

## "Assessing Flood vulnerabilities in Paradip coastal area, through Weighted overlay index"

**Abstract:** Paradip, a renowned coastal city on India's eastern seaboard, offers an intriguing mix of environmental dynamics and urban difficulties. Paradip is the local with the most extensive tidal range among the region's important tidal gauge stations, including Vishakhapatnam and Chennai. Significantly, the city experiences a 2.33mm annual relative sea level rise; projections indicate that this will increase by 0.183 feet by 2047 and 0.76 feet over a century. The city's unique environmental and urban issues are exacerbated by its placement within the Mahanadi River's deltaic deposits, floodplains, and coastal marine deposits along the Bay of Bengal. The shoreline of Paradip is topographically uniform, with ground elevations ranging from 3.6 to 5.7 meters. According to India's Wind and Cyclone Hazard Map, Paradip is in the "Very High Damage Risk Zone," indicating the presence of significant wind speeds along the coast. The paper digs into these vulnerabilities and their possible influence on the coastal community, emphasizing the city's need to strike a balance between urban growth and ecological preservation. One of the main problems is flooding. Rainwater enters government buildings and impoverished areas because of encroachments on natural drainage systems. Dryland capable of residential, agricultural, and other economic activities is submerged by overflowing water which causes loss of life, property, and infrastructure. This study applies the GIS technique to analyze to produce a flood vulnerability map of the Paradip urban area, For this study, satellite image data (Landsat 8), To map locations susceptible to flooding, SRTM DEM, GPS coordinates, rainfall data, soil data, and a location map of the Paradip development area were combined. ArcGIS Pro 2.7.3 software and a weighted overlay index were utilized for the collection, processing, and display of spatial and attribute data. spatial analysis was the process used to produce the flood vulnerability map. The flood vulnerability map was then compared to the masterplan of Paradip which was proposed for 2030, to know the actual vulnerable area and to defy some major which were proposed by Paradip development authority. This study demonstrates how remote sensing and GIS may be used to analyze and produce the flood vulnerability data needed for efficient flood decision-making.

**Keywords:** Environment, Vulnerabilities, community, flood, Urban issues

### **Introduction**

Floods are the most frequent natural disasters to impact society worldwide; it is estimated that over one-third of the planet's geographical area is susceptible to flooding, which affects over 82% of the world's population. (Argaz, 2019). These high-magnitude earthquakes have the potential to cause significant topographic modifications as well as massive geomorphic changes. India is a nation prone to natural disasters, with multiple natural disasters occurring there year. Among them, India experiences its most frequent and severe natural calamities like floods. Researchers and the UN's sustainable development objectives indicate that between 1995 and 2015, floods were the worst natural hazard, affecting an estimated 2.3 billion people and accounting for 157,000 documented deaths globally. (Halder, 2023) The Brahmaputra River can go as deep as approximately 440 feet (135 meters), with an average depth of 100 feet (30 meters). Floodwaters can reach up to 3,500,000 cubic feet per second (100,000 m<sup>3</sup>/s), whereas the annual average discharge is roughly 700,000 cubic feet per second (19,000 m<sup>3</sup>/s) [14]. The average flow of the Ganga-Brahmaputra river delta is around 1,086,500 cubic feet per second (30,770 m<sup>3</sup>/s), which is the third biggest in the world. It also has the largest yearly load of suspended silt, weighing about 1.87 billion tons [14]. The districts of Mymensingh and Jamalpur in the lower Brahmaputra River basin are primarily affected by flooding (Halder, 2023).

This project aims to **assess evaluate and map flood risks in the coastal region of Paradip using advanced GIS techniques and weighted overlay index in order to enhance risk management, disaster planning, and sustainable development** in the coastal region of Paradip, an important location within Odisha. The creation of a Comprehensive Weighted Overlay Index, which incorporates geographical layers like topography, past flood data, land use patterns, and sea level rise estimates, is the first goal. This index, which is customized to the particular geographic and meteorological characteristics of Paradip, attempts to offer a sophisticated perspective on the composite flood risk in the area. The second objective is to identify and prioritize high-risk areas in the Paradip coastal region after the Weighted Overlay Index has been created. This will provide a clear spatial representation of susceptibility levels for effective resource allocation and targeted intervention strategies. Expanding upon the vulnerability evaluation, the third purpose endeavors to suggest focused mitigation tactics, offering counsel to regional administrations and interested parties to augment flood resilience in Paradip. This project attempts to provide useful insights for evidence-based decision-making by utilizing cutting-edge GIS techniques, ultimately promoting resilience and sustainable development in response to the increasing flood threats in Paradip.

Many factors affect an area's vulnerability to flooding, but topography is one of the most important ones. The study area's topography, which takes into account factors like land use, elevation, rainfall, and land cover, greatly affects how prone it is to flooding. Gently sloping low-lying locations are more vulnerable to flooding, whereas higher topography may be less susceptible. Flood risks can be increased by changes in natural drainage patterns brought about by land use practices like urbanization and forestry.

Authorities' mitigation initiatives are vital to controlling flood risks. This entails putting policies and infrastructure in place to manage and reroute water flow, like building levees, dams, and stormwater drainage systems. Flood damage is also mitigated by effective disaster response and preparedness plans. Activities around coasts are largely regulated by Coastal Regulation Zones (CRZ). CRZs seek to strike a balance between environmental conservation and development by defining permitted and restricted zones. To ensure sustainable coastal development and reduce flood vulnerabilities, the enforcement of these restrictions is crucially dependent on the Odisha Coastal Zone Management Authority.

A natural barrier against flooding is provided by the vegetation in the study region. Mangroves serve as a buffer, for example, lessening the force of storm surges and preserving coastal ecosystems. Flood dangers can be considerably reduced by maintaining and replanting vegetation in flood-prone locations. The identification and safeguarding of ecologically vulnerable regions is essential to reducing the risk of flooding. These places, which are frequently abundant in biodiversity, offer crucial ecosystem services and serve as organic barriers against severe weather. By putting conservation measures into place, these areas can remain resilient to flooding and retain their biological balance.

