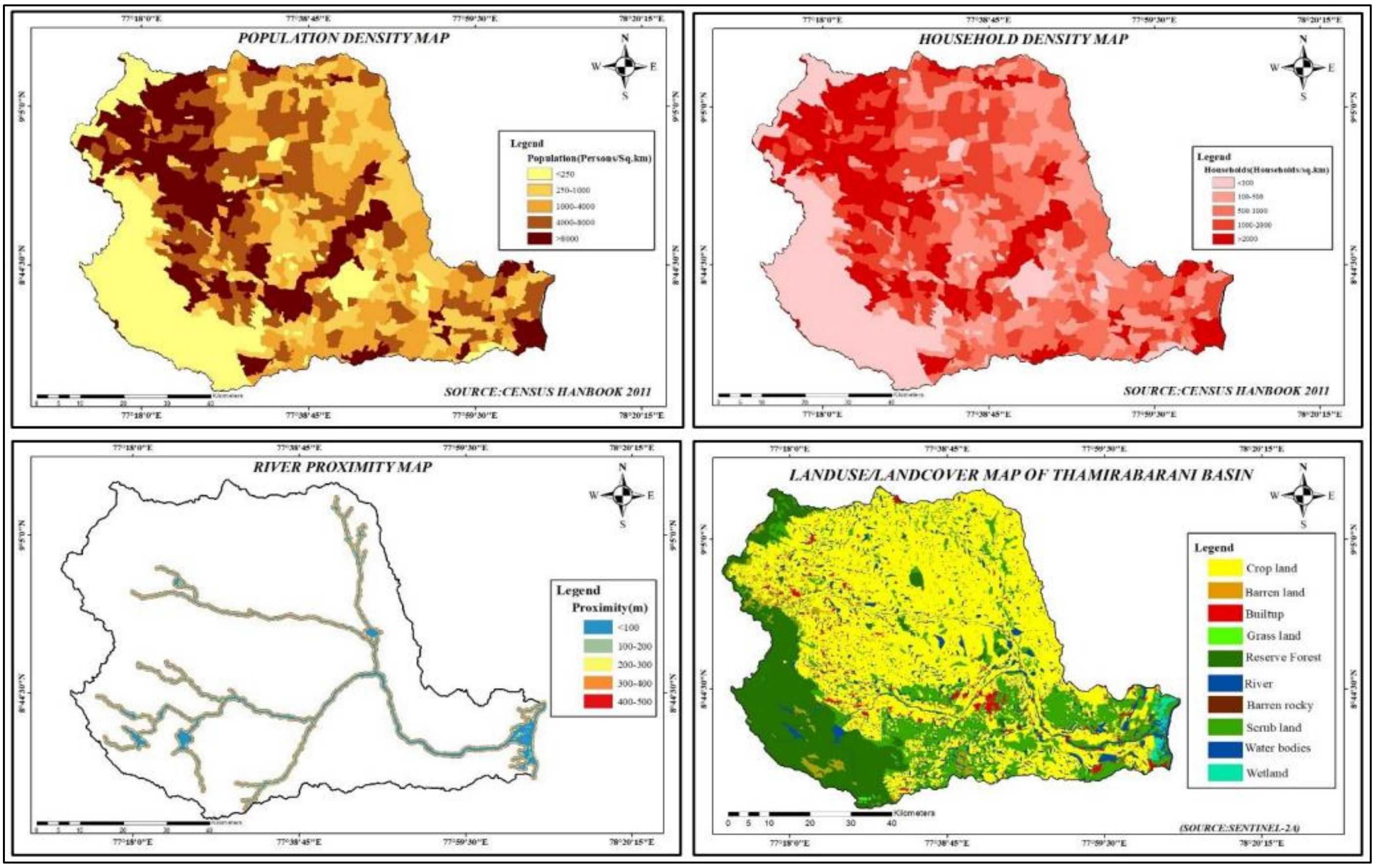
approximately 57% of the region, with 15% designated for agriculture and 15% for scrub and bush vegetation. Dense forests are primarily located in the southern part of the basin. Water bodies, essential for sustaining local populations, accounted for 3.2% of the land, with human settlements frequently located near these resources. Notably, urban development has significantly transformed several villages.



