सत्यमेव जयते

Department of Science, Technology & Environment
Government of Puducherry

Visualising Climate Change Risks

The Climate Risk Assessment Tool (CRAT) for Puducherry UT

Visualising Climate Change Risks: The Climate Risk Assessment Tool (CRAT) for Puducherry UT

Center for Study of Science, Technology and Policy

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This report is a testament of the power of collaboration and shared commitment of the Government of India and GoP in addressing the pressing challenges of climate change. We hope that the findings and recommendations presented here will serve as a robust foundation for informed decision-making and strategic action in the face of evolving climate risks.

Executive Summary

The Union Territory (UT) of Puducherry, comprising four regions, is primarily located in low-lying coastal and water-adjacent lands, making it highly vulnerable to climate change extremities and hazards such as droughts, heatwaves, floods, sea level rise (SLR), and coastal erosion. These pose significant challenges to the UT of Puducherry's agriculture, biodiversity, coastal ecosystems, infrastructure, and water resources. A comprehensive multi-hazard risk assessment is crucial to address and manage these multifaceted challenges effectively. Therefore, the Center for Study of Science, Technology and Policy (CSTEP), in collaboration with the Puducherry Climate Change Cell (PCCC), conducted a climate risk assessment and developed the Climate Risk Assessment Tool (CRAT) to visualise the climate risks to agriculture, fisheries, health, livestock, tourism, urban, and water sectors. This web-based interactive tool is envisaged to support climate adaptation efforts by helping to visualise climate risks to various sectors.

This report presents the findings of the climate risk assessment conducted using the framework published in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (2014). The study involved performing necessary computations to assess the three climate risk components, namely, hazard, exposure, and vulnerability (adaptive capacity and sensitivity), which can now be visualised in the developed tool as interactive components, as well as climate risk.

Hazard analysis

To compute the probability of occurrences of the selected hazards, both current and future climate scenarios were considered. The following points summarise the findings of this hazard assessment:

- ***Drought*:** The historical severe and extreme droughts were assessed using 30 years of monthly rainfall data from the India Meteorological Department (IMD). The Standardised Precipitation Index (SPI) was used for the analysis. All four regions of Puducherry UT have experienced moderate drought during the current time period (1993–2023) and are projected to experience the same in the future time period (2041–2070) under the Representative Concentration Pathway (RCP) 4.5 (moderate emissions). Puducherry and Yanam have experienced a high probability of occurrence of moderate drought in the current time period. In the future time period, Puducherry and Karaikal will witness a high probability of occurrence of moderate drought.
- ***Flood:*** The flood dynamics in all four regions were estimated for the current (1993–2023) and future (2041–2070) time periods. Riverine flood modelling was performed using the Hydrologic Engineering Center's River Analysis System (HEC–RAS) to simulate the flood occurrences for 2, 5, 10, 50, and 100 years of return periods. Across all time periods, Puducherry has the greatest spatial extent of flooding, with the 100-year return period showing the greatest magnitude of spatial inundation for the current and future (RCP-4.5 scenario) time periods.
- ***Heatwave:*** Heatwave events were identified on the basis of respective temperature thresholds for each region, for both current and future time periods. Puducherry currently experiences the highest number of heatwave events, with 16 out of 30 years having at least one heatwave event. Yanam is projected to experience the highest number of heatwave events under the RCP-4.5 scenario, with 19 out of 30 years having at least one heatwave event.
- ***SLR:*** As all four regions are located on the coast, they are experiencing rising sea levels. Yanam has the highest probability of exceeding the chosen threshold of 2.12 cm, with SLR crossing the threshold for 13 years in the current time period. All regions show a 100% probability of exceedance of SLR threshold in the future, under the Shared Socio-economic Pathway 2-4.5 (SSP2-4.5).

Exposure analysis

Exposure was assessed in the Geographical Information System (GIS) environment using the overlay approach, between the spatial extent of various hazards and sector-specific indicators. All indicators are uniformly exposed to droughts and heatwaves. For the remaining hazards, the key findings are as follows:

- In the current time period, Puducherry has the highest exposure to SLR with assets in the water sector exposed the most. Most regions will face a high exposure to SLR in the future time period under the SSP2-4.5 scenario. Notably, the fisheries sector in Karaikal and Puducherry will face the highest extent of exposure in the future time period.
- All regions are exposed to floods of different return periods. However, Yanam has a relatively higher number of assets that are exposed to flooding across all return periods and sectors in the current and future time periods, with the livestock sector assets exposed the highest.

Vulnerability analysis

An indicator-based, integrated inter-sectoral and inter-regional vulnerability assessment was conducted, incorporating biophysical, socio-economic, institutional, and governance indicators. Future vulnerability was assumed to be equivalent to the current inherent vulnerability. The indicators were normalised to dimensionless units for aggregation, with relationships showing direct or inverse proportionality to overall vulnerability, as the case may be. The drivers of vulnerability were categorised into socio-economic, biophysical, and institutional factors. The findings of the inter-sectoral assessment are presented below.

- In Puducherry, the tourism sector is at high vulnerability while all other sectors are at moderate vulnerability.
- In Karaikal, the fisheries sector is at high vulnerability while all other sectors are at moderate vulnerability.
- In Yanam, the livestock and water sectors are at high vulnerability while all other sectors are at moderate vulnerability.
- In Mahe, the fisheries sector is at high vulnerability while the tourism sector is at low vulnerability. All other sectors are at moderate vulnerability.

The key findings of the inter-regional assessment are discussed below.

The key findings of the inter-regional assessment are discussed below.

1. Agriculture

- Yanam and Mahe are relatively more vulnerable than Puducherry and Karaikal.
- High vulnerability stems from low cropping intensity, low coverage of cluster-based farming, low insurance coverage, and a high predominance of rainfed farming.

2. Livestock

- Karaikal and Yanam are highly vulnerable while Puducherry is at moderate vulnerability and Mahe the least vulnerable.
- High vulnerability in the livestock sector stems from a high variation in livestock productivity, a low livestock-to-human ratio, low female literacy rates, poor insurance coverage, and a low percentage of local breeds.

3. Fisheries

- Karaikal and Mahe are at high vulnerability, Puducherry at moderate vulnerability, and Yanam at low vulnerability.
- High vulnerability in these regions is primarily driven by a high ratio of marine to inland fisherfolk, a low ratio of the coastal wetland area to total coastal area, a low

average distance of coastal villages from the high tide line, poor involvement of women in the catch and sale of fish, and a poor access to essential infrastructure and financial support systems.

4. Urban

- Yanam and Mahe are ranked highly vulnerable while Puducherry and Karaikal are at low vulnerability.
- High vulnerability is primarily driven by a low percentage of blue and green area coverage in urban areas, poor surface water quality, and a high economically sensitive population density.

5. Tourism

- Puducherry and Karaikal are highly vulnerable. Further, Yanam is moderately vulnerable, and Mahe is least vulnerable.
- High vulnerability is driven by few police stations per 1,000 tourists, poor surface water quality, high variation in tourists, low road density, a high tourist burden on hotels, and poor groundwater quality.

6. Water

- Yanam is ranked as highly vulnerable while the remaining regions are at low vulnerability.
- High vulnerability is driven by poor groundwater quality, many homes with poor drainage, and a few homes with borewells, tube wells, open wells, and rainwater harvesting structures.

7. Health

- Puducherry and Karaikal are at high vulnerability while Yanam and Mahe are at low vulnerability.
- High vulnerability is primarily driven by high infant mortality rates, high disease prevalence, low female literacy rates, a high number of households living below the poverty line, and a poor availability of reliable healthcare services.

Risk assessment

The overall climate risk is computed as a geometric mean of hazard, exposure, and vulnerability and is ranked on a three-point scale of low, medium, and high. This assessment aids in comprehending social, spatial, and climatic factors driving risk, which is essential for effective disaster risk management and long-term resilience planning. The CRAT functions as a dynamic visualisation interface, allowing users to visualise overall climate risk or individual determinants of risk. Users can also select indicators of their choice, tailoring the tool to their specific needs and creating vulnerability, exposure, and hazard maps for any sector.

This study provides two types of risk assessments: inter-sectoral and inter-regional. The first allows users to prioritise a region(s) for adaptation planning, for a given sector and hazard. The second type of assessment allows users to compare across different sectors to gauge which sector needs to be prioritised within each region.

With regard to the inter-sectoral risk assessment, the overall findings are presented below.

1. Drought

- In the current time period, most regions lie between moderate and low risk for all sectors.
- For the future time period, all sectors in Puducherry and Karaikal are moderately at risk to drought. Yanam and Mahe display mixed trends.

2. Heatwave

- In Puducherry, the tourism and health sectors are at high risk to heatwaves in the current time period while the remaining sectors are moderately at risk (Table 39). In Karaikal, the fisheries, health, and tourism sectors are at high risk while the rest are moderately at risk. The livestock and water sectors are at high risk in Yanam, and all sectors in Mahe are at low risk.
- In the future time period, aside from the tourism and health sectors, all other sectors are at low risk in Puducherry. In Karaikal, the health, fisheries, and tourism sectors are at high risk, and the remaining are moderately at risk to heatwaves. In Yanam, aside from the fisheries and health sector, all others are at high heatwave risk. In Mahe, all sectors are moderately at risk.

3. SLR

- In the current time period, all sectors are uniformly at low risk in all regions.
- In the future time period, in Puducherry, the urban sector is moderately at risk to SLR while the remaining sectors are at low risk. In Yanam, the water sector is moderately at risk while the remaining sectors are at low risk. In Mahe, all sectors are equally at low risk to SLR. The health and livestock sectors are excluded as they are not exposed to SLR across all regions.

4. Flood

2-Year return period

- All sectors are uniformly at low flood risk in Karaikal in the current time period. In Puducherry, the fisheries and water sector are at moderate risk while all other sectors are at low risk. In Yanam, the agriculture, fisheries, and health sectors are at low risk while the remaining sectors are moderately at risk. In Mahe, the water sector is moderately at risk while all other sectors are at low risk.
- For the future time period, in Puducherry, the fisheries and water sector are moderately at risk to flooding while all other sectors are at low risk. In Karaikal, the fisheries sector is moderately at risk while all others remain at low risk. In contrast, in Yanam, the fisheries, agriculture, and health sector are at low risk while all other sectors are moderately at risk. In Mahe, the water sector is moderately at risk while all other sectors are at low risk.

5-Year return period

- Aside from the fisheries sector in Karaikal, the livestock sector in Yanam, and the water sector in Mahe, all regions exhibit low flood risk in the current time period.
- Under the future time period, the agriculture sector in Puducherry and Karaikal, the fisheries sector in Karaikal, the livestock sector in Karaikal, and the water sector in Mahe are moderately at risk. The remaining regions remain low at risk across all sectors.

For the current and future flood risk under the 10-, 25-, 50-, and 100-year return periods, all regions across all sectors are uniformly at low risk to flooding.

Tool development

The findings of the risk assessment are visualised through a web-based interactive tool built using Angular, Geoserver, Django (Python), and PostgreSQL database.

The tool allows users to independently visualise the probability of occurrence of the selected hazard and their corresponding spatial extents, as well as sector-specific exposure, vulnerability, and overall risk. The tool will be particularly useful to the various line departments within the Government of Puducherry, facilitating climate-smart decision-making within their respective sectors.