## Study Area



*Figure 1 Location of Paradip*



*Figure 2 Paradip Port*

Paradip is situated 210 nautical miles from Kolkata and 260 nautical miles from Visakhapatnam, the other two major ports in the eastern part of the country. Its latitude is 20°15' 55.44" N, and its longitude is 86° 40' 34.62" E. State Highway No. 12 and National Highway No. 5A provide excellent connections between Bhubaneswar and Cuttack with Paradip. It is situated roughly 94 kilometers (by road) from the Cuttack railway station and 125 kilometers (by road) from the Bhubaneswar Airport.

The port city of Paradip, located in the Odisha district of Jagatsinghpur on the country's east coast, is an intriguing example of how environmental dynamics and urban growth interact. Paradip, spanning 248 square kilometers, serves as a crucial hub for the region's economy and industry. Its transition from a mangrove-covered coastal region to an artificial deep-water port is symbolic of the intricate dance that occurs between the protection of the environment and the pursuit of economic progress. This study explores the distinctive environmental characteristics of Paradip, looking at how its location and climate have influenced the city's identity and presented difficulties for sustainable growth.

**Location:** Paradip's prime location at the confluence of the Mahanadi River and the Bay of Bengal emphasizes the city's economic importance. Ideally positioned between the major metropolises of Visakhapatnam and Kolkata, Paradip is essential to trade and business between the states of Odisha, Jharkhand, Chhattisgarh, Madhya Pradesh, Uttar Pradesh, Bihar, and West Bengal. Because of the city's relative flatness and gentle slope towards the sea, a strong transportation network, including highways and railroads, has grown. To incorporate Paradip into the economic activity of its hinterlands, this link is essential.

Beyond its economic significance, Paradip's location has unique advantages and disadvantages. The city is protected from severe winds, choppy waves, and storms by the naturally occurring deep bay created by the meeting of the Mahanadi River and the Bay of Bengal. This protected site lowers the dangers associated with bad weather by guaranteeing safe ship docking and anchoring. The Mahanadi River, a notable part of the city's landscape, is essential to Paradip's environment because it serves as both an inland waterway and a source of water for home and industrial usage.

However, Paradip is vulnerable to environmental risks due to its unique location, which offers strategic and economic advantages. The city's location along the Bay of Bengal's deltaic deposits, floodplains, and coastal marine deposits makes it naturally vulnerable to flooding and cyclonic storms, especially during the southwest monsoon season. The urban and environmental fabric of Paradip is always in danger due to storm surges because of the flat geography, which has ground elevations ranging from 3.6 to 5.7 meters. Because of its location, Paradip Port is vulnerable to the effects of cyclones that originate in the Bay of Bengal. The 1999 super cyclone demonstrated the extraordinarily high wind speeds that may be experienced in this area, up to 248 km/h. Super Cyclone AMPHAN, an extraordinarily powerful cyclone with associated wind gusts of 200 to 210 km/h, is currently posing a threat to the port. Right now, AMPHAN is situated about 360 kilometers south of Paradip. The port should take the necessary safety measures to reduce potential dangers since bad weather is expected. (Das, 2011)

The region is humid and hot because it sits on India's eastern coast. The mean temperature of the year is between 35.96°C and 13.30°C, meaning that it does not change much. The range of the mean maximum temperature is 28.6°C to 35.8°C, and the range of the mean minimum temperature is 13.3°C to 22.5°C. Paradip receives roughly 1400 mm of rainfall annually, which is more than the 1180 mm national average but less than the 1489 mm state average. Seventy-five percent of the rainfall falls in Paradip between June and September. Because of the significant precipitation, Paradip experiences high humidity levels, ranging from an average of 80.1% in December to a maximum of 98.6% in July. The lowest humidity level is 44.4%. (Simulated historical climate & weather data for Paradip, 2023)

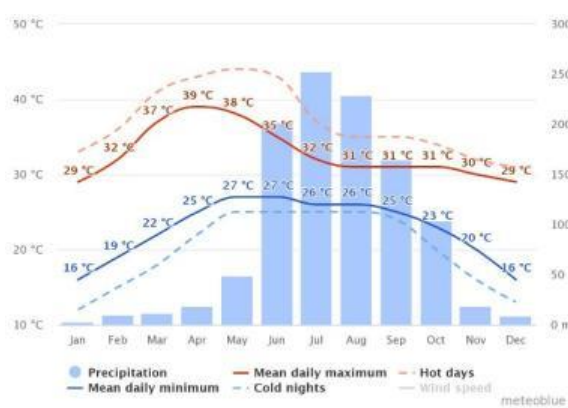


Figure 3 Temperature



Figure 4 Wind Speed

**Wind** – Wind: The wind raise for Paradip shows how many hours a year the wind blows in the designated direction. Example SW: The wind is blowing from the northeast (NE) to the southwest (SW). Particularly for sailing vessels, voyages from East to West are extremely challenging at Cape Horn, the southernmost landmass in South America, due to its distinctively strong west wind. (Simulated historical climate & weather data for Paradip, 2023)

The days of the month when the wind reaches a particular speed are depicted in the Paradip figure. The Tibetan Plateau provides an intriguing illustration of this, as the monsoon produces consistent strong winds from December to April and calm winds from June to October.

Sea level - Every lunar day, Paradip has two high tides and two low tides that are roughly similar in magnitude. These tides are known as semi-diurnal. The lowest water level is +0.40 meters, while the highest is +3.50 meters. There are 2.58 meters for the mean high-water spring and 0.71 meters for the

mean low-water spring. There are 2.02 meters of mean high water neaps and 1.32 meters of mean low water neaps. (Relative Sea Level Trend 500-106 Paradip, India, 2021)

### Coastal Regulation Zones

Paradip is a seaside city spanning 23 kilometers along the shore. 37.68 kilometers are all under coastal regulatory zones. Approximately 15.3% of the property is located in coastal control zones. The Odisha Forest and Environment Department, the Odisha Space Applications Center (the science and technology department), and the Odisha Coastal Regulation Zone (CRZ) notification 2019 have prepared these coastal zones.

The Coastal Regulation Zone (CRZ) is a key component in regulating coastal development and mitigating the effects of flooding. It also plays a significant role in preventing environmental deterioration. It promotes in ensuring the preservation of coastal resources in addition to protecting the delicate coastal habitats. To protect the coastal environment and promote sustainable development, India's Coastal Reserve Zone (CRZ) laws restrict industrial and human activity near beaches. The CRZ facilitates the general planning, coordination, and implementation of actions aimed at resolving environmental issues in coastal zones. By regulating activities including as construction, mining, and waste dumping, Coastal Regulation Zones (CRZs) help maintain the ecological balance and biodiversity of the coastal regions. It aims to create a balance between the coastal environment's priceless resources, economic development, and preservation.