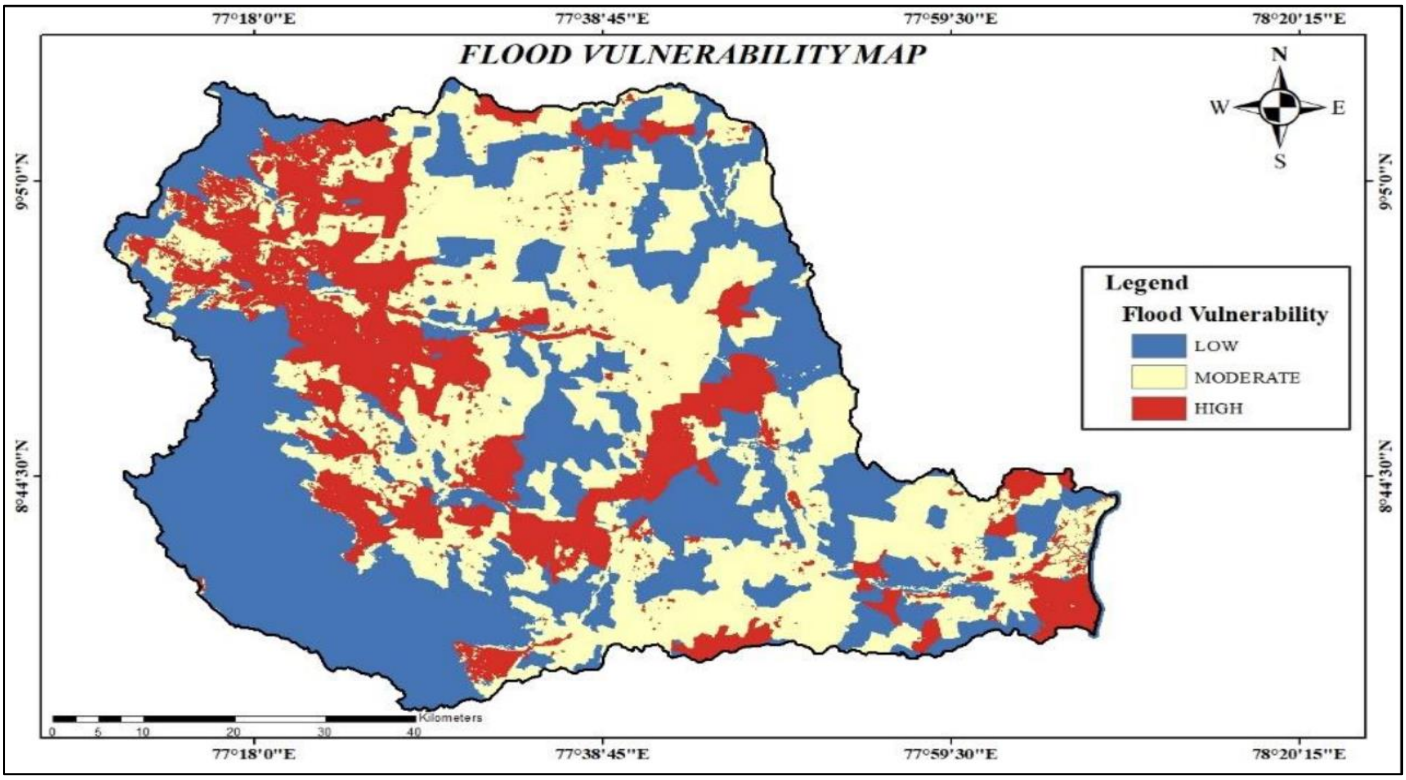


Fig 3 Flood Vulnerability Map

Specific villages, including Srivaikuntam, Kayalpattinam, Sankarankoil, Kadayanallur, Kulasekarapatti, Alangulam, Tirunelveli, Ambasamudram, Cheranmahadevi, and Manimuthar, exhibit heightened socio-economic vulnerability to flooding. This increased susceptibility is attributed to their high population density and proximity to water bodies, particularly rivers. These conditions amplify the potential for adverse effects from flooding events.

The GIS-based assessment integrated key parameters to evaluate flood vulnerability, emphasizing socio-economic factors. Population density served as a primary indicator, revealing areas with concentrated populations that are at greater risk during flooding. Household density also significantly impacted residential areas and critical infrastructure. Additionally, proximity to water bodies emerged as a vital factor, with villages closer to rivers experiencing higher exposure to flood hazards. The LULC data illuminated areas prone to inundation and highlighted regions crucial for effective flood management strategies.

By synthesizing these parameters within a GIS framework, the study achieved a comprehensive assessment of flood vulnerability, facilitating informed decision-making and the implementation of targeted mitigation measures to alleviate the socio-economic impacts of flooding in at-risk communities.

- *Flood Hazard Assessment*

Flood hazard assessment involves evaluating the probability of a flood event occurring within a specific area, factoring in elements such as the Curve Number (CN), proximity to rivers, slope gradients, land cover types (pervious/impervious), and precipitation patterns. By analyzing these variables, the assessment identifies regions more likely to experience flooding, aiding in the development of flood risk mitigation strategies. The Consistency Ratio of 0.0489, below the threshold of 0.1, indicates the pairwise comparison matrix successfully passed the consistency test.