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Abbreviations

ALOS PALSAR	Alaska Satellite Facility Phased Array Type L-Band Synthetic Aperture Radar
API	Application programming interface
AR6	Sixth Assessment Report
ASHA	Accredited Social Health Activist
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BOD	Biological oxygen demand
BPL	Below poverty line
CMIP5	Coupled Model Intercomparison Project Phase
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRAT	Climate Risk Assessment Tool
CSO	Civil society organisation
CWC	Central Water Commission
DEM	Digital elevation model
DO	Dissolved oxygen
DRF	Django REST framework
DSTE	Department of Science, Technology and Engineering
EDI	Effective Drought Index
FABDEM	Forest and Buildings removed Copernicus Digital Elevation Model
GIS	Geographical Information System
GLW	Global Livestock of the World
GoP	Government of Puducherry
HEC–RAS	Hydrologic Engineering Center–River Analysis System
HTL	High tide line
HydroSHEDS	Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales
IMD	India Meteorological Department

IPCC	Intergovernmental Panel on Climate Change
LULC	Land use land cover
MGNREGS	Mahatma Gandhi Rural Employment Scheme
MSME	Micro, small, and medium enterprise
NbS	Nature-based solution
NGO	Non-governmental organisation
NMSKCC	National Mission on Strategic Knowledge for Climate Change
OSM	OpenStreetMap
PCCC	Puducherry Climate Change Cell
PDN	Percentage Departure from Normal
PDSI	Palmer Drought Severity Index
PHC	Primary health centre
PSMSL	Permanent Service for Mean Sea Level
RCP	Representative Concentration Pathway
SLR	Sea level rise
SNCU	Special Newborn Care Unit
SPI	Standardised Precipitation Index
SRTM	Shuttle Radar Topography Mission
SSP	Shared Socio-economic Pathway
TSS	Total suspended solids
UT	Union territory
VI	Vulnerability index
WRIS	India-Water Resource Information System

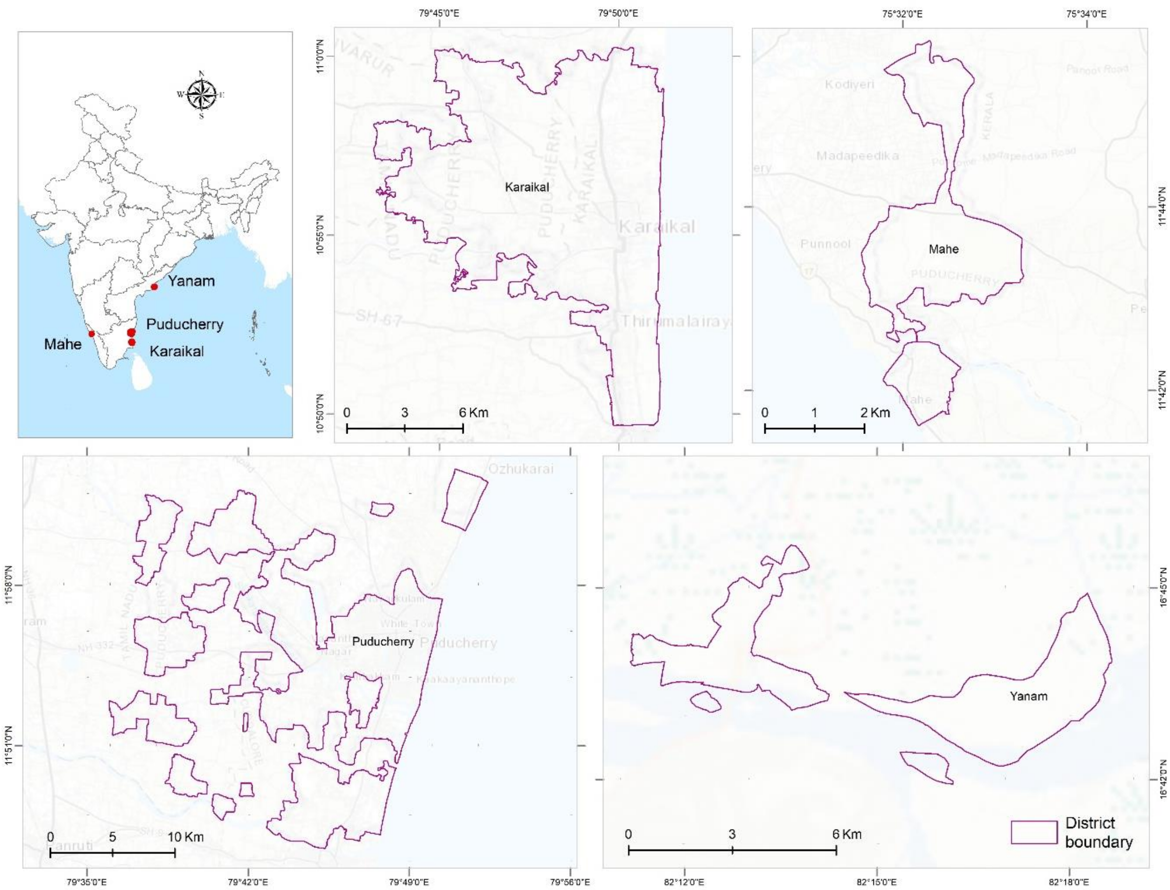
1. Introduction

Climate change is intensifying at an alarming rate, and climate disasters such as wildfires, droughts, floods, and heatwaves have become increasingly common. As global emissions continue to increase, the frequency and intensity of climate disasters are also expected to increase in the future (United Nations Office for Disaster Risk Reduction, 2024).

Coastal regions are one of the most vulnerable geographies with respect to climate change. Cities on the coast are acutely vulnerable to sea level rise (SLR), coastal surges, cyclones, and land subsidence. Given that 40% of the world's population lives within 100 km of a coast, it is imperative to aid coastal geographies to become resilient to the impacts of climate change (United Nations, n.d).

The Union Territory (UT) of Puducherry is one such coastal region situated on the south-eastern coast (Figure 1). Excluding Mahe, which is located on the Malabar stretch of the western coast of Kerala, all regions lie on the eastern coast of India. While Puducherry and Karaikal are bound by Tamil Nadu, Yanam is surrounded by Andhra Pradesh.

Figure 1: Region map of Puducherry UT



Owing to the close proximity to the ocean, these regions are increasingly being affected by extreme weather events. Recent observations indicate a significant shift in weather patterns in Puducherry UT, characterised by more frequent and intense cyclones, unseasonal rainfall, prolonged dry spells, and heatwaves (Department of Science, Technology & Environment, Government of Puducherry, n.d.; Sudha Rani et al., 2017). With a coastline of 45 km, the low-lying areas of Puducherry are particularly susceptible to the effects of coastal flooding, SLR, and storm surges (Government of Puducherry, 2020). Further, the regions of Puducherry and Karaikal are experiencing a heightened frequency of natural hazards, including storm surges, tsunamis, and cyclones (e.g. cyclone Thane in 2011 and cyclone Nivar in 2020). These climatic anomalies have led to severe coastal soil erosion and saltwater intrusion into coastal aquifers, highlighting the need and urgency to address climate-related challenges in Puducherry UT.

In light of these increasing climate-related extreme events and disasters, a comprehensive multi-hazard risk assessment is essential for Puducherry UT to effectively evaluate and manage the increasing risks. Many international frameworks, including the Sendai Framework for Disaster Risk Reduction, the Global Assessment Report on Disaster Risk Reduction, and the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), emphasise the importance of adopting a multi-hazard approach in disaster risk reduction and policymaking (IPCC, 2023; UNDRR, 2015; UNDRR, 2024). Moreover, robust risk information is critical for various sectors to gain insights into potential impacts, thereby guiding proactive measures. Timely communication of this information enhances awareness and facilitates prompt actions to mitigate risks and implement adaptation strategies (Murnane et al., 2016). Understanding the physical, social, environmental, and climatic processes that drive risk is essential for responding to immediate impacts and planning for long-term resilience through evidence-based decision-making for effective disaster risk management.

The Center for Study of Science, Technology and Policy (CSTEP), along with the Puducherry Climate Change Cell (PCCC) in the Department of Science, Technology and Engineering (DSTE), Government of Puducherry (GoP), has developed a Climate Risk Assessment Tool (CRAT) to visualise the risk of climate hazards such as drought, flood, SLR, and heatwave to agriculture, livestock, health, water, urban, fisheries, and tourism sectors under current and future climate scenarios. The interactive tool is envisaged to aid policymakers in making evidence-based decisions on adaptation measures to combat climate change and increase the resilience of the various sectors in Puducherry UT.

The key questions addressed in this project include the following:

- What is the current and future probability of occurrence of climate hazards, particularly, drought, flood, heatwave, and SLR in Puducherry UT?
- What is the current and future exposure of the agriculture, livestock, fisheries, water, health, tourism, and urban sectors to the aforementioned hazards?
- What is the inherent vulnerability and the drivers of vulnerability for the different sectors?
- What is the current and future climate risk to the various sectors in Puducherry UT?

This report presents the assessment for the four regions of Puducherry UT and is organised as follows:

- Section 2: Overall methodology of climate risk assessment, including hazard, exposure, and vulnerability
- Section 3: Hazard- and sector-specific results. Drivers of vulnerability and measures to reduce the impact across sectors
- Section 4: Way forward

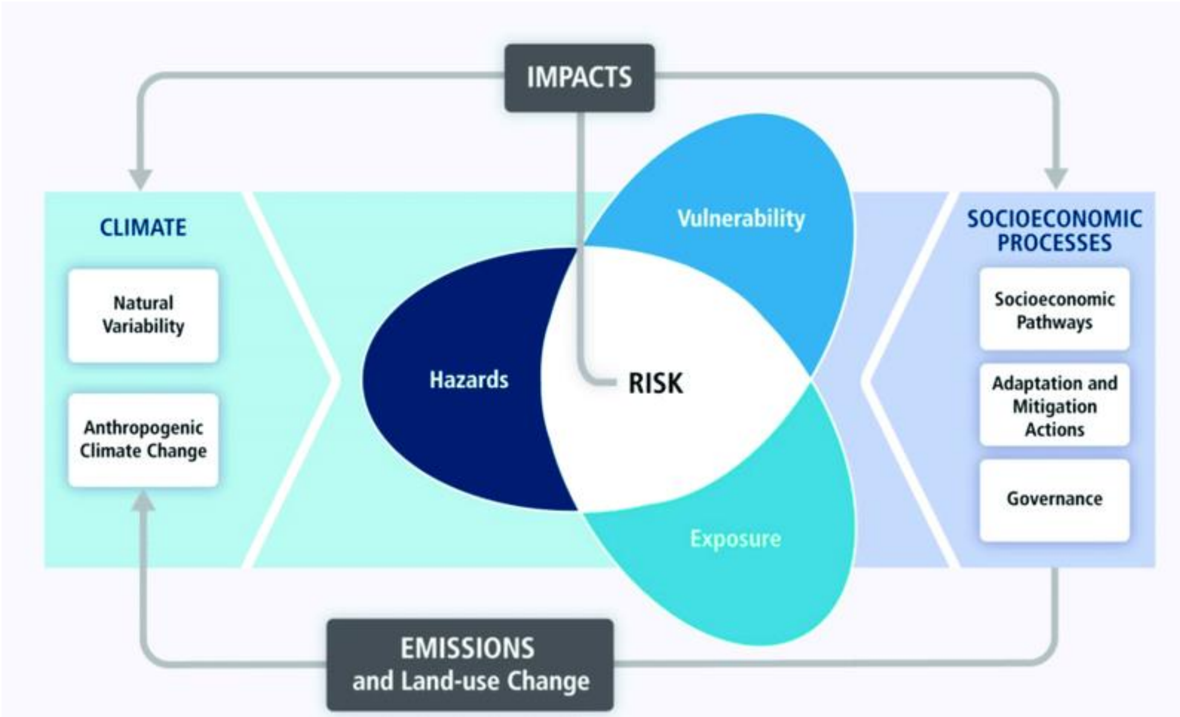
The findings of this study have been integrated into an online tool for policymakers to visualise current and future climate risks to different sectors for the four regions of Puducherry UT. The tool allows the user to toggle through all sectors and hazards to gain a thorough understanding of current and future hazards, exposure, vulnerability, and risk.