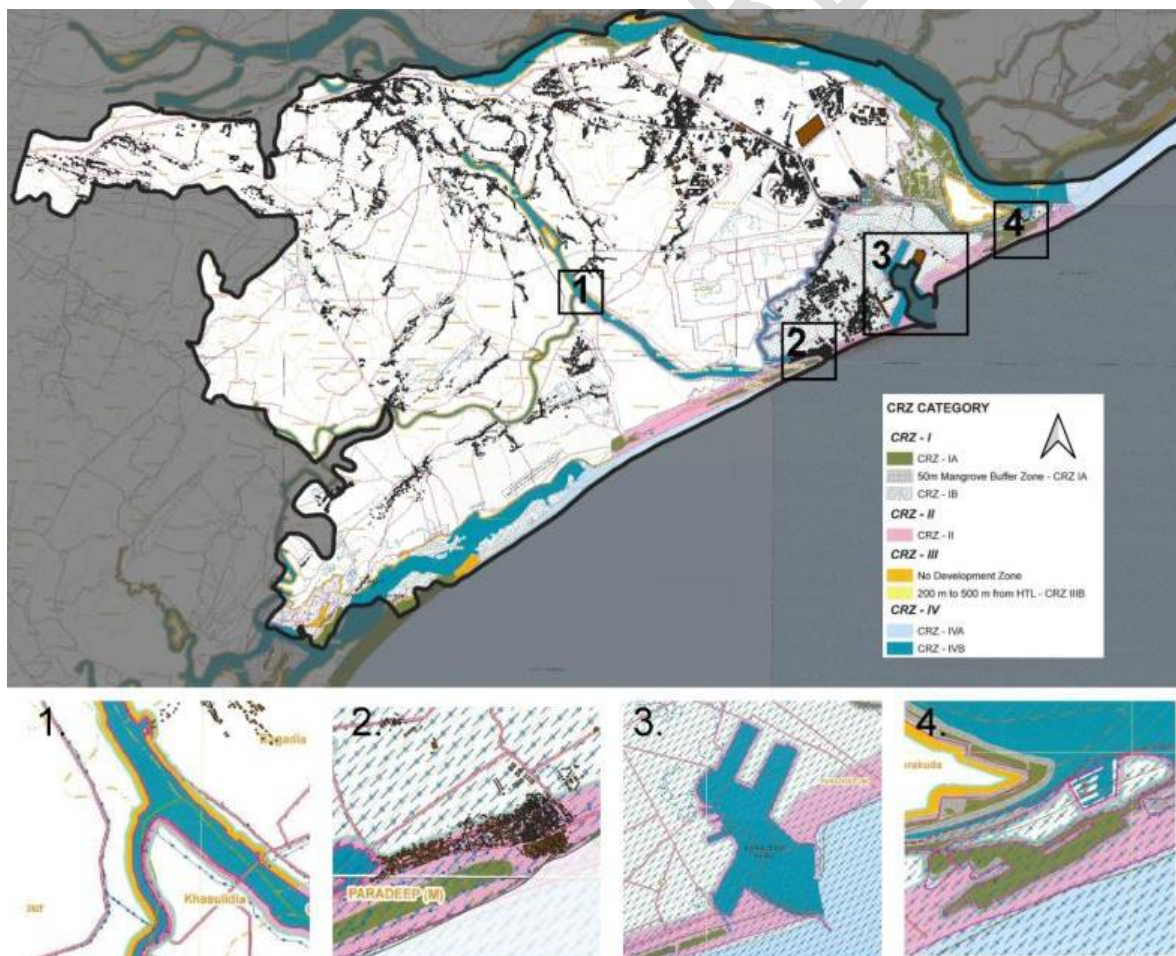


Figure 5 Coastal Regulation Zone

India's Coastal Regulation Zone (CRZ) is a strategic framework that categorizes coastal zones in order to govern and regulate activities throughout the vast coastline of the nation. The most restrictive zone, designated as CRZ-I, includes national parks and other environmentally sensitive locations where new construction is prohibited. The strict ban is meant to protect these important ecosystems' virgin state. Furthermore, there is a sub classification (Table-1) inside CRZ-I, which highlights the importance of conservation even more. The first sub-classification restates the outright ban on new construction, particularly in regions that are ecologically fragile like national parks. The second subclassification, which recognizes its ecological relevance and sensitivity, defines the area between low and high tide.

Buildings are allowed in CRZ-II, however, there are limitations. On the landward side of currently-constructed roadways, construction is permitted to balance environmental preservation with developmental demands. While recognizing the importance of infrastructure development, this classification ensures moral land use practices.

CRZ-III, which is 200 meters from the high tide line and is classified as a "No Development Zone." No building is allowed in this area to protect the coastal ecosystem from the damaging effects of human activity. To ensure a cautious and controlled approach to coastal development, some developments may be permitted within the 200–500 meter range with prior approval from the Ministry of Environment and Forests (MEF).

The watery region up to territorial boundaries is covered by CRZ-IV. This classification highlights the need to control activities in these seas in order to preserve biological balance and stop environmental degradation, while also acknowledging the dynamic nature of coastal ecosystems. (MINISTRY OF ENVIRONMENT, 2019)

	Define	Leg	Type	%	Area (Kmsq)
CRZ- I	No new construction		CRZ-IA	12	4.33
	(Ecologically sensitive areas i.e. national parks)		50m Mangrove Buffer	8	3.09
	The area between Low & high Tide area.		CRZ - IB	14	5.2
CRZ- II	Permitted Buildings (landward side of existing road)		CRZ-II	23	8.57
CRZ- III	No Development Zone (200m area from the high tide line)		No development Zone	7	2.7
	200-500 m (developed by prior approval MEF)		CRZ IIIB	-	-
CRZ- IV	Aquatic area up to territorial limits		CRZ- 1VA	7	2.79
			CRZ-IVB	29	11

Table 1 Coastal Regulation Zone

Source- (MINISTRY OF ENVIRONMENT, 2019) & Odisha space application centre (centre, 2021)

## Methodology and approach



The research team used a thorough methodology to investigate flood hazards in the coastal region of Paradip. To lay the groundwork for a foundational grasp of flood vulnerabilities, GIS methodologies, and environmental evaluations, the journey began with a thorough analysis of the current literature. After that, a thorough process of gathering data was initiated, which included compiling pertinent data and obtaining historical flood records, land use patterns, topographical data, and sea level rise estimates. Maintaining the reliability of the information required cooperation with environmental agencies and municipal authorities to obtain current and reliable data.