- *Curve Number (CN) Map*

For this assessment, land use, soil type, and hydrological data for the Thamirabarani River Basin were gathered from reliable sources. Using GIS software, average CN values were computed for various combinations of land use and soil types based on established methodologies. The resulting CN map revealed spatial variations in runoff potential, with areas exhibiting higher CN values indicating a greater likelihood of flooding. The CN map serves as an essential tool for identifying high-risk flood zones and informs future flood management efforts.

- *River Proximity Map*

The river network within the Thamirabarani River Basin was mapped using GIS with vector layers representing river polygons. Buffer zones at intervals (less than 100 m, 100-200 m, 200-300 m, 300-400 m, and 400-500 m) from riverbanks were created to analyze flood hazard risks at varying distances from the river. Areas within closer proximity to rivers were identified as having higher flood hazard potential due to their vulnerability to overflow and inundation during periods of heavy rainfall.

- *Pervious/Impervious Surface Map*

Satellite imagery from Sentinel-2 was processed to generate a high-resolution land cover map for the Thamirabarani River Basin, classifying the terrain into pervious and impervious surfaces. Remote sensing techniques were employed to distinguish areas with impervious surfaces, which inhibit water infiltration and exacerbate surface runoff. The GIS-generated pervious/impervious surface map provided a clear visualization of these areas, identifying urbanized regions with extensive impervious surfaces that are more prone to increased flood risks due to inadequate water absorption.

- *Slope Map*

Using Digital Elevation Models (DEMs) of the Thamirabarani Basin, slope gradients were calculated to assess the impact of terrain on flood hazard potential. GIS software was utilized to generate a slope map, categorizing the terrain into various slope ranges. Areas with steeper slopes were identified as having higher runoff potential, increasing the likelihood of rapid water movement and flooding. Conversely, flatter areas exhibited lower runoff potential but were prone to water accumulation, particularly in low-lying regions.

- *Precipitation Map*

Precipitation data for 2023 were acquired from the India Meteorological Department (IMD), covering the entire Thamirabarani River Basin. The precipitation map illustrated variations in rainfall intensity and distribution across the basin. Areas with higher rainfall accumulation were identified as flood-prone due to the greater volume of water contributing to potential flood events. The spatial analysis of this map highlighted regions with elevated precipitation levels that correlate with higher flood hazard potential.

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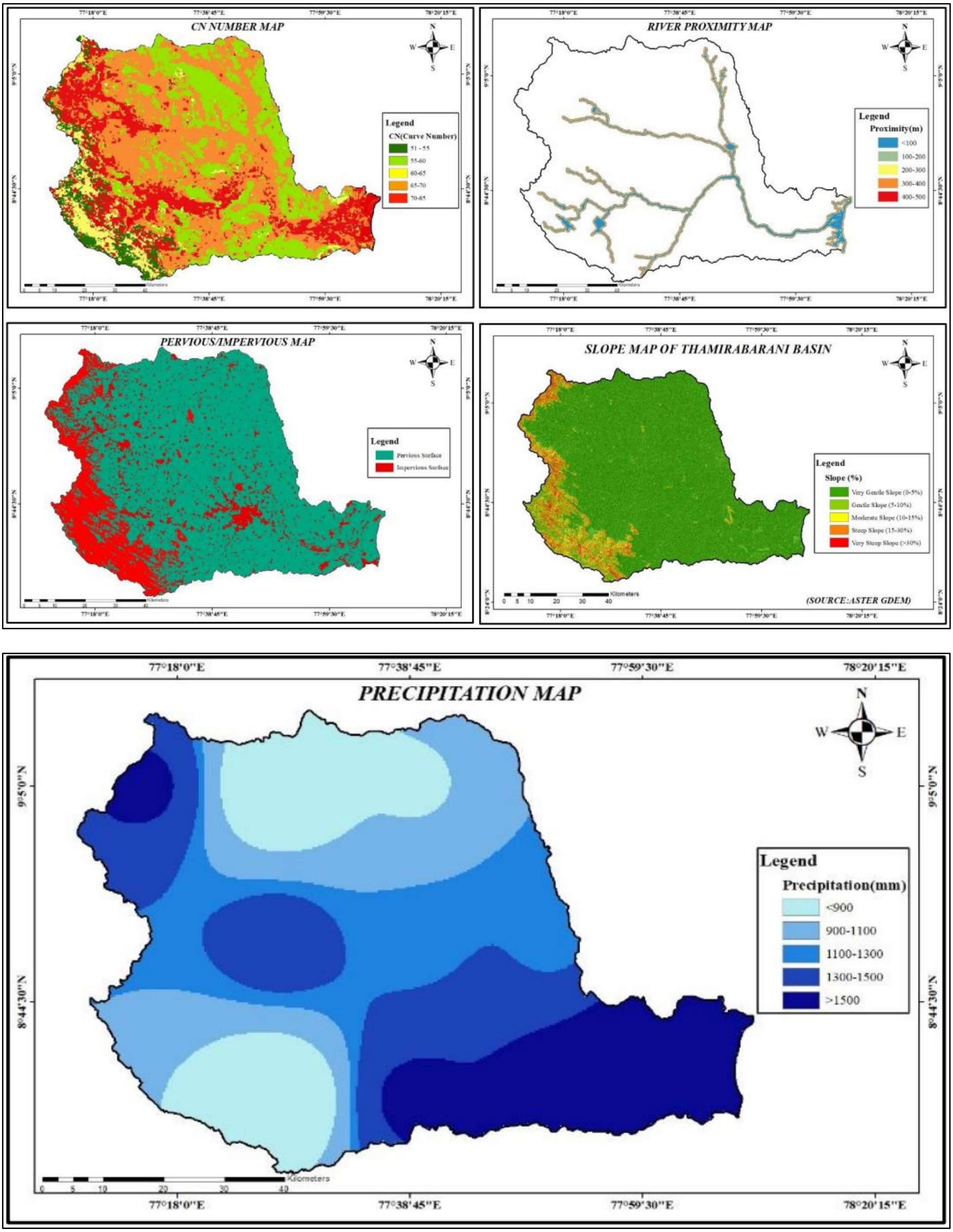