2. Methodology

This section details the methods employed to undertake the hazard, exposure, vulnerability, and risk assessments to compute the current and future climate risks to the agriculture, livestock, fisheries, water, health, tourism, and urban sectors of Puducherry UT.

The study employed the risk assessment framework of the IPCC AR5 report, 2014 (Figure 2). The framework computes risk as the dynamic interaction of hazard, exposure, and vulnerability, which are defined in Sections 2.1, 2.2, and 3, respectively.

Figure 2: IPCC AR5 risk assessment framework (2014)



2.1. Hazard

The IPCC (2023) defines hazard as 'The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources'.

For this study, only climate-change-related hazards were considered. In consultation with the PCCC and DSTE, GoP, four hazards—drought, heatwave, flood, and SLR—were identified for the assessment.

The assessment of each hazard followed a twofold process.

Step 1: The **probability of occurrence** of a given hazard was computed using Equation 1.

Equation 1: Probability of occurrence

$$Probability\ of\ occurrence = \frac{Number\ of\ recorded\ or\ projected\ hazard\ events}{Total\ number\ of\ possible\ events}$$

Here, an 'event' is defined on the basis of the specific hazard, the details of which are provided for each hazard from Section 2.1.1. to 2.1.4.

Step 2: The **spatial extent of the hazard** was computed by identifying and extracting grids corresponding to specific regions. The findings were subsequently mapped using the Geographical Information System (GIS) software. Data employed to compute the spatial extent are provided in Table 1

Table 1: Summary of data used to compute the probability of occurrence and spatial extents for all four hazards

Hazard	Time period	Data	Scenario	Source
Drought	Current: 1993–2023	Daily rainfall gridded data of spatial resolution 0.25° × 0.25°	-	India Meteorological Department (IMD)
	Future: 2041–2070	Ensemble of 15 Coupled Model Intercomparison Project Phase 5 (CMIP5) models of resolution 0.50° × 0.50°, gridded to 0.25° × 0.25° by using bi-linear interpolation	RCP 4.5	Coordinated Regional Climate Downscaling Experiment (CORDEX)
Flood	Current: 1993–2023	Topography, land use land cover (LULC), soil type, and rainfall for the observed period	-	Forest and Buildings removed Copernicus Digital Elevation Model (FABDEM), ESA WorldCover 10 m 2020 v100 (Zanaga et al., 2021), the Food and Agriculture Organization (FAO) Soil Grids (250 m), IMD, Central Water Commission (CWC), HydroSHEDS (Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales), Global Surface Water Explorer by the Joint Research Center (Pekel et al., 2016), and CORDEX
	Future: 2041–2070	Topography, LULC, soil type, water mask, and rainfall for the future period	RCP 4.5	
Heatwave	Current: 1993–2022	Daily gridded maximum temperature data of resolution 1° × 1°, gridded to 25° × 25° by using bi-linear interpolation	-	IMD

Hazard	Time period	Data	Scenario	Source
	Future: 2041–2070	Ensemble of 15 CMIP5 models of resolution 0.50° × 0.50°, gridded to 25° × 25° by using bi-linear interpolation	RCP 4.5	CORDEX
SLR	Current: 1972–2021[1]	Yearly sea level data	-	Permanent Service for Mean Sea Level (PSMSL); tide gauge stations: Chennai, Visakhapatnam, and Kochi
	Future: 2041–2070	SLR change. An ensemble of 29 CMIP6 models	SSP2-4.5	SimClim AR6 tool

2.1.1. Drought

Droughts are in general, characterised as a period of below-average water availability that is insufficient to meet the needs of the environment and people (Wilhite & Pulwarty, 2017). There are several types of droughts: meteorological, hydrological, socio-economic, agricultural, and ecological. This study considered meteorological droughts, defined on the basis of the degree of rainfall deficit (or degree of dryness; Reddy & Nagamani, 2008; Roy & Hirway, 2007).

To quantify droughts, several drought indices have been developed over time, such as the Palmer Drought Severity Index (PDSI), Decile Index, Standardised Precipitation Index (SPI), Standardised Precipitation Evapotranspiration Index, Percentage Departure from Normal (PDN), and Effective Drought Index (EDI; Byun & Wilhite, 1999; McKee, 1993; Palmer, 1965; Vicente-Serrano et al., 2010; Willeke et al., 1994). The SPI, created by McKee et al. (1993), is used in this study to identify short- and long-term meteorological droughts on timelines of one, three, six, nine, and twelve months.

Because meteorological station data is only available for Puducherry and not for the other three regions, we employed gridded daily IMD rainfall data of resolution 0.25° × 0.25° for the current time period. For the future time period, an ensemble of 15 CMIP5 models of resolution 0.50° × 0.50°, which were re-gridded using bilinear interpolation to 0.25° × 0.25° resolution, were employed. The grid points that cover the particular regions were considered for the analysis. For Puducherry, four grids (Grid 1-lat-79.5, long-12; Grid 2-lat-79.75, long-12; Grid 3-lat-79.5, long-11.75; and Grid 4-lat-79.75, long-11.75) were considered. Two grids each were considered for Karaikal (Grid 1-lat-79.75, long-11 and Grid 2-lat- 79.75, long-10.75) and Yanam (Grid 1- lat-82, long-16.75 and Grid 2- lat- 82.25, long-16.75) regions. Mahe, the smallest among the four regions, lies in a single grid point (lat-11.75, long-75.5). The data for all grid points were extracted, and the daily rainfall data were converted to monthly rainfall as an input for the SPI generator.

SPI values were computed using the National Drought Mitigation Centre, University of Nebraska's SPI generator application based on McKee et al. (1993). The SPI generator functions by using monthly rainfall data as inputs for both current and future time periods (Table 1). The generator outputs an SPI value for each month of the year. The SPI value of less than −1 is considered a drought, which is further classified as 'moderate drought',

[1]Due to the lack of data availability, the considered time period for Puducherry and Karaikal (the Chennai station) was 1977–2012 while that for Mahe and Yanam (the Kochi and Vishakhapatnam stations, respectively) was 1972–2021.

‘severe drought’, and ‘extreme drought’ (Table 2). This study used the 9-month SPI scale, which indicates inter-seasonal precipitation patterns over the medium accumulation period.

Table 2: Categorisation of drought using SPI (McKee et al., 1993)

Drought type	SPI
Extreme drought	−2 or less
Severe drought	−1.50 to −1.99
Moderate drought	−1.99 to −1.49
Near normal	−0.99 to 0.99
Moderately wet	1 to 1.49
Severely wet	1.5 to 2
Extremely wet	2 or above

Probability of occurrence

The probability of occurrence of drought is computed using Equation 1, where

$$Number\ of\ recorded\ or\ projected\ hazard\ events = Number\ of\ months\ with\ SPI < 1 \text{ and}$$
$$Total\ number\ of\ possible\ events = Total\ number\ of\ months\ in\ 30\ years.$$

Spatial extent

The gridded data from IMD (Table 1) were used to compute the spatial extent of drought. The gridded data was overlaid on the shape files of the four regions of Puducherry UT. The SPI value obtained for each of the grids was subsequently mapped in a GIS environment to arrive at the spatial extent of drought.

2.1.2. Heatwave

A prolonged stretch of considerably hotter-than-average temperatures is commonly referred to as a heatwave. Definitions for a heatwave vary by geographical setting. For India, the IMD declares a heatwave ‘if the maximum temperature of a station reaches at least 40 °C or more over the plains, 30 °C or more in hilly regions, and 37 °C for the coastal regions’ (IMD, 2023). Moreover, these conditions must be met for at least two days before a heatwave is declared. Because Puducherry, Karaikal, and Yanam are coastal regions, a threshold of 37 °C was chosen for these regions in this study. For Mahe, the threshold considered was 30 ℃ as Mahe is a hilly region.

Similar to drought quantification, heatwave quantification used the daily gridded maximum temperature data from IMD of resolution 0.25° × 0.25° (re-gridded using bi-linear interpolation from 1° × 1°) for the current time period and an ensemble of 15 CMIP5 models of resolution 0.25° × 0.25° (re-gridded using bi-linear interpolation from 0.5° × 0.5°) for the future time period.

Probability of occurrence

For this study, we computed the probability of occurrence of at least one heatwave occurring in a year. This was computed using Equation 1, where

$$Number\ of\ recorded\ or\ projected\ heatwave\ events =$$
$$Number\ of\ years\ with\ one\ heatwave\ event, \text{ and}$$

$$Total\ number\ of\ possible\ events = Total\ number\ of\ years.$$

Spatial extent

As explained in the earlier section, the gridded data (averaged over the specific regions) were overlaid on the shape files of the four regions of Puducherry UT.

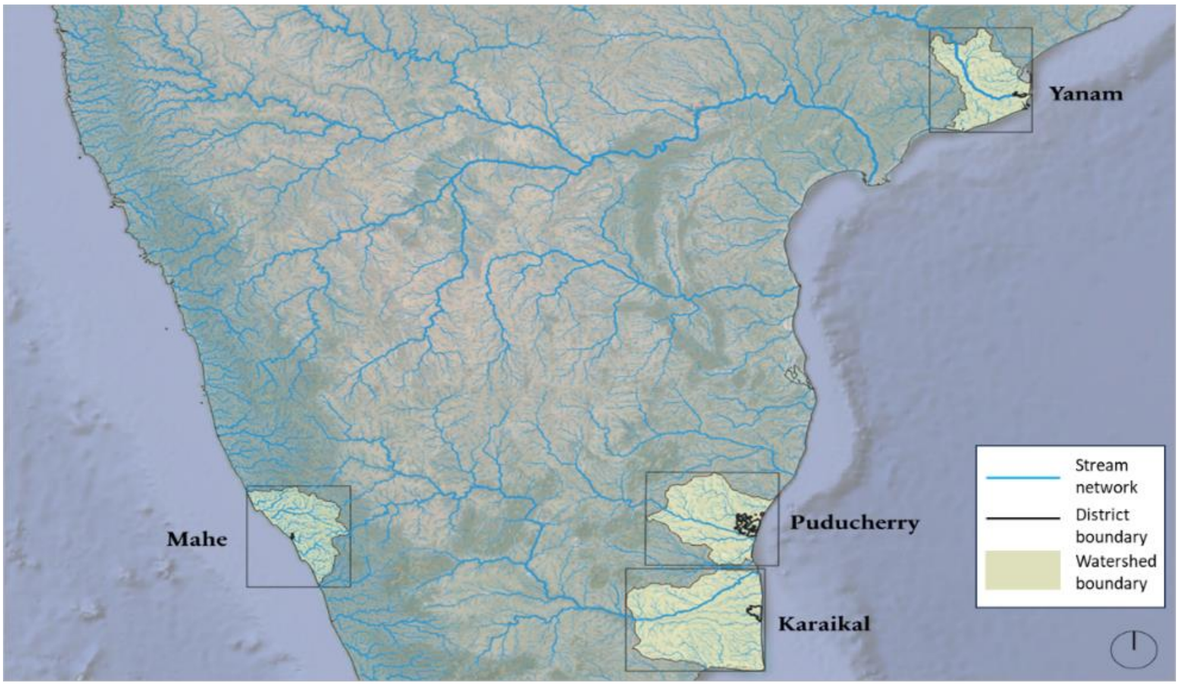
Daily temperature data for the grids were extracted and an average was computed. Heatwave events were classified following the IMD definition. The average number of heatwave events for current and future time periods was then spatially mapped in the GIS environment.