Throughout the whole research process, the engagement of multiple agencies remained essential. These partnerships made it easier to validate data and gave us a comprehensive understanding of Paradip's environmental dynamics. After obtaining the necessary data, the study moved on to the analytical stage, where sophisticated GIS methods were used to combine geographical layers and derive important conclusions. A detailed environmental assessment was conducted, accounting for topographical considerations, tidal range, and coastal characteristics to investigate the unique dynamics of Paradip. The purpose of this study was to find stresses and potential weak points unique to the surrounding area.

After defining the problem, the study described the challenges associated with Paradip's flood vulnerabilities in light of the environmental dynamics discovered during the assessment phase. One of the main results was the development of a Flood Susceptibility Map, which gives stakeholders and decision-makers a useful tool and depicts areas that are in danger. To improve the accuracy of risk assessment, a Comprehensive Weighted Overlay Index was created by combining many spatial layers to quantitatively evaluate and rank flood vulnerabilities in the coastal region of Paradip.

The study's final step was to rate the issues that were found according to their seriousness, possible impact, and urgency for remediation. This approach took into account both immediate and long-term issues, giving rise to a sophisticated comprehension of the order of importance for intervention. The research's methodology, conclusions, and findings were ultimately produced in a thorough documentation. In light of the increasing flood vulnerabilities in Paradip, this documentation is an invaluable tool for future research projects, decision-making procedures, and the application of focused mitigation strategies. In the end, it will improve risk management, disaster planning, and sustainable development.

The collection of data is the main process in terms of digital mapping or GIS operation to conduct this study methodologically. This study makes use of both primary and secondary data. GPS-acquired Ground Control Points (GCPs) made up the majority of the data. The digital elevation model (DEM) data from the Shuttle Radar Topography Mission (SRTM), the Landsat 8 soil vector map, the Tropical Rainfall Measuring Mission (TRMM), and the area's administrative map were the secondary data used.

**Flood vulnerability mapping** - Using the ArcGIS Pro program, six thematic-layer factors were developed in a GIS environment to identify the study area's flood-vulnerability zones. The study's flood vulnerability factors were selected using a combination of in-depth research, resident consultation, and

literature reviews. The distribution of rainfall, land cover and usage, elevation, slope, drainage density, and soil type are the contributing elements. The metropolis of Paradip was divided into four regions (high, moderate, and low) with differing levels of flood susceptibility to estimate the flood risk zones. The Analytical Hierarchical Process (AHP), which is based on multi-criteria decision-making, is used to classify the flood vulnerability aspects by giving them proportionate weights. AHP is a decision-making process that takes into account people's actual ability to make significant decisions. It permits the active involvement of decision-makers in fully comprehending all feasible possibilities before reaching a consensus or making a decision. The AHP implementation uses a pairwise comparison technique to ascertain the relative value of each step toward accomplishing the goal. Similarly, pairwise evaluations of the alternatives' performance against each criterion define their priorities, which in turn determines how the alternatives' rankings (i.e., the competing options under consideration) are established.

Using the four vulnerability levels as a framework for ranking, each vulnerability element in this study was ranked based on the decision maker's preference. To create criterion values for each evaluation unit, each element was weighted according to its expected impact on floods. The inverse ranking was applied to some of these criteria, with weights ranging from 1 (the least significant component) to 4 (the most significant element). The Weighted Linear Combination (WLC) method was used to superimpose all of the map layers, or the factors, in the final GIS spatial analysis for the flood vulnerability zone simulation.

## **Results and discussions:**

### **Flood vulnerability factors**

#### ***1. Landuse land cover***

The initial onset of flooding is significantly influenced by changes in land use and land cover, according to several specialists in flood hazard management. The primary reason for this is that this element takes into account the effects of current land use patterns and their varieties on soil stability and water infiltration (Dalia Farghaly, 2016). Satellite image from Landsat 8 was used to define the land cover classes in the research area. A minimum of eight and a maximum of twelve different classes could be identified by the use of the ISO cluster classifier in an unsupervised classification technique. To identify four distinct classes that significantly affect flood susceptibility, reclassification efforts were subsequently conducted. The four categories are made up of built-up areas, green cover, forests, and vacant grounds. The built-up regions were awarded a value of 4, indicating that they are more susceptible to flooding, whilst the areas with fewer settlements were assigned a reduced risk of flooding. The generated map of land cover factors is shown in Figure 6.