Fig 4(a) Curve Number (CN) Map (b) River Proximity Map (c) Pervious/Impervious Surface Map
(d) Slope Map (e) Precipitation Map

The proximity to rivers emerged as a significant contributor to flood hazard levels, especially in adjacent areas where heavy rainfall or river overflow increases inundation risks. These riverine zones are particularly vulnerable, affecting nearby communities and infrastructure. Additionally, urbanized areas with a high percentage of impervious surfaces were identified as more susceptible to flooding. The lack of water absorption in these areas leads to increased surface runoff, which heightens the risk of property damage, service disruptions, and threats to public safety during flood events.

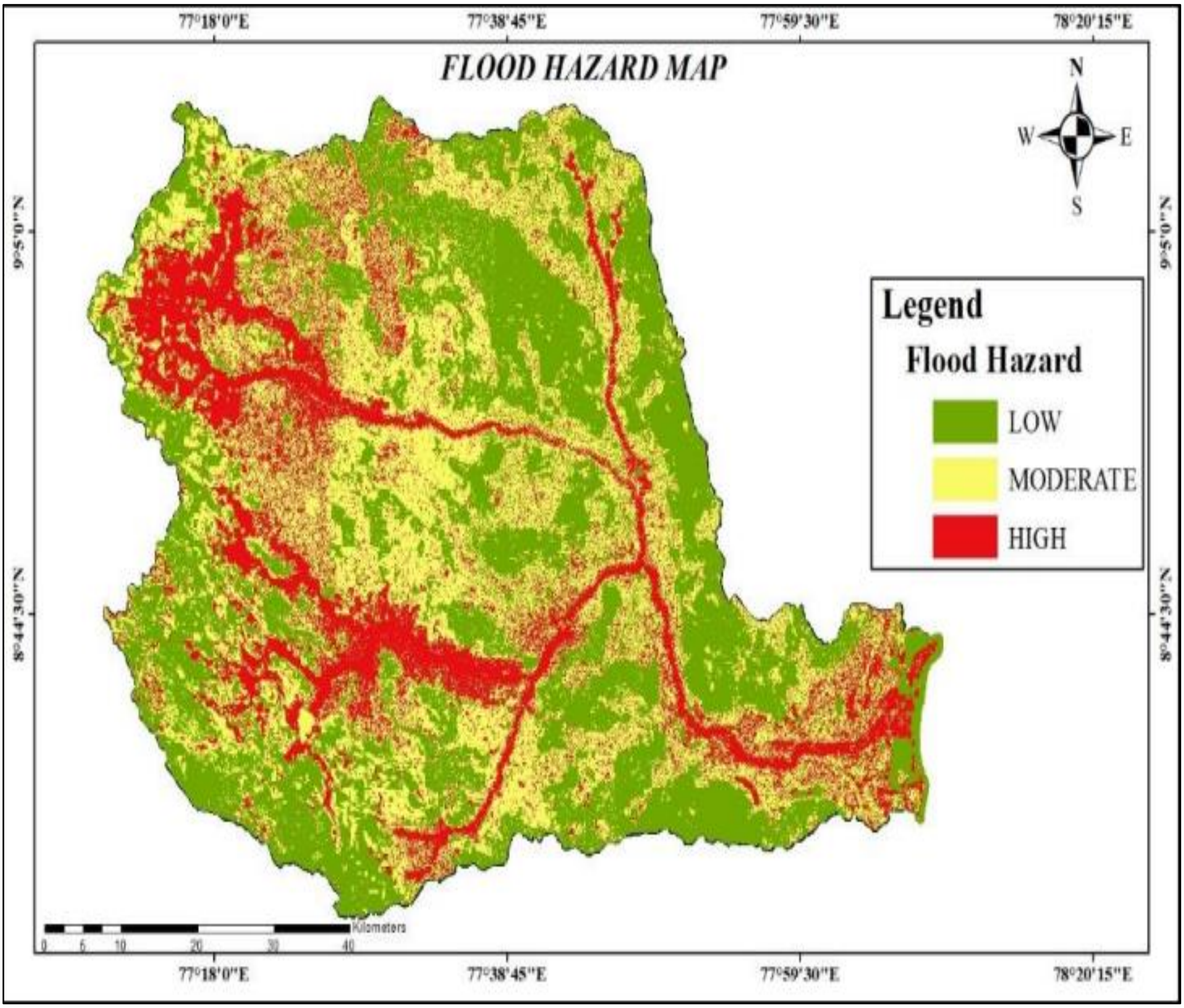

Fig 5 Flood Hazard Map

The results indicate that built-up areas, particularly those near rivers or with extensive impervious surfaces, face the greatest flood hazards. The integration of these findings into flood risk management strategies underscores the need for robust urban planning, including effective stormwater management systems, resilient infrastructure development, and adherence to floodplain management regulations.

➢ *Flood Inundation Analysis*

This study utilized Sentinel-1 satellite imagery from the ESA Copernicus Portal to analyze flood inundation in the Thamirabarani Basin. Pre-processing of the satellite data improved image clarity and resolution, aiding in the accurate identification of land features and flood extents. The analysis focused on VV polarization backscattering, which enabled differentiation between various land cover types, such as water bodies, wetlands, and areas affected by flooding.