2.1.3. Flood

The IPCC (2023) defines a flood as the 'overflowing of the normal confines of a stream or other waterbody, or the accumulation of water over areas that are not normally submerged'. Floods can be caused by unusually heavy rainfall, usually, during storm surges and cyclones. Floods comprise fluvial (riverine), pluvial (storm drain), and coastal floods. For this study, riverine flood hazard assessment was undertaken for Puducherry UT by using hydraulic modelling[2].

The four regions of Puducherry UT are drained by different rivers. The Karaikal region is part of the Karur drainage system of the Cauvery basin, Mahe is drained by the Mahe river, Puducherry is intersected by the deltaic channels of Gingee and Pennaiyar rivers, and Yanam is part of the Godavari barrage (Figure 3).

Figure 3: Stream network and sub-basin boundaries of Puducherry UT



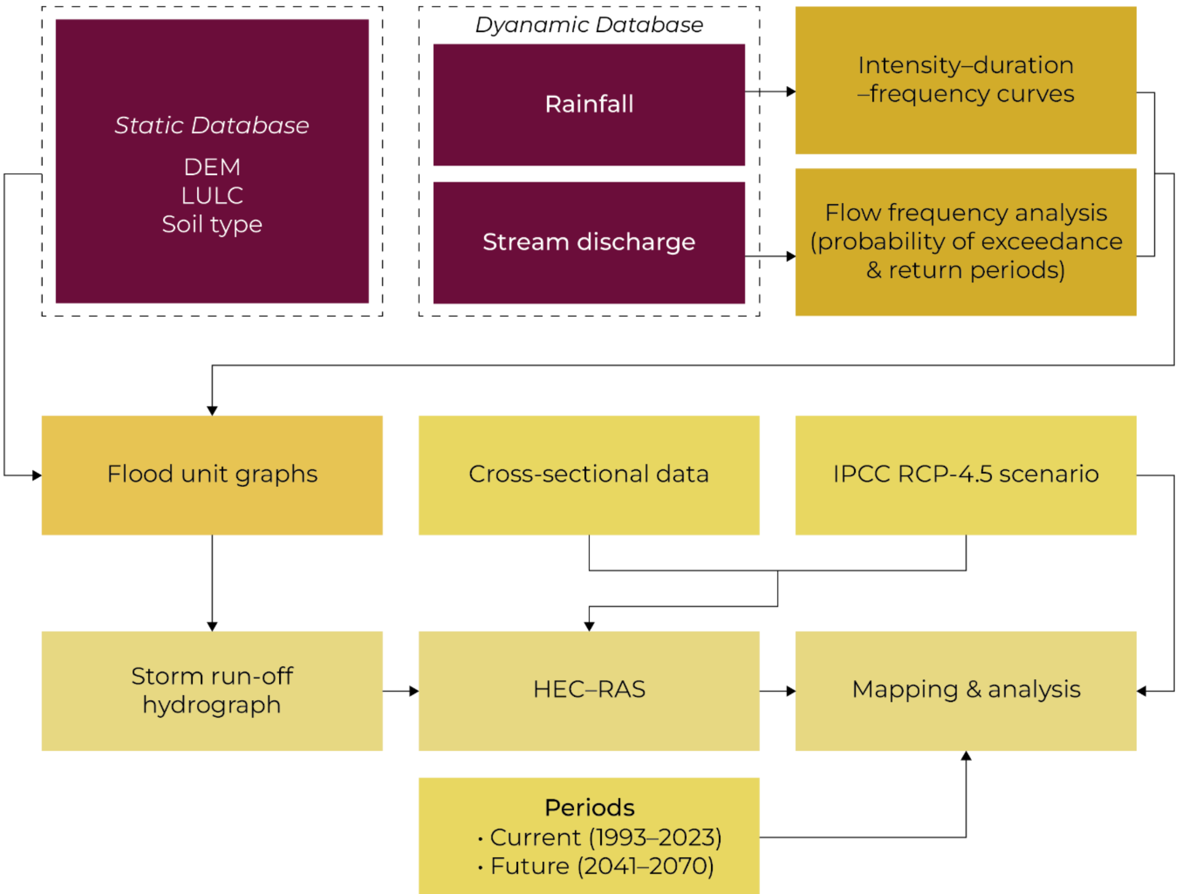
The flood modelling methodology commenced with the collection and categorisation of input data into static and dynamic datasets (Table 1) to estimate the spatial extent of floods for the current (1993–2023) and future time periods (2041–2070) under the IPCC Representative Concentration Pathway (RCP) 4.5 scenario (Figure 4). This methodology leveraged a combination of GIS tools and hydraulic modelling techniques designed for geographic and hydrological data analysis, with a particular focus on integration with the Hydrologic Engineering Center–River Analysis System (HEC–RAS) platform (USACE, 2016).

[2]Hydraulic modelling involves simulating water movement within rivers, channels, and floodplains.

Static datasets included topography (DEM), LULC, and soil type. These datasets were utilised to derive catchment parameters, such as stream order, floodplain delineation, and roughness coefficients. The DEM provided cross-sectional data, including reach lengths and river connectivity, which are essential for hydraulic simulations and floodplain mapping (Tarboton, et al., 1991). Dynamic datasets consisted of rainfall time series, observed stream discharge, and water-level time series. These datasets were analysed to estimate flood characteristics through the development of storm run-off hydrographs, which represent the temporal distribution of run-off during storm events (Chow, et al., 1988). Intensity–duration–frequency curves were generated to evaluate the relationship between rainfall intensity, duration, and frequency, an essential step in understanding extreme precipitation events and their implications for flood modelling (Koutsoyiannis, et al., 1998). Flow frequency analysis was performed to calculate return periods, thereby enabling the assessment of flood risks under various scenarios (FLOODsite, 2009).

The prepared datasets were used to calibrate and validate the HEC–RAS hydraulic model for both current and future conditions. Developed by the United States Army Corps of Engineers, HEC–RAS is a widely accepted and robust tool for simulating water flow dynamics and predicting flood extents and depths under varying hydrological and climatic conditions (USACE, 2016). The outputs from the HEC–RAS simulations, including flood extents and depths for different return periods, were visualised using GIS tools. These outputs provide a detailed spatial representation of flood-prone areas, supporting effective risk assessment and decision-making for both present and future scenarios.

Figure 4: Flood mapping methodology



Probability of occurrence

The probability of occurrence of flood events was determined by their return periods. Return periods are defined as 'an estimate of the average time interval between occurrence of an event (e.g. flood or extreme rainfall) of (or below/above) a defined size or intensity'

(IPCC, 2023). For instance, a return period of 100 years implies a flood that occurs once in 100 years.

To compute the probability of occurrence, Equation 2 was used in this study.

Equation 2: Probability of occurrence of floods

$$Probability\ of\ occurrence = \frac{1}{Return\ period}$$

Spatial extent

The spatial extent of flood for return periods 2, 5, 10, 50, and 100 years was derived through a multi-tier process by using the HEC–RAS 2D model (Figure 4).

In this study, FABDEM topographic data, hydraulic data from HydroSHEDS, and discharge data from CWC and India-Water Resource Information System (WRIS) were used as inputs to the model. The dataset was pre-processed and digitised for seamless integration into HEC–RAS. The model set-up included defining flow boundary conditions, configuring computational grids, and specifying simulation parameters. Calibration involved iterative adjustments to align simulated results with observed data. By utilising a rain-on-grid approach, rainfall inputs were distributed across the computational domain, effectively capturing geographical variations in rainfall and flood patterns. This method integrated various rainfall scenarios and land surface characteristics, making it suitable for assessing flood risk. By solving shallow water equations in HEC–RAS, flow velocities, and water depths, flood extents were predicted using hydraulic modelling.

2.1.4. SLR

Relative sea level change refers to fluctuations in the ocean's elevation relative to adjacent land at a particular site. It is determined by the sum of global, regional, and local sea level influences (Nicholls & Leatherman, 1995; Nicholls, 2002).

To assess the probability of exceedance and spatial extent of SLR in the current time period, annual mean sea level observation data between 1977 and 2012 for Puducherry and Karaikal and 1972 and 2021 for Mahe and Yanam were obtained from the PSMSL[3] databank. Details of tide gauge stations used to compute the probability of occurrence of SLR in Puducherry UT are provided in Table 3.

Table 3: Region-wise details of tide gauge stations

Region	Station
Puducherry	Chennai
Karaikal	
Yanam	Visakhapatnam
Mahe	Kochi

The SimCLIM[4], an integrated assessment modelling tool, was utilised for generating SLR projections for the coastal territories of Puducherry UT by employing the pattern-scaling method.

[3]PSMSL is the global archive for data on long-term sea level changes obtained from tide gauges and bottom pressure recorders (https://psmsl.org/).
[4]SimCLIM Data Manual 4, 2017 (https://www.climsystems.com/)

Probability of exceedance

The probability of exceedance for SLR was computed by selecting SLR thresholds for each region in Puducherry UT (Table 4). The threshold was determined by computing the average SLR over the time period of 1977–2012 for Puducherry and Karaikal, and 1972–2021 for Mahe and Yanam.