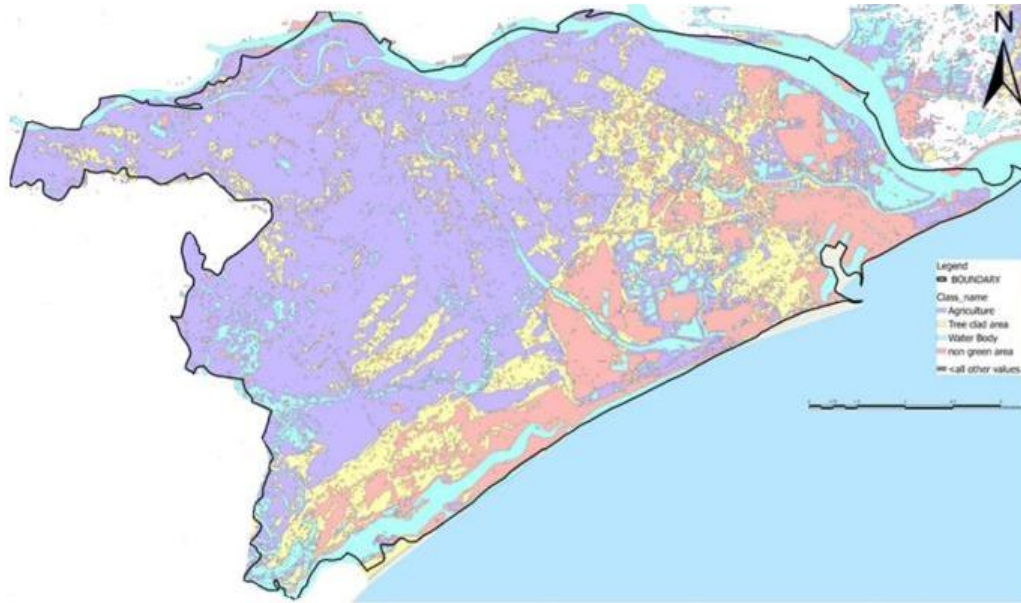


Figure 6 LULC Map

## 2. Rainfall Distribution

Heavy rains are a major contributing factor to floods, frequently overflowing natural waterways. When these systems are unable to control the excess water, widespread flooding usually results. Flood typically occur when a lot of rain falls and doesn't seep into the earth quickly enough to cause overflow to become surface runoff. The TRMM recordings in the research region provided the daily rainfall data for this particular investigation. An average daily rainfall assessment was calculated using a geographic information system (GIS) and the kriging technique. The result was merged into a rainfall data raster layer. The study area's southern sectors have the highest recorded rainfall amounts, which range from 50mm to 90mm. To streamline the study, the rainfall distribution raster was divided into four classes: 1 represented the lowest rainfall, and 4 represented the highest rainfall.

## 3. Elevation and slope factor

The regions that are most vulnerable to floods are shaped by elevation and slope, which are crucial factors in determining flood vulnerability. Slope determines the velocity and duration of water movement, whereas elevation affects the direction and intensity of water flow. Floods usually happen when water moves quickly over smooth or level ground, while harder terrain takes longer to flood. Steeper slopes are more likely to see surface runoff, but flat terrain is more likely to see waterlogging (Dalia Farghaly, 2016). The research area's SRTM DEM data provided the elevation and slope factor data, which were then divided into four different classes. Based on the features of its terrain, the class with the lowest value was ranked higher at 4, while the class with the highest value was ranked lower at 1, indicating that it was more vulnerable to surface runoff. The figures show the reclassified slope and elevation maps.

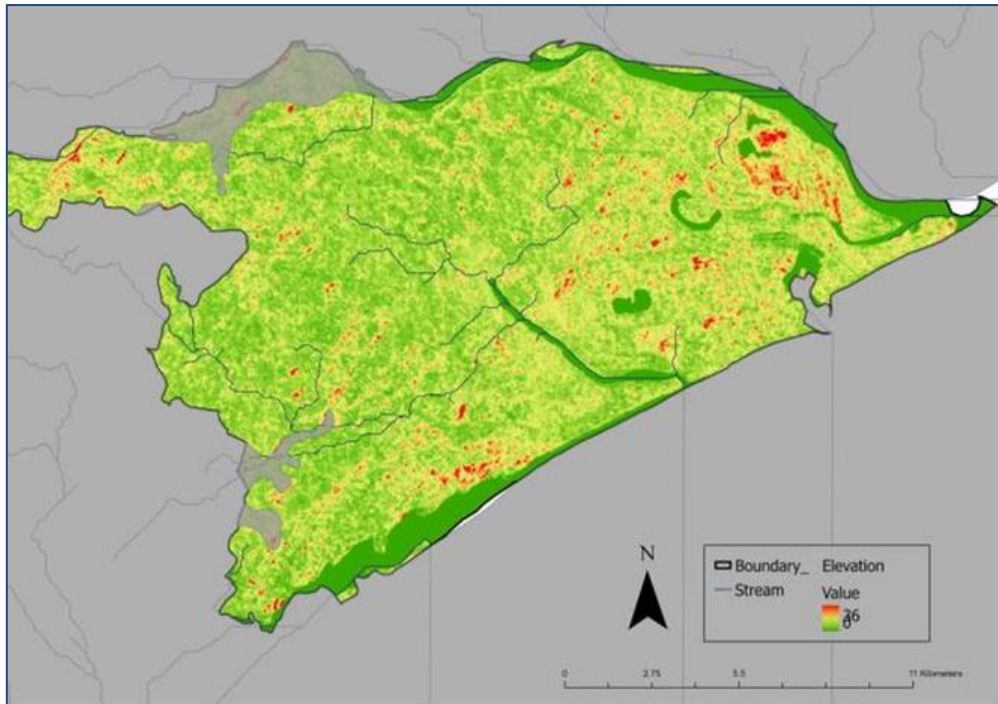


Figure 7 Elevation Map

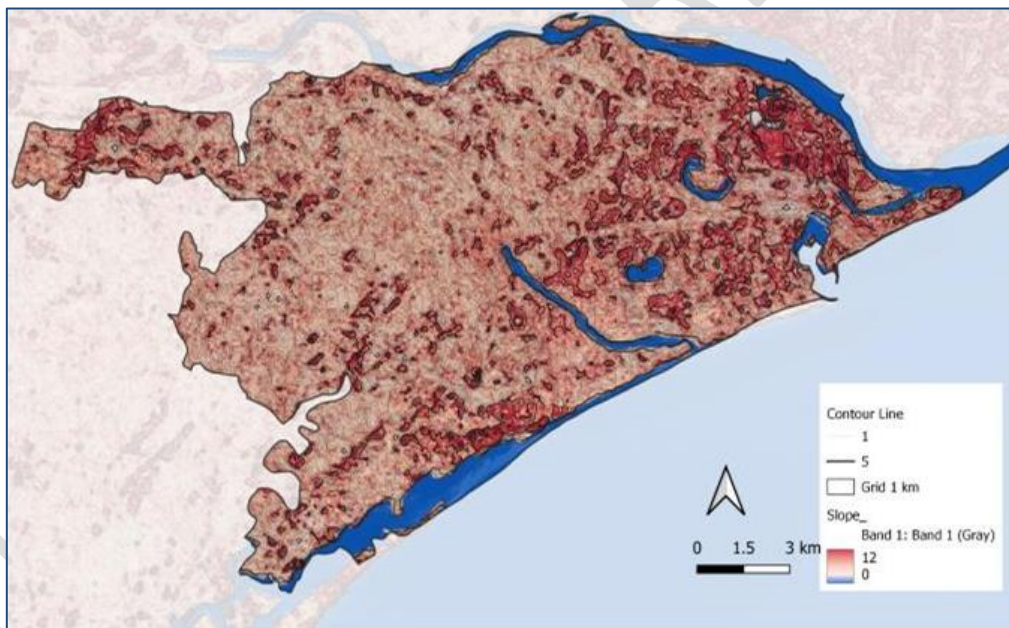


Figure 8 Slope Map

#### 4. Drainage Density factor

There is an inverse link between infiltrate and drainage density. Increased runoff within basin areas, especially in geologically erodible zones, is indicated by a higher drainage density. This lowers the risk of flooded areas (Gemetchu Shale Ogato, 2020). As a result, when drainage density levels rises, the drainage density rating decreases. After the SRTM DEM's data for the drainage density factor was recovered, the strata were divided into four different groups. The class that had the lowest drainage density rating was ranked higher, at 4, indicating that it was more susceptible to flooding. On the other