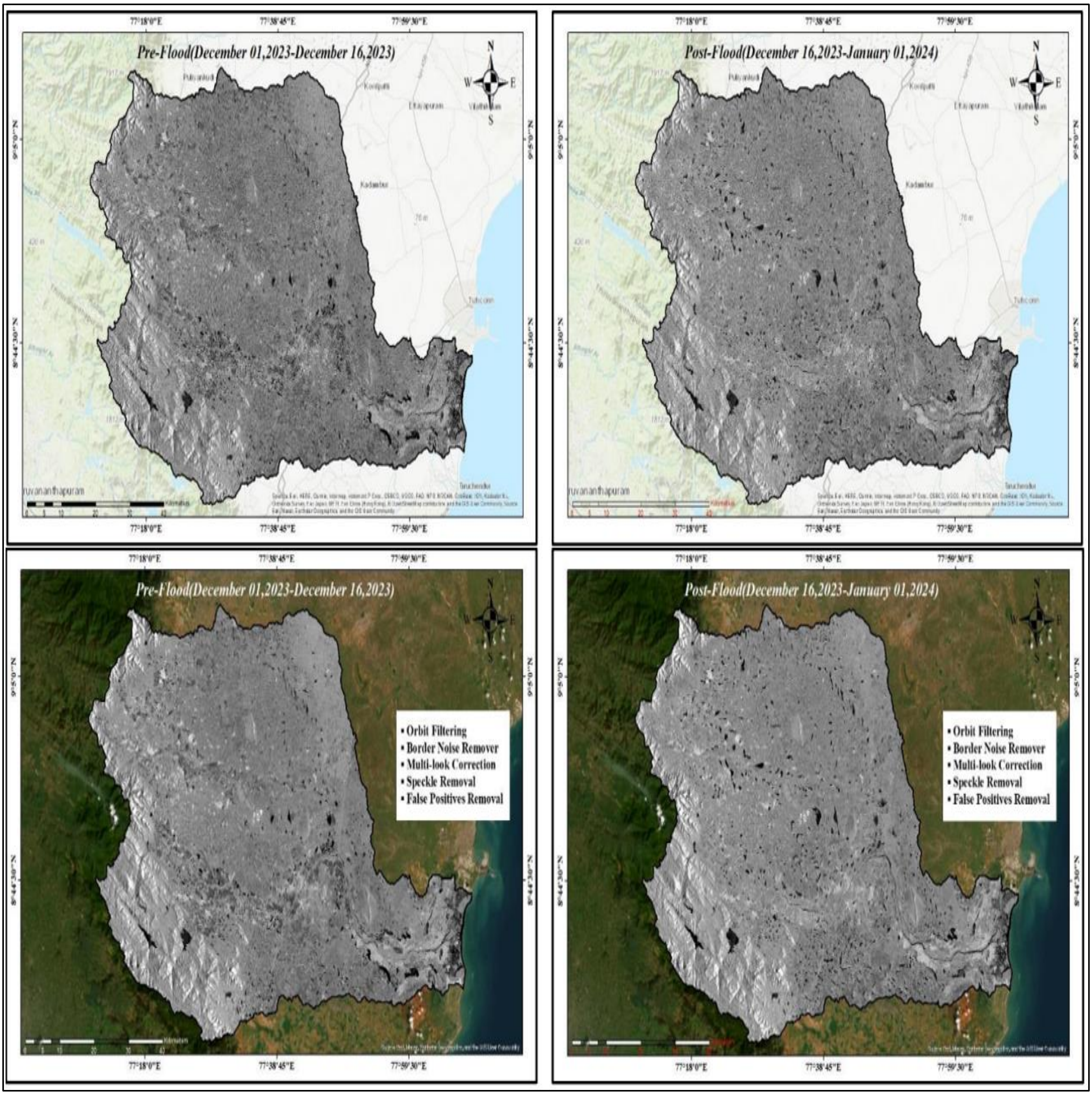

Fig 6 (a) Pre-flood (Raw scene)(b)) Post-flood (Raw scene) (c)) Pre-processed Pre-flood (d) Preprocessed Post-flood

By comparing pre-flood and post-flood images, significant changes in the land surface, particularly in agricultural regions, were observed. Flood-affected areas, including infrastructure like roads and settlements, were identified for two specific periods: December 1–16, 2023, and December 17–31, 2023. Pre-processing steps effectively highlighted water bodies in dark tones, with land cover appearing in shades of grey. This visual distinction underscored the success of the pre-processing techniques in delineating flooded zones.

A threshold value of 0.25, determined through radar backscatter coefficient analysis, was applied to differentiate flooded regions from other land types. VV polarization data further revealed flood extent, with backscatter values ranging from -0.9 dB to 0 dB for land areas and from -21 dB to -18 dB for water bodies. The before-and-after flood images from December 2023 demonstrated the spread of inundated areas, particularly in agricultural and settlement regions. Moreover, water pixel delineation allowed for accurate estimation of total flood coverage and helped differentiate between permanent water bodies and newly inundated areas, facilitating a comprehensive understanding of flood dynamics in the region.