Table 4: SLR thresholds for all regions of Puducherry UT

Region	Tide gauge station	Threshold (cm)
Puducherry	Chennai	0.69
Karaikal		
Yanam	Visakhapatnam	2.12
Mahe	Kochi	2.38

The probability of exceedance for SLR is computed using Equation 1, where

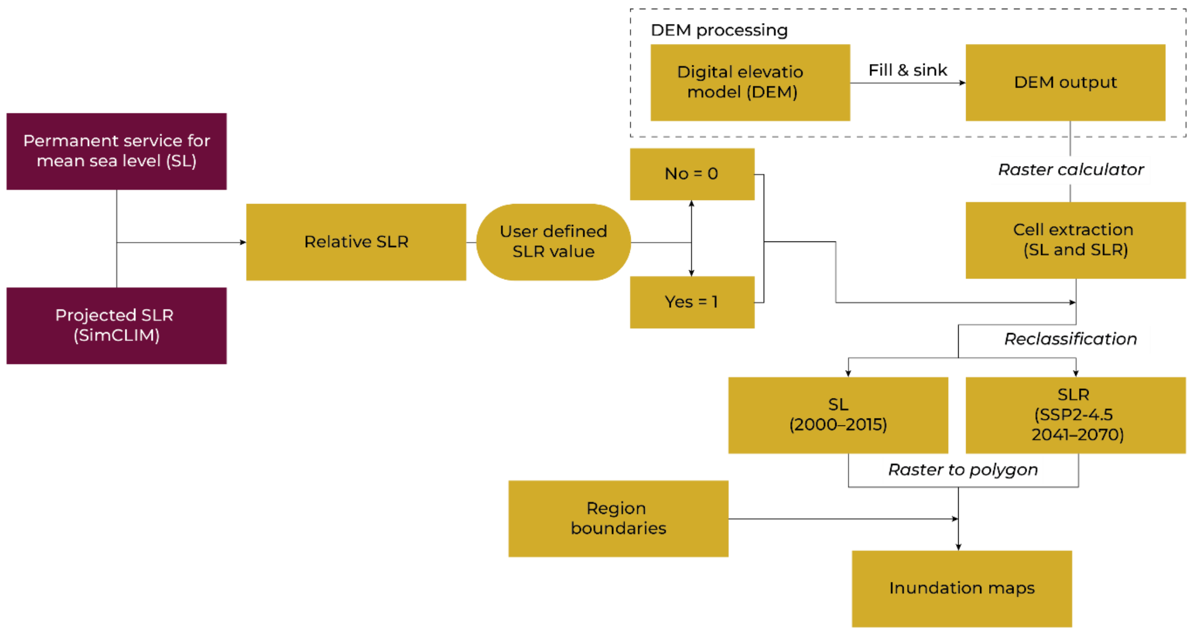
$Number\ of\ recorded\ or\ projected\ hazard\ events = Number\ of\ years\ with\ SLR > threshold$, and

$$Total\ number\ of\ possible\ events = Total\ number\ of\ years.$$

Spatial extent

SLR inundation mapping for the four regions of Puducherry UT employed a comprehensive methodology integrating the GIS-based bathtub model[5] (Phua et al., 2024; Williams & Lück-Vogel, 2020). High-resolution elevation data from Alaska Satellite Facility (ALOS) Phased Array Type L-Band Synthetic Aperture Radar (PALSAR)[6] and DeltaDTM were used to map the inundation area for the considered observed (1972–2021) and projected SSP2-4.5 (2041–2070) scenario (Figure 5). The bathtub model assumes a uniform rise across the study area and effectively identifies areas below the projected sea level by using a DEM (NOAA, 2017; Doyle et al, 2015).

Figure 5: Methodology to generate SLR inundation maps



[5]The most commonly used GIS-based approach to assess the elevation-based inundation area by using a DEM (NOAA, https://coast.noaa.gov/data/digitalcoast/pdf/coastal-inundation-guidebook.pdf).
[6]Alaska Satellite Facility - Distributed Active Archive Center https://asf.alaska.edu/datasets/daac/alos-palsar/.

The DEM was pre-processed to avoid imperfections. Sinks (and peaks)[7] are often errors due to the resolution of data or rounding of elevations to the nearest integer value (Tarboton, et al., 1991). To overcome this, the DEM was processed using a spatial analysis tool, 'Fill and Sink'.

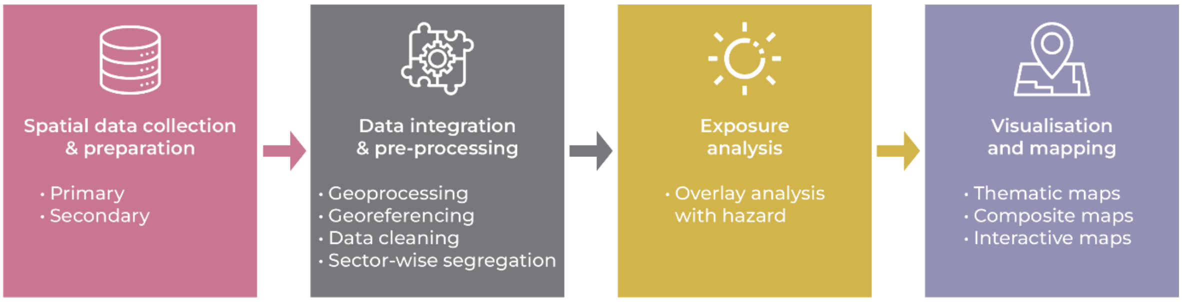
The DEM from ALOS PALSAR offers higher resolution and greater vertical accuracy compared with other DEMs, such as the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Shuttle Radar Topography Mission (SRTM), and Cartosat-1 (Gautam, 2023; Kaliappan & Venkatraman, 2023). Peer-reviewed studies have reported the vertical accuracy of the ALOS PALSAR DEM to be 4.76–5 m; this variation is attributed to different terrain types (Gautam, 2023). This study considered DEM values from 0 m (coastal line) to 5 m as 1 m. Further, a reclassification of the DEM was performed to identify areas with elevation less than 1 m. The ALOS DEM's minimum pixel value over ocean areas is −95, which was considered as zero elevation. Utilising Map Algebra expressions in the Raster Calculator tool, the DEM was reclassified to delineate the desired inundation cells, generating new rasters in accordance with the SSP scenario and the years under consideration.

The reclassified raster layers were converted to a polygon using the Raster to Polygon conversion tool in ArcGIS, followed by the calculation of the inundation area for each region.

2.2. Exposure

IPCC AR6 (2023) defines exposure as the 'presence of people; livelihoods; ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected'. Exposure is assessed geo-spatially and involves identifying and visualising people, assets, and livelihoods that are in hazard zones or regions susceptible to climate hazards. GIS is an effective tool to integrate various types of spatial data, perform complex analyses, and produce detailed maps.

Figure 6: Exposure mapping methodology



The first step in exposure assessment involved collecting indicators' datasets for various sectors (Table 6). Data for the assessment were majorly collected by PCCC and DSTE, GoP. Data on indicators such as 'net sown area', 'gridded livestock', and 'road network data' were sourced from open-source datasets, including Sentinel-2 LULC, Global Livestock of the World (GLW; v4)[8], and OpenStreetMap (OSM[9]; Gilbert et al., 2018). These datasets underwent rigorous quality checks using satellite images from Google Earth Pro[10].

[7]A sink is a specific area in a DEM that is surrounded by higher elevation values on all sides, making it a local minimum in the elevation data. A peak is a specific area in a DEM that is surrounded by low elevation values on all sides (ArcGIS pro-2024).
[8] GLW is a sub-national global spatial dataset depicting livestock distribution at approximately 10 km resolution near the equator. It is derived from a statistical model that considers various spatial predictors such as human population density, vegetation indexes, topography, and other factors.
[9] OSM is a collaborative project that creates geospatial datasets at global scales and is made available to use it in open licenses (/www.openstreetmap.org/).
[10] Google Earth Pro is a free desktop application that allows users to view and analyse high-resolution satellite imagery and maps.

The quality assurance process included evaluating spatial accuracy, verifying attribute data, and ensuring consistency across layers, which improved the reliability and usability of OSM data for the assessment. The gridded livestock data were further cross-verified and validated against the 2019 Indian Animal Husbandry Census data (Ministry of Fisheries, Animal Husbandry and Dairying, 2019).

The datasets were then integrated and pre-processed. This involved geoprocessing all spatial data layers to align them within a common coordinate system, cleaning the data to remove errors and inconsistencies, and creating layers for each data for different sectors for the four regions of the UT. The datasets were then categorised on the basis of their geometry into three classes: point, line, and polygon (Appendix 1). These categorised datasets were subsequently used for exposure analysis.

The purpose of exposure assessment is to identify assets and livelihoods through an indicator-based approach in hazard-prone zones. The results of the exposure assessment were calculated as a percentage (Equation 3) and used for risk computation.

The exposure analysis sought to produce two outputs:

1. Exposure maps: The spatial extent maps were overlaid with the spatial layers of the indicators in Table 5, and
2. Percentage of exposure, as calculated using Equation 3.

Equation 3: Percentage of exposure

$$Percentage\ of\ exposure = \frac{Total\ number\ of\ (people, assets, and\ livelihoods)\ within\ the\ hazard\ zone}{Total\ number\ of\ (people, assets, and\ livelihoods)\ in\ the\ district}$$

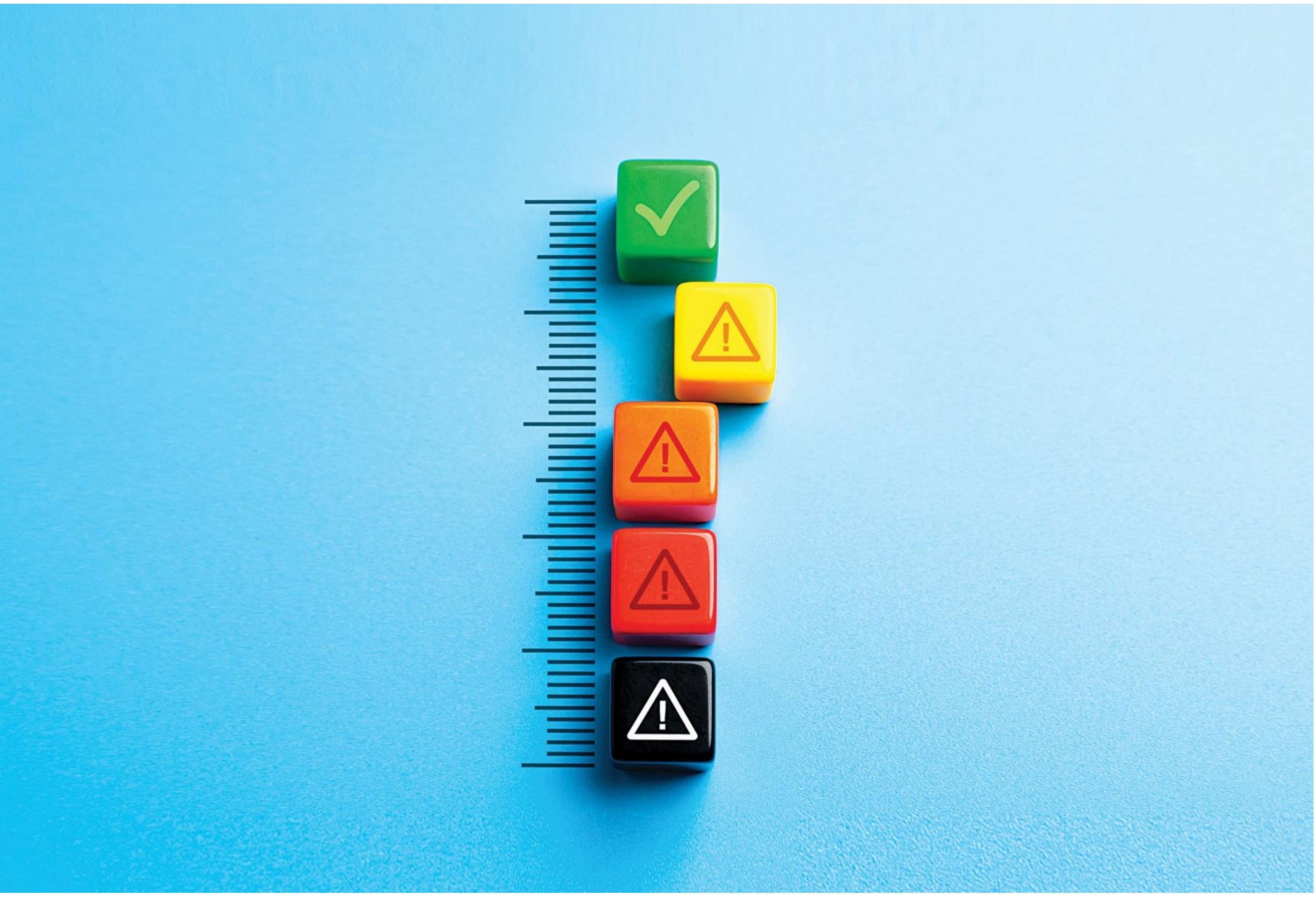


Table 5: Sector-wise exposure indicators

Sector	Indicator	Sub-indicator	Data source
Agriculture	Agriculture market	-	PCCC
	Food processing unit	-	
	Net sown area	-	Sentinel-2A/ PCCC
	Storage godown	-	PCCC
Fisheries	Essential infrastructure	Cold storage	PCCC
		Community hall	
		Diesel bunk	
		Fish auction hall	
		Fish curing yard	
		Fish drying platform	
		Net mending sheds	
		Work shelters	
	Mangrove	-	
Health	Anganwadi	-	PCCC
	Medical facility	Diagnostic centre	
		Government hospital	
		Nursing home	
		Pharmacy	
		Private hospital	
	Old age home	-	
Livestock	Cattle	-	PCCC
	Dairy booth	-	
	Dairy farm	-	
	Key village unit	-	
	Livestock population	Cattle	GLW-v3
		Chicken	
		Sheep	
	Medical facility	Government hospital	PCCC
	Poultry farm	-	
	Slaughterhouse	-	
	Veterinary dispensary	-	
Tourism	Bus stand	-	PCCC
	Church	-	
	Guesthouse	-	