hand, the class with the highest drainage density score received a lower rank—1, indicating that it was less vulnerable to flooding. This shows the reclassified drainage density map factor.

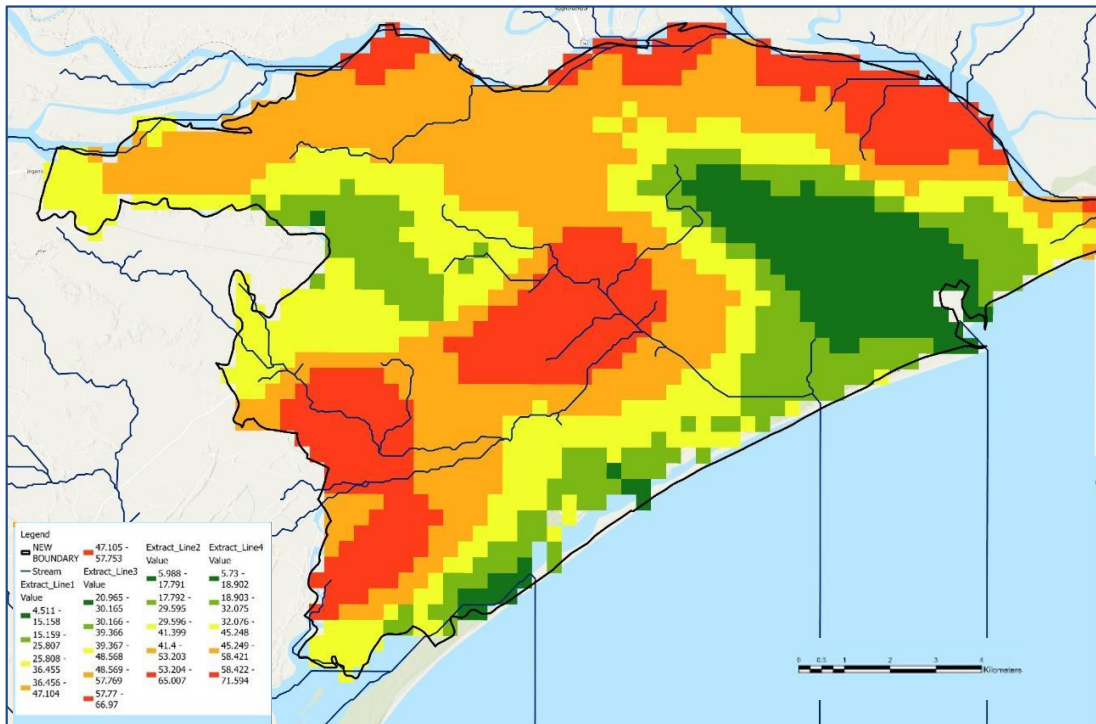


Figure 9 Drainage Density Map

## 5. Soil factor

The structure and infiltration capacities of the soil play a major role in determining its water-absorbing capacity and might differ across different types of soil. Flooding is more likely when surface runoff rises and the soil's infiltration capacity declines. The soil type map used in this study was created using data from the Nigeria Geological Survey and showed the variety of soil types present in the study area. These types of soil were then divided into four classes: gravelly sandy clay loam, stony sandy clay, stony sandy loam, and gravelly sandy clay. Based on each class's propensity to contribute to the creation of floods, a weight was assigned. The soil type that has the greatest ability to generate extremely high flood rates was ranked 4, while the soil type that has the least capacity to generate floods was ranked 1.

### Criteria for ranking

The results and ranking criteria were produced using multi-criteria ranking, as shown in the table below, where relative weights of criteria, where R1 = LULC, R2 = RAINFALL, R3 = ELEVATION, R4 = SLOPE, R5 = DRAINAGE DENSITY, R6 = SOIL. Weight values are absolute numbers between 0 and 1 that represent the priorities. When using a weighted linear combination, the overall weights are assumed to add up to 1. When an element has a higher weight value, it impacts the overall research more. The rainfall component has the largest weights, as seen from the factor weights obtained for this study region, showing that it affects more floods in the area than the other elements.

	R1	R2	R3	R4	R5	R6	WEIGHTS	PERCENT (%)
R1	0.20	0.20	0.20	0.20	0.20	0.20	0.20	20
R2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	35
R3	0.11	0.11	0.11	0.11	0.11	0.11	0.11	11
R4	0.11	0.11	0.11	0.11	0.11	0.11	0.11	11
R5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	15
R6	0.08	0.08	0.08	0.08	0.08	0.08	0.08	8
<b>Total</b>	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>	<b>100</b>

Table 2 Summary of vulnerability weights and ranking

### Flood Vulnerability mapping for Paradip

In our research, we used a methodical approach in our research area to evaluate the characteristics that make a place vulnerable to flooding. A four-tier vulnerability scale was used to rate these elements according to their perceived importance, with weights ranging from 1 (least important) to 4 (most important). To model flood susceptibility zones, we combined different map layers in the last phases of spatial analysis using the weighted overlay index method. A thorough flood vulnerability map was produced by overlaying the classed layers in ArcGIS after a multi-criteria evaluation with weights given to each factor was completed. Within the study area, the overlay analysis's conclusion identified four unique risk zones: flood zones with high, moderate, and low levels of vulnerability. The results indicate that the low vulnerability area occupied 12.1% (33.4 sq km), moderate vulnerability in 61.5% (168.2 sq km), and high vulnerability in 26.4% of (72.4 sq km).