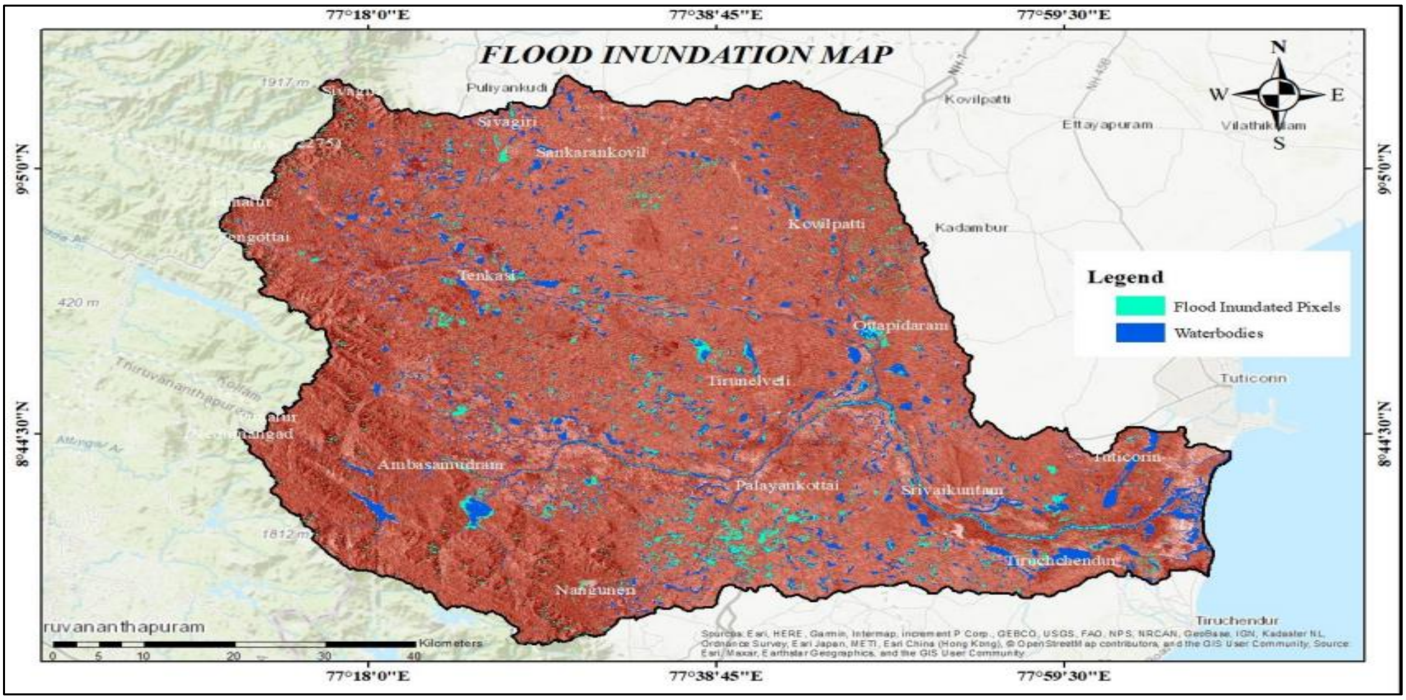

Fig 7 Flood Inundation Map

➢ *Flood Risk Assessment*

Flood risk assessment is a crucial process that integrates both vulnerability and hazard assessments to evaluate the potential impact of flooding on a specific area. Vulnerability assessment examines the exposure and sensitivity of communities and infrastructure to flood-related impacts. Key factors influencing vulnerability include population density, proximity to water bodies, and socio-economic indicators. On the other hand, hazard assessment focuses on the probability and intensity of flooding events, taking into account variables such as rainfall patterns, topography, and land cover characteristics.

By multiplying the results of vulnerability and hazard assessments, a more comprehensive understanding of flood risk can be achieved. This integrated approach enables decision-makers to identify areas most at risk, allowing for targeted resource allocation, prioritization of emergency responses, and the development of effective flood mitigation strategies. The equation for calculating flood risk can be expressed as:

RISK=VULNERABILITY×HAZARD

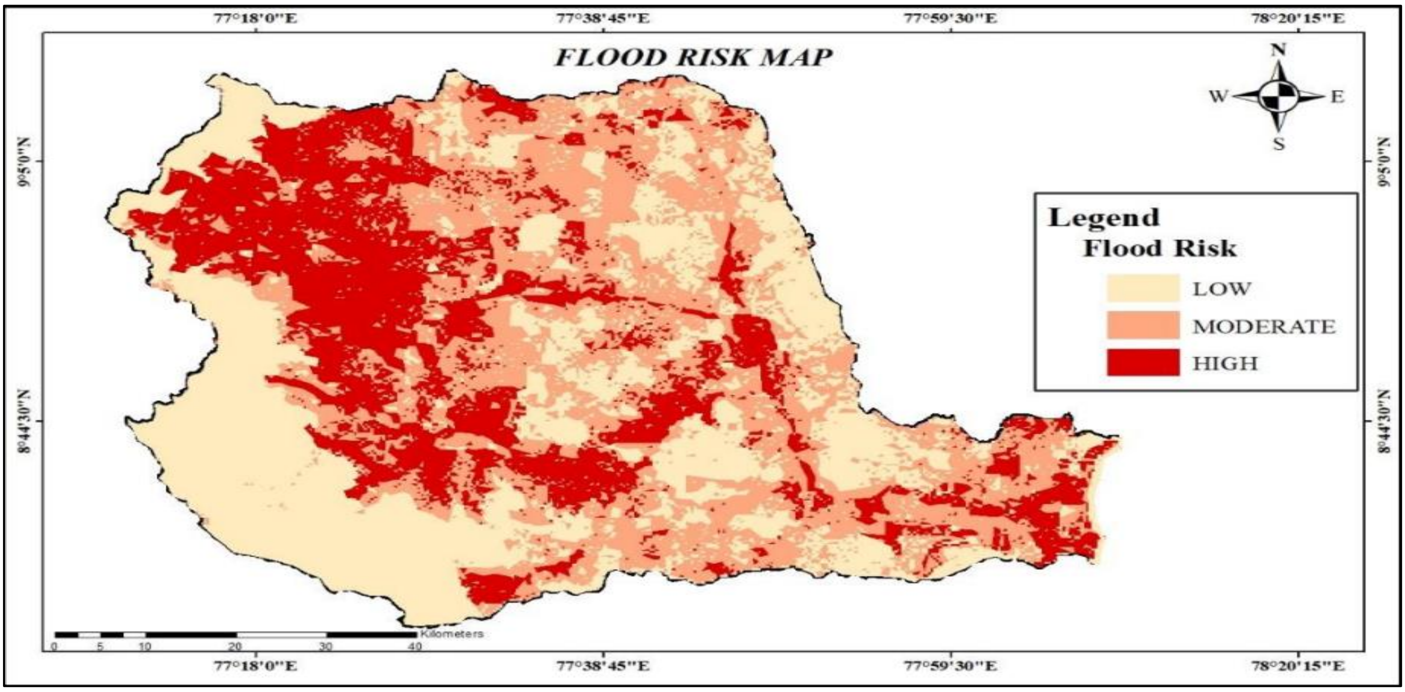

Fig 8 Flood Risk Map

The final risk map combines the data from both the vulnerability and hazard maps, offering a local perspective of flood risk in the Thamirabarani River Basin. Spatial analysis across the districts of Tirunelveli, Tenkasi, and Thoothukudi indicates that 94 out of 583 villages fall within high-risk flood zones. These areas are characterized by their proximity to rivers, elevated population densities, and a significant proportion of built-up land, making them particularly susceptible to flooding events.

In contrast, the remaining villages show moderate to low flood risk. These regions are typically farther from riverbanks and have lower population densities, which reduces their overall vulnerability to flooding. The flood risk map, derived from this analysis, serves as a critical tool for local authorities, enabling them to implement targeted flood prevention and preparedness strategies, particularly in the high-risk zones identified by this study.

V. DISCUSSION

The findings of this study contribute significantly to the understanding of flood vulnerability, hazard, and inundation in the Thamirabarani River Basin, revealing crucial insights into the region's susceptibility to flooding events. The application of GIS-based Analytic Hierarchy Process (AHP) methodology allowed for a comprehensive assessment of multiple parameters affecting flood risk, including population density, proximity to water bodies, land use, and socio-economic indicators.

The identification of high-risk zones, particularly in the Tirunelveli, Tenkasi, and Thoothukudi districts, aligns with existing literature that underscores the vulnerability of communities situated near riverbanks. Previous studies have indicated that such areas are particularly prone to flooding, especially during intense rainfall events [13][14]. The results of this study corroborate these findings, as they highlight the direct correlation between population density and proximity to rivers with flood vulnerability. This reinforces the necessity for targeted flood management interventions in densely populated areas.

The Curvilinear Number (CN) map generated in this study illustrates the spatial distribution of runoff potential across the basin, indicating that areas with a higher proportion of impervious surfaces are at greater risk of flooding. This aligns with the conclusions of [15], who found that urbanization and land cover changes significantly exacerbate flood risks by increasing surface runoff. Such findings emphasize the importance of incorporating land use planning into flood risk management strategies.

The flood inundation analysis utilizing Sentinel-1 imagery revealed substantial changes in land surface characteristics, highlighting the effectiveness of remote sensing techniques in monitoring flood events. The ability to distinguish between flooded and non-flooded areas through backscattering analysis is a crucial advancement in flood assessment methodologies [16]. This study's approach provides a replicable framework for future flood monitoring efforts, emphasizing the need for real-time data integration in flood risk assessment.

From a socio-economic perspective, the results indicate that high-risk communities are particularly vulnerable due to their limited adaptive capacity. This finding supports the principles of integrated flood risk management, advocating for a holistic approach that combines socio-economic and environmental considerations in flood mitigation planning [17]. Policymakers must prioritize these vulnerable areas to enhance resilience against future flooding events.

Looking ahead, future research could benefit from the development of predictive models that incorporate climate change scenarios, as changing precipitation patterns will likely impact flood dynamics in the Thamirabarani Basin and similar regions [18]. Additionally, exploring the socio-economic implications of flood events, including the potential displacement of communities and impacts on local economies, will be essential for creating more effective flood management strategies.

VI. CONCLUSIONS

This study provides a comprehensive assessment of flood risk and inundation dynamics within the Thamirabarani River Basin, employing advanced geospatial methodologies to analyze the interplay between various environmental and socio-economic factors. The integration of GIS and the Analytic Hierarchy Process (AHP) has proven effective in identifying high-risk zones, highlighting the vulnerability of 94 villages in the Tirunelveli, Tenkasi, and Thoothukudi districts. This underscores the necessity for targeted flood risk management strategies that consider the unique geographical and socio-economic contexts of these areas.

Moreover, the utilization of remote sensing data from Sentinel-1 has enhanced the understanding of flood inundation patterns, allowing for accurate identification of affected areas through rigorous backscattering analysis. The findings not only contribute to the existing body of knowledge on flood risk assessment but also offer actionable insights for policymakers and stakeholders involved in flood management and disaster preparedness.

Future research directions should focus on refining methodologies that integrate socio-economic factors alongside environmental variables, ensuring a holistic approach to flood risk assessment. By advancing our understanding of flood dynamics, we can better prepare for and mitigate the impacts of flooding, ultimately fostering more resilient communities in vulnerable regions. This study highlights the critical need for ongoing research and collaboration among various stakeholders to enhance flood resilience in the Thamirabarani River Basin and similar flood-prone areas.

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➢ *Conflicts of Interest:*

The author declares no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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