Sector	Indicator	Sub-indicator	Data source
	Hotel, lodge, and restaurant	-	
	Monument	-	
	Mosque	-	
	Railway station	-	
	Resort	-	
	Temple	-	
	Tourist facility centre	-	
Urban	Green space	-	Sentinel-2A/ PCCC
	Municipal urban area	-	PCCC
	Railway line	-	
	Railway station	-	
	Road network	-	
Water	Canal network	-	PCCC
	Check dam	-	
	Drainage network	-	
	River	-	
	Sewage treatment plant	-	
	Water pumping station	-	
	Water treatment plant	-	
	Waterbody	-	

2.3. Vulnerability

The IPCC AR5 (2014) defines vulnerability as 'the propensity or predisposition to be adversely affected'. Further, vulnerability encompasses sensitivity, 'the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change,' and adaptive capacity, 'the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences' (Agard & Schipper, 2014).

To assess the inherent vulnerability of the agriculture, livestock, fisheries, water, health, tourism, and urban sectors of Puducherry UT, the broad steps listed in Table 6 were followed.

Table 6: Broad steps adopted for sectoral vulnerability assessment

SN	Step	Description
1	Scoping and objective	A comprehensive ranking of the regions within Puducherry UT based on a vulnerability scale ranging from high to low. This ranking may be used to prioritise and implement targeted resilience and adaptation strategies.
2	Type of vulnerability assessment	An indicator-based, integrated vulnerability assessment by choosing bio-physical, socio-economic, institutional, and governance indicators that represent the sectors of interest.
3	Selection of tier	A tier-3 methodology using secondary data, data from relevant line departments, and geospatial tools and techniques to quantify indicators.
4	Selection of sector, spatial scale, and period	Current or inherent vulnerability was assessed for the agriculture, livestock, fisheries, water, health, tourism, and urban sectors at the UT level.
5	Identification, definition, and selection of indicators	An initial list of indicators was compiled on the basis of literature review and expert judgement. Indicators were finalised through consultation with stakeholders from all relevant line departments. The consultation was organised by PCCC and DSTE, GoP, on 20 July 2023, wherein 39 stakeholders from 21 line departments were in attendance. Details on the attendees are provided in the Appendix.
6	Quantification of indicators	Indicators were quantified using GIS and data provided by line departments (compiled and shared by PCCC and DSTE) and secondary data sources.
7	Normalisation of indicators	The involvement of various bio-physical, socio-economic, institutional, and governance-related variables with differing units required the normalisation of these indicators to dimensionless units for aggregation. This normalisation process was based on their functional relationship with vulnerability to enable their aggregation into a vulnerability index (VI). There are two types of functional relationships: A positive relationship, where vulnerability rises as the value of the indicator increases. In this scenario, the

SN	Step	Description
		variables have a direct and positive functional relationship with vulnerability, and normalisation is performed using the following equation: Equation 4: Computation of VI when the variable exhibits a positive relationship with vulnerability $$x_{ij} = \frac{X_{ij} - Min\, X_{ij}}{Max\, X_{ij} - Min\, X_{ij}},$$ where, X_{ij} is the value of the indicator j corresponding to the region i. In (1), X_{ij} is the variable that is being normalised, and x_{ij} is the normalised value of X_{ij}. All x_{ij} scores will lie between 0 and 1. Value 1 will correspond to the region with maximum sensitivity, and 0 will correspond to the region with minimum sensitivity. Similarly, indicators can have a negative relationship, where vulnerability increases with a decrease in the value of the indicator. Here, indicators have a negative or inverse functional relationship with vulnerability. In this case, the normalised score is computed using the following equation: Equation 5: Computation of VI when the variable exhibits a negative relationship with vulnerability $$x_{ij} = \frac{Max\, X_{ij} - X_{ij}}{Max\, X_{ij} - Min\, X_{ij}}$$ Further, outliers were computed using the interquartile method and were excluded from the normalisation process. Outlier values of sensitivity indicators that are lower than the lower limit get a score of 0 and values that are over the upper limit get a score of 1. The inverse is true for adaptive capacity indicators.
8	Assigning weights	Equal weights were assigned to all indicators.
9	Aggregation	Indicators were aggregated by taking a simple mean of normalised scores for each region. This is the VI value for each region.
10	Ranking	Regions were ranked on a three-point scale: high, moderate, and low vulnerability for visualisation.
11	Representation of results	Sectoral vulnerability assessment results have been represented as bar graphs in this report, but are represented as colour-coded region maps in the CRAT.
12	Drivers of vulnerability	The drivers of vulnerability were identified for each sector and region for the development of targeted interventions.

2.3.1. Vulnerability classification

The vulnerability results are presented as inter-regional vulnerability and inter-sectoral vulnerability. An inter-sectoral vulnerability assessment allows the user to compare the vulnerability across sectors for any given region. An inter-regional vulnerability assessment allows the user to compare between different regions for the same sector. For the former, the classification is performed by simply dividing the range of 0 to 1 into three equal classes (Table 7).

Table 7: Vulnerability classification

Range	Class
0–33.3	Low
33.34–66.67	Medium
66.68–100	High

Inter-regional vulnerability classification follows an equal-interval classification method, wherein the data range is split into three equal intervals. The classification legend for each sector is provided in Appendix 4.

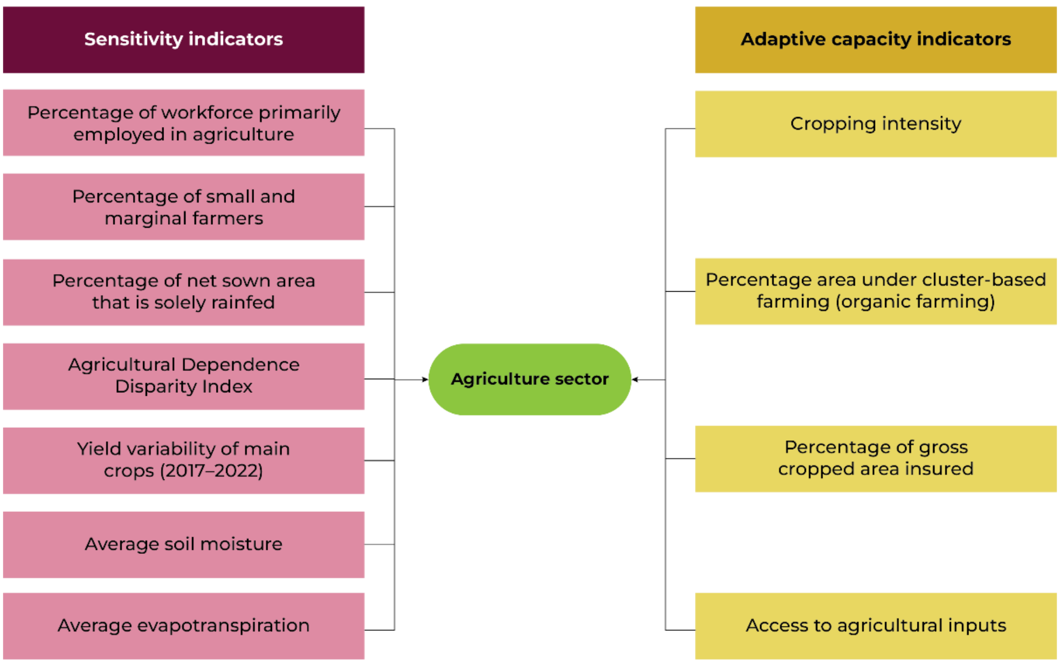
2.3.2. Sector-wise vulnerability indicators

The indicators used to represent each sector and compute sectoral VIs are provided in Figure 7 to Figure 13. The detailed description and rationale for the selection of indicators are provided in Appendix 3.

1. Agriculture sector

In this study, 11 indicators were selected to compute the vulnerability of the agriculture sector (Figure 7). The indicator, 'access to agricultural inputs', comprises four sub-indicators: number of input stores per farmer, number of seed processing units per farmer, number of tractors for the total area cultivated, and number of tillers for the total area cultivated. These sub-indicators were normalised using Equation 4 in Table 6 and aggregated by taking a simple arithmetic mean of normalised scores.

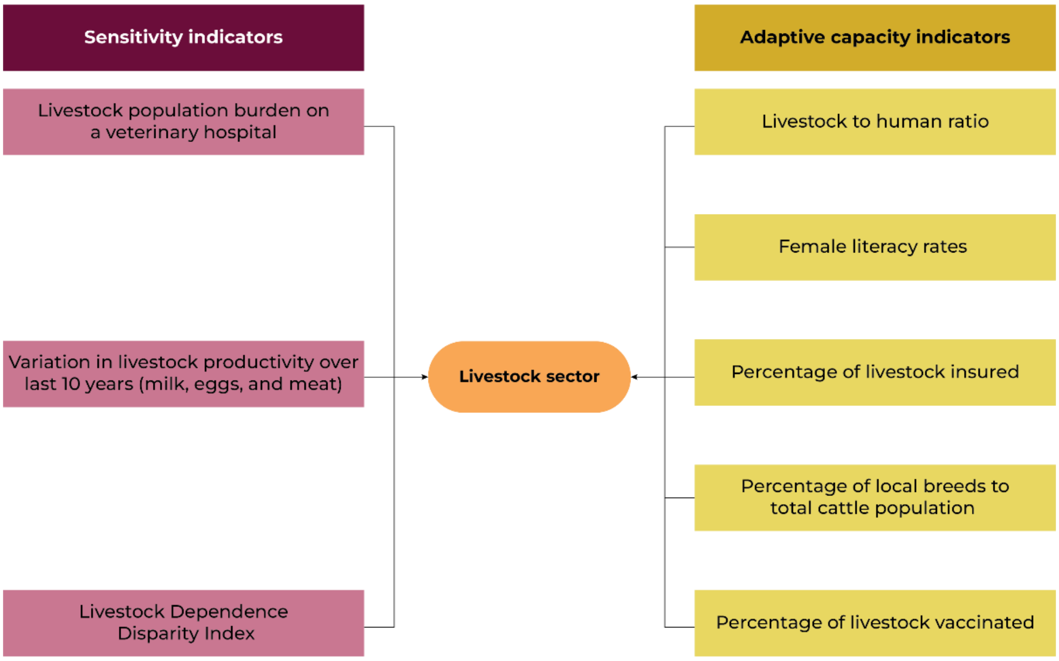
Figure 7: Indicators used for vulnerability assessment of the agriculture sector