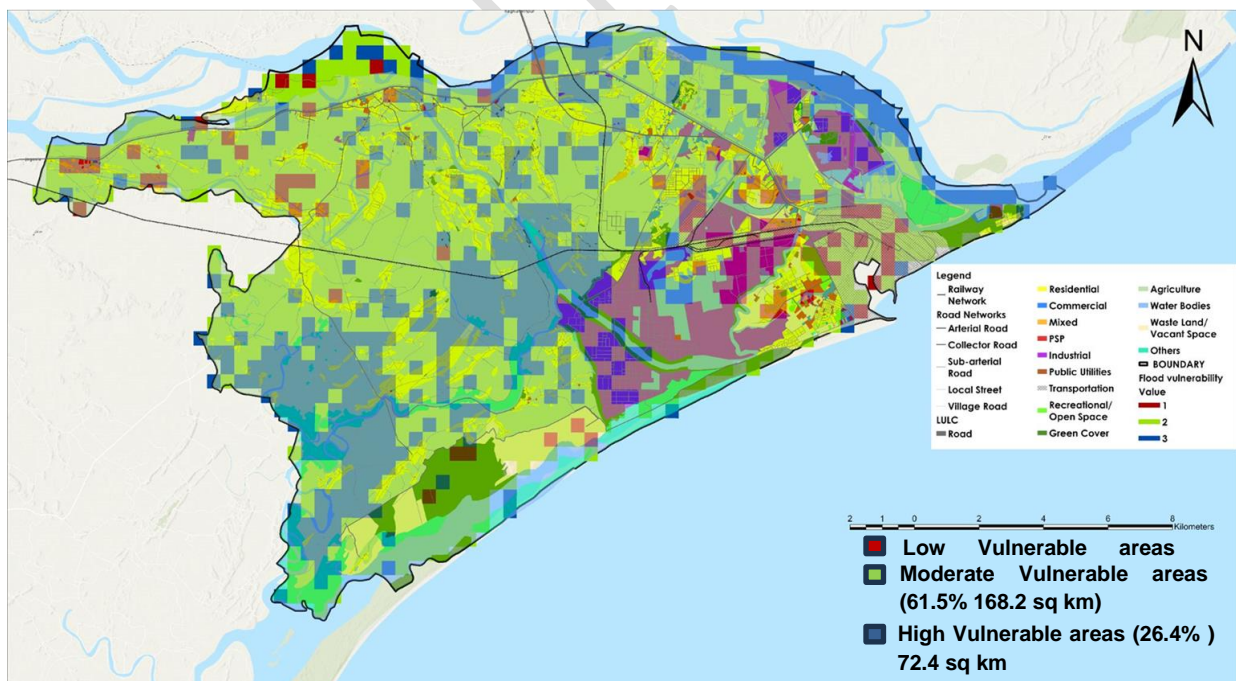


Figure 10 Flood Susceptibility Map

**Comparing flood susceptibility map and the proposed master plan of Paradip (2030)**

By comparing the proposed Paradip Master Plan for 2030 with the flood susceptibility map, we were able to find discrepancies in our study. We identified through overlay analysis that the affected areas are specifically the planned master plan sites, accounting for 12.3% of the entire study region. This makes up 3.22% of the total area set aside for industrial use, 8.78% for residential areas vulnerable to flooding, and 0.2% for Public Semi-Public (PSP). Furthermore, according to our demographic forecasts for 2031, 13 villages—which together account for nearly 46,104 residents—will be affected by areas that are susceptible to flooding.

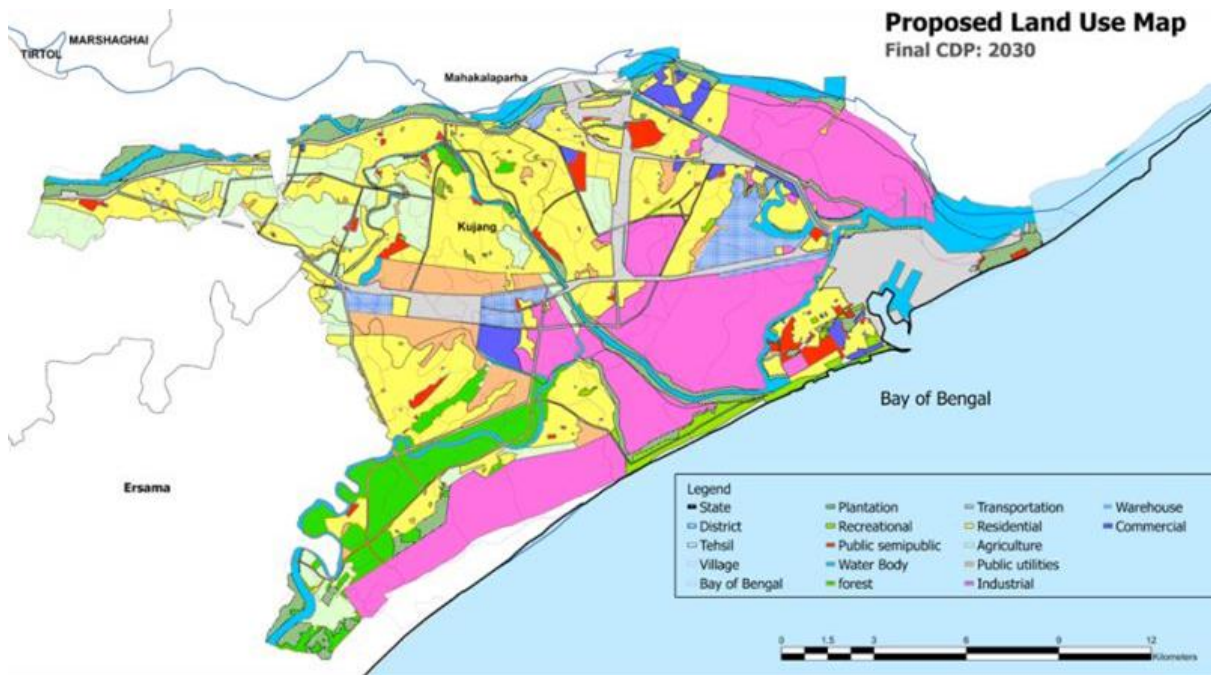


Figure 11 Proposed Masterplan of Paradip 2030

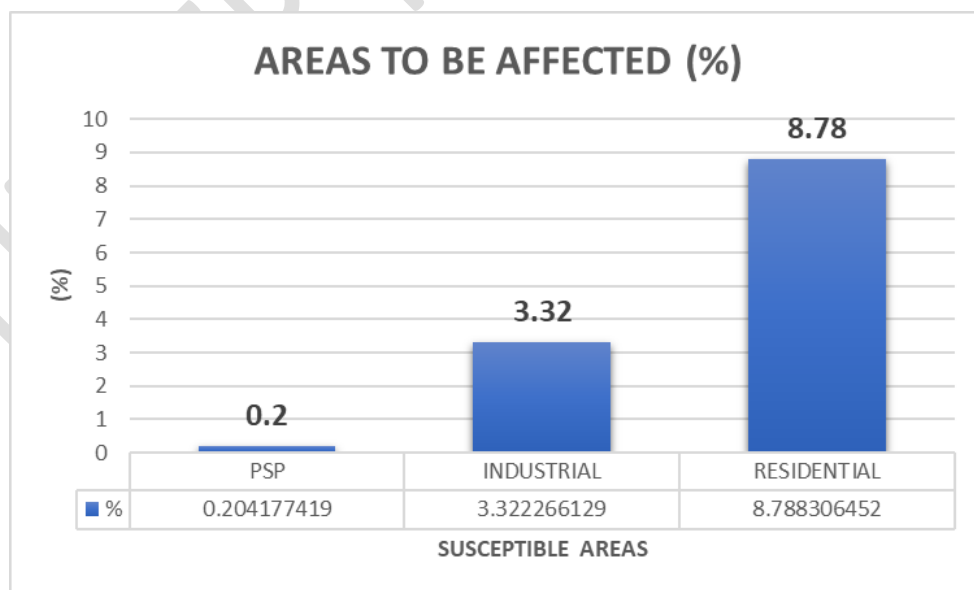
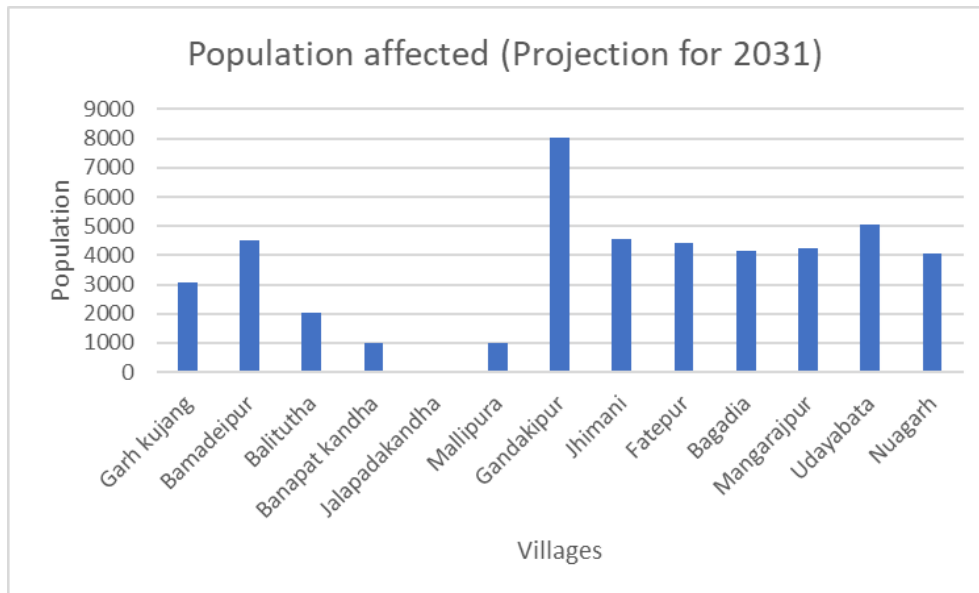


Fig 12 : Graphical presentation showing affected areas



**Fig 13 : Graphical presentation showing affected population**

### Conclusions:

In conclusion, by creating a thorough map of flood vulnerability that shows the various levels of flood risk, our study effectively accomplished all three of its goals. This information is extremely beneficial in preventing the potential effects of flood catastrophes in the area and protecting the lives and property of the people living in Paradip. The results of the mapping of flood vulnerability clearly categorize the area, with 26.4% (72.4 sqkm) having high susceptibility, 61.5% (168.2 sqkm) having a moderate vulnerability, and 12.1% (33.4 sqkm) showing low vulnerability. These discoveries must be addressed to protect the community's safety and well-being in flood-prone locations.

Several important things to ponder based on our analysis: Locations Risked by Floods: The susceptibility map makes it evident which places are more likely to flood. Because of the possibility of flooding, it is best to avoid large-scale development initiatives in these areas. For planners, carriers, and emergency services, flood vulnerability maps are an invaluable tool that facilitates a thorough evaluation of flood risk. Planners in particular need to assess risks in light of potential outcomes to take appropriate measures to mitigate the problem. Given the discussion that came before it, using flood risk mapping as a key element of flood control strategies has a lot of potential to lower damages in regularly impacted places. Delineating likely inundated areas within a given catchment is made possible by the integration of flood frequency analysis with GIS. This study highlights how well GIS and remote sensing technologies work to categorize and identify regions in the study area that are at different risk of floods. The paper concludes with recommendations for resolving the flooding problem in the Paradip study region.

1. **Residential Zones:** The proposed master plan proposes a significant increase in the number of residential buildings in flood-prone zones, which could endanger public safety, cause property damage, and make emergency response plans necessary in the case of floods.
2. **Industrial Zones:** The proposal suggests the establishment of industrial zones in flood-prone areas, which would pose serious hazards to the environment, enterprises, and investments. Infrastructure damage and the release of dangerous materials could result from floods.
3. **Population Safety:** There are worries about possible casualties, injuries, and displacement, and the planned development in flood-prone areas immediately jeopardizes the safety of locals and workers.

In conclusion, a critical review and revision of the proposed master plan for Paradip, based on the flood susceptibility map, are essential to reduce possible risks to the population, environment, and economy. Relocating residential and industrial areas as well as bringing flood mitigation and climate resilience plans into effect may be necessary for this.

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