2. Livestock sector

Eight indicators were selected for computing livestock sector vulnerability (Figure 8)

Figure 8: Indicators used for vulnerability assessment of the livestock sector



3. Fisheries sector

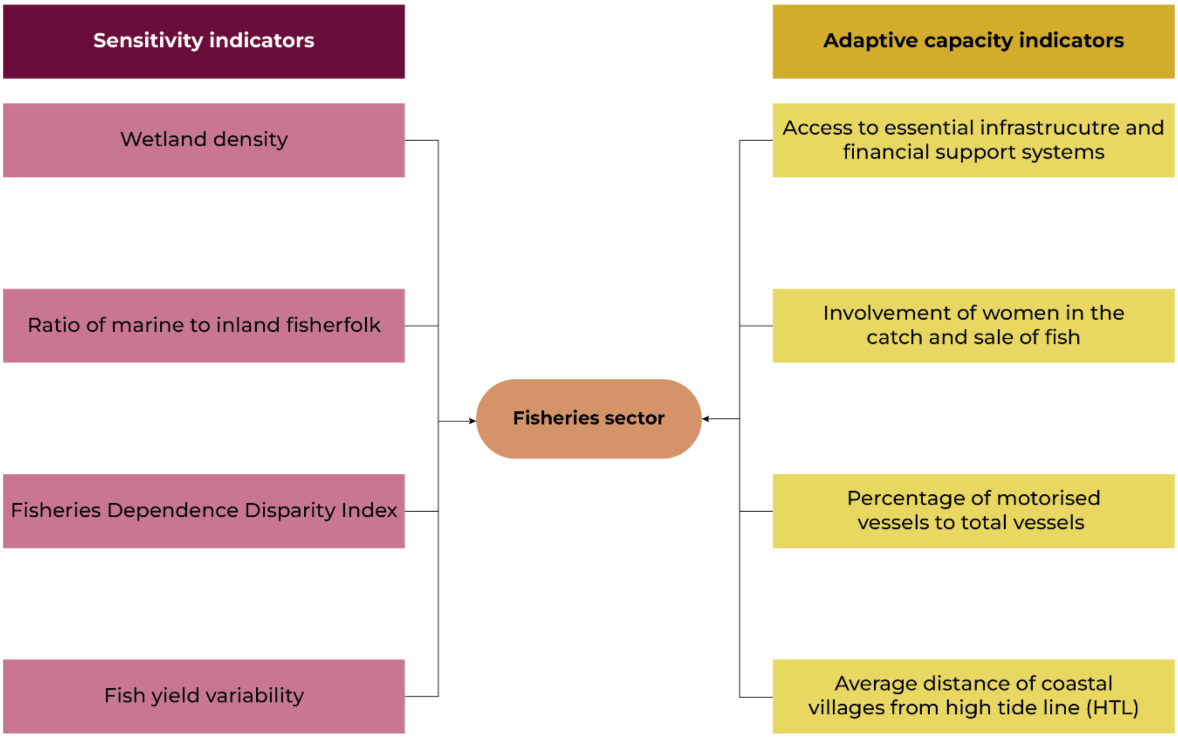
Eight indicators were used to calculate the vulnerability of the fisheries sector (Figure 9).

The indicator 'access to essential infrastructure and financial support systems' comprises the following 11 sub-indicators:

i. Cold storage
ii. Community hall
iii. Fish auction hall
iv. Fish curing yard
v. Net mending shed
vi. Work shelter
vii. Fish drying platform
viii. Diesel bunk
ix. Fish landing point
x. Fish harbour
xi. Co-operative society

These sub-indicators were standardised using the total fisherfolk population, followed by aggregation using Equation 5.

Figure 9: Indicators used for vulnerability assessment of the fisheries sector

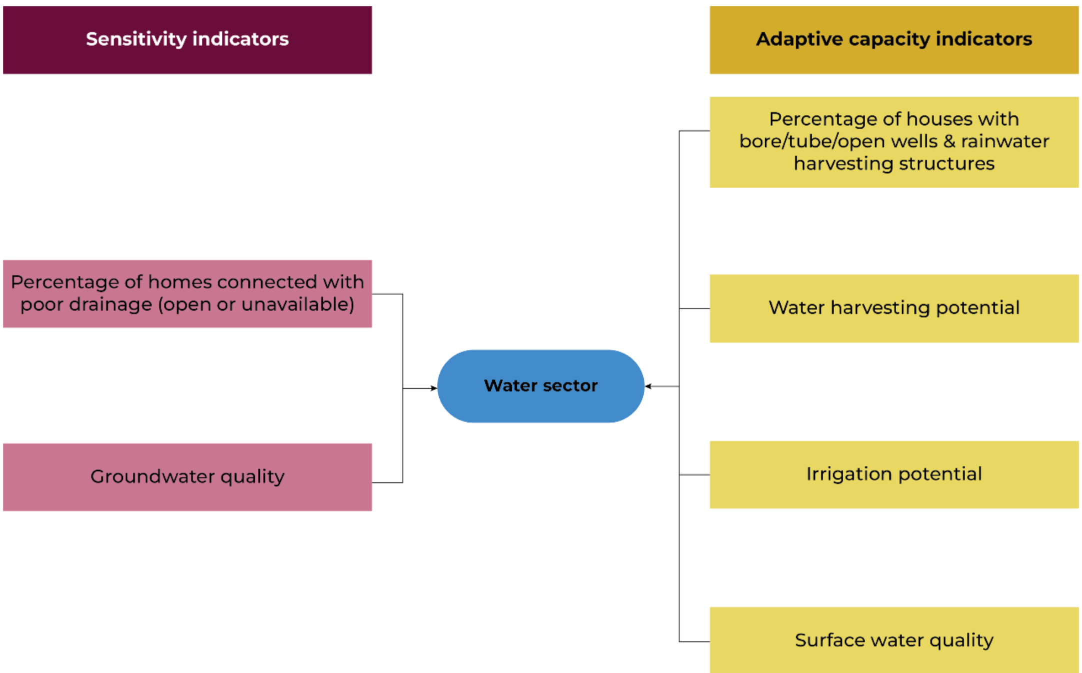


4. Water sector

Six indicators were used to calculate the vulnerability of the water sector (Figure 10). 'Percentage of homes with poor drainage (open or unavailable)' is a composite indicator, comprising the following two indicators:

1. Percentage of homes with open drainage
2. Percentage of homes with no drainage

Figure 10: Indicators used for vulnerability assessment of the water sector



5. Health sector

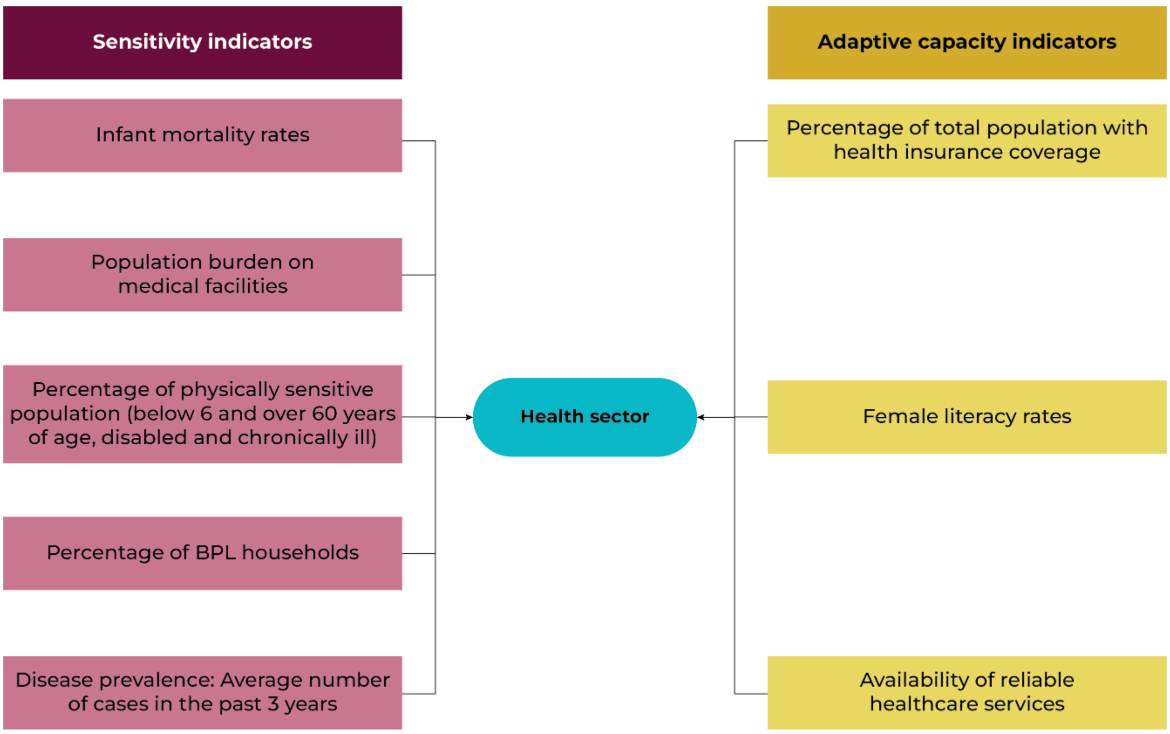
Eight indicators were used to assess vulnerability of the health sector (Figure 11). Two of these indicators are composed of the following sub-indicators:

a. Physically sensitive population density (below 6 and above 60 years of age; disabled and chronically ill)
   i. Percentage of population below 6 years of age
   ii. Percentage of population above 60 years of age
   iii. Percentage of population living with disability

b. Availability of reliable healthcare services
   i. Number of doctors/medical facility
   ii. Number of beds/medical facility

The indicator 'disease prevalence rate' was computed by considering the total number of cases of tuberculosis, influenza, malaria, typhoid, dengue, chikungunya, kala-azar, Japanese encephalitis, lymphatic filariasis, acute diarrhoeal diseases, viral hepatitis (A and E), acute encephalitis syndrome, heatstroke, diabetes, hypertension, heart disease, all types of cancer, and AIDS, reported in the past three years.

Figure 11: Indicators used for vulnerability assessment of the health sector



6. Urban sector

Eight indicators were used to compute the vulnerability of urban areas (Figure 12). Of these, four indicators are composed of the following sub-indicators:

a) Percentage of houses with basic amenities

   i. Percentage of houses with drinking water sources within the house
   ii. Percentage of houses with latrine within their premises
   iii. Percentage of houses where cooking happens indoors
   iv. Percentage of houses that receive water from a treated source
   v. Percentage of houses with a bathroom within their premises
   vi. Percentage of houses where wastewater is connected to a closed drain

b) Surface water quality

   i. Temperature
   ii. Biological oxygen demand (BOD; mg/L)
   iii. Dissolved oxygen (DO; mg/L)
   iv. Total suspended solids (TSS; mg/L)
   v. Conductivity (uS/cm)

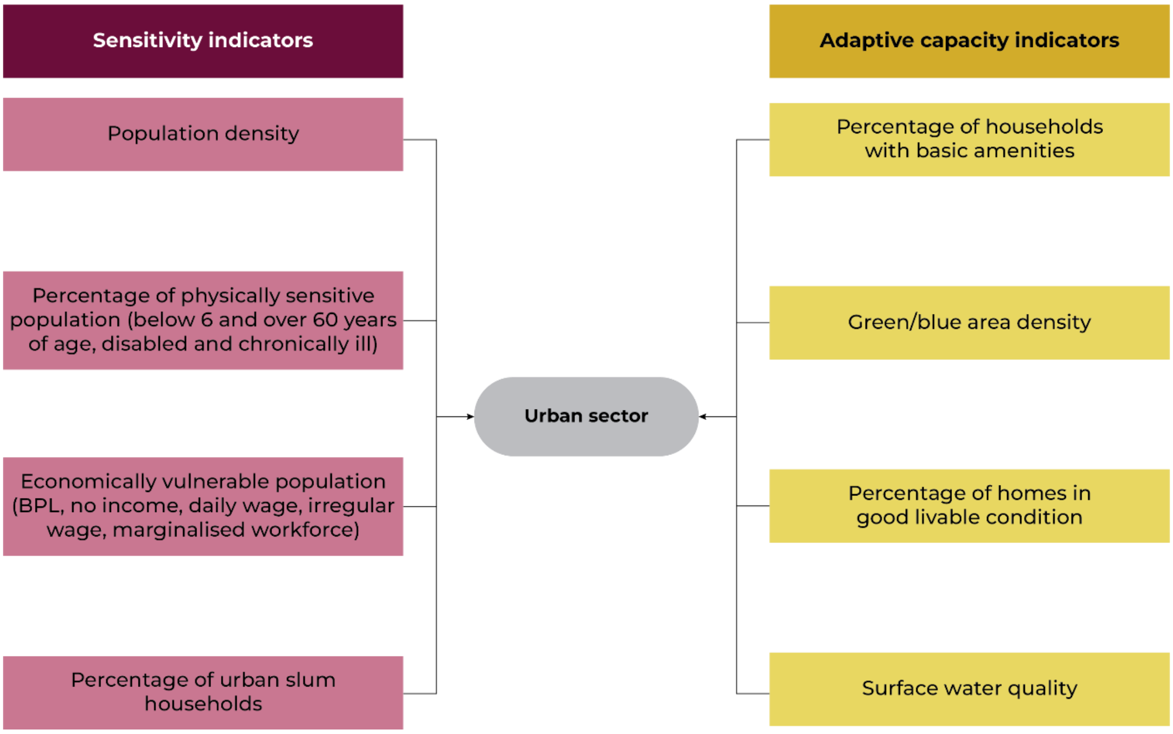
c) Physically sensitive population density

   i. Percentage of population below 6 years of age
   ii. Percentage of population above 60 years of age
   iii. Percentage of chronically ill population (suffering from diabetes, hypertension, heart disease, cancer, and/or AIDS)

d) Economically sensitive population density

   i. Percentage of population living below the poverty line
   ii. Percentage of population with no income
   iii. Percentage of population with irregular wages

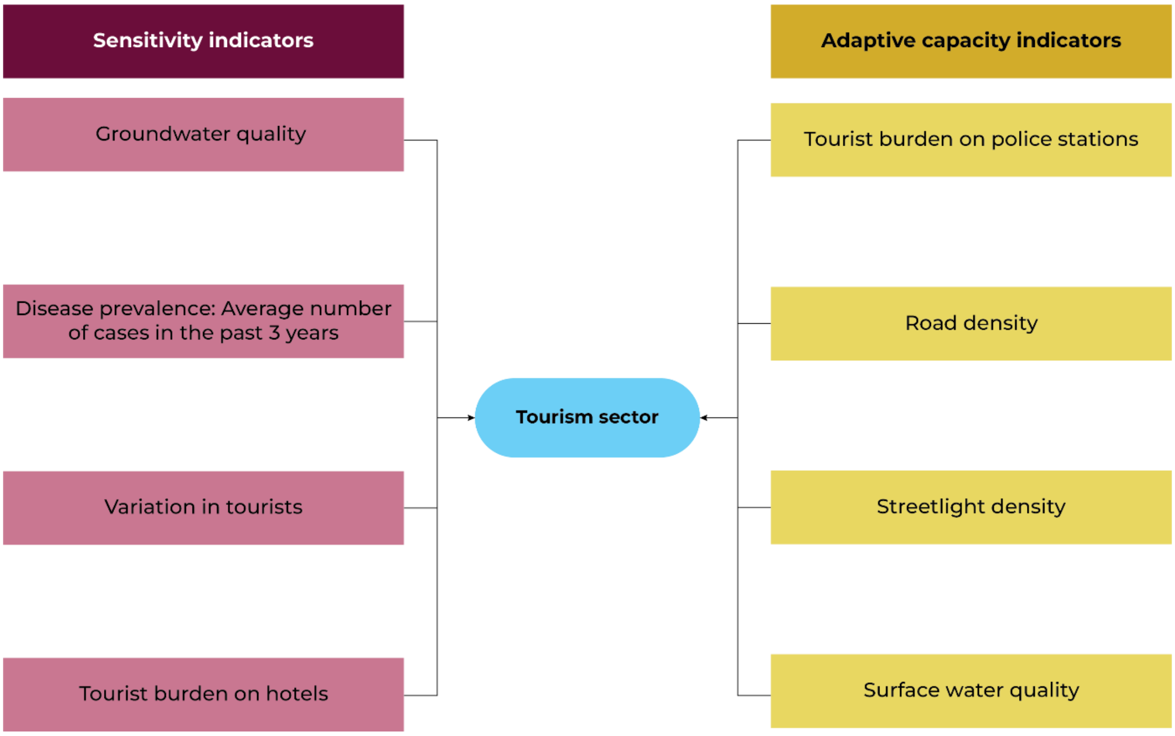
Figure 12: Indicators used for vulnerability assessment of the urban sector



7. Tourism

Vulnerability was assessed for the tourism sector by using eight indicators (Figure 13). Two indicators, 'variation in tourists' and 'surface water quality', are composed of sub-indicators. The sub-indicators for surface water quality are the ones presented under the urban sector. The sub-indicators for 'variation in tourists' are the number of domestic tourists recorded between 2018 and 2022 and the number of international tourists recorded between 2018 and 2022.

Figure 13: Indicators used for vulnerability assessment of the tourism sector



Inherent sectoral VI scores were utilised for assessing the current climate risks to selected sectors. To assess the future climate risk to the selected sectors, the current inherent vulnerability was considered due to data limitations and non-feasibility of predictive assessment methodologies.

2.4. Risk

The IPCC AR6 (2023) defines risk as the 'potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change, as well as human responses to climate change'.

Risk is computed as the geometric mean (Equation 6) of the probability of occurrence, percentage of exposure, and vulnerability. In this study, a risk score was computed for each sector and hazard for both current and future time periods. These scores were then used to rank the regions on a three-point scale of high, moderate, and low risk to the hazards selected in this study.

Equation 6: Equation to compute risk

$$Risk_{(hazard,\ sector,\ time-period)} = \sqrt[3]{(Probability\ of\ occurrence\ of\ hazard\ \times Percentgae\ of\ exposure\ \times Vulnerability)}$$

2.4.1. Risk classification

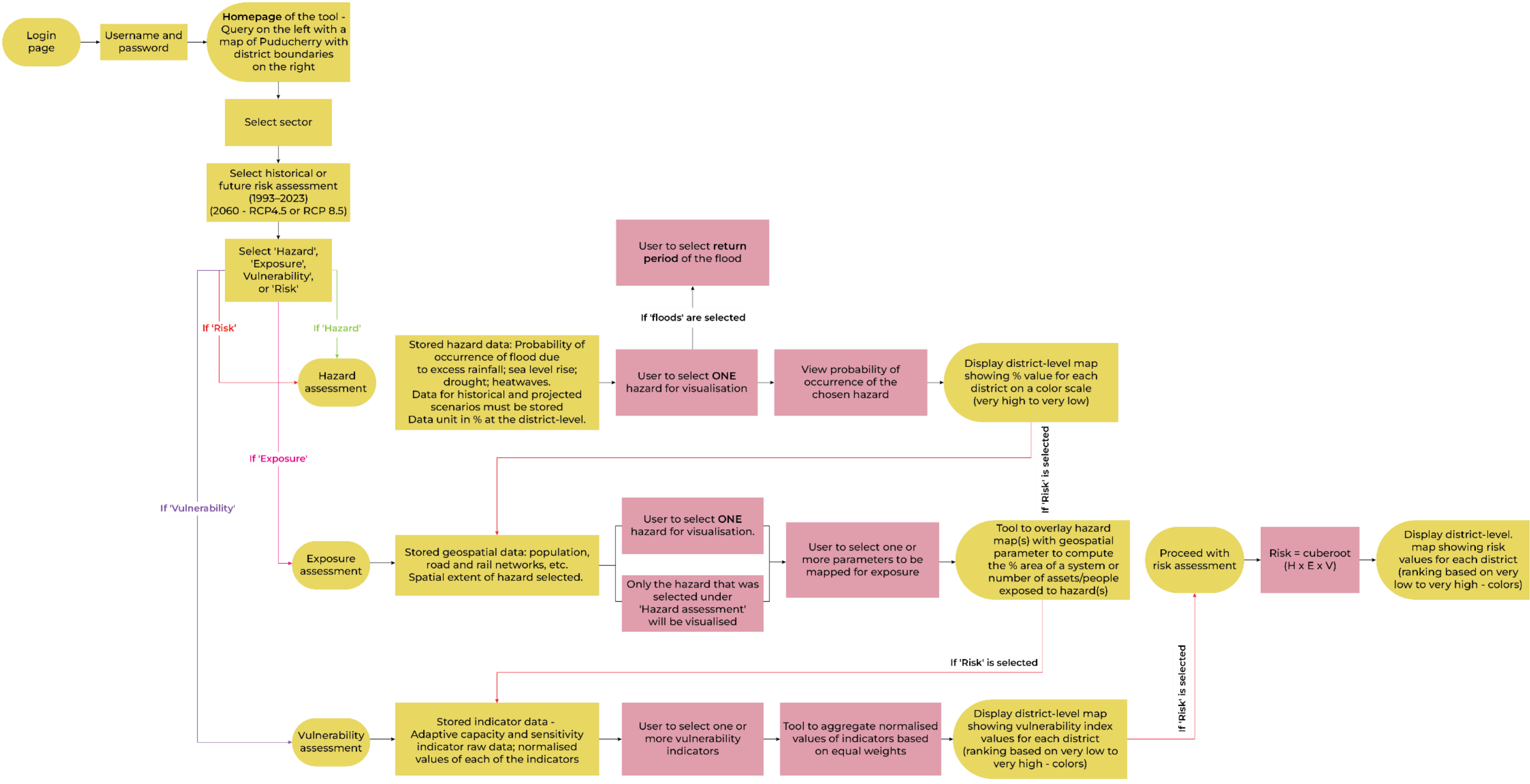
Similar to the classification of vulnerability, risk is presented as inter-regional and inter-sectoral. Inter-sectoral risk allows users to compare risk across multiple sectors for a given region, while inter-regional risk allows users to compare risk between regions, for a given sector. The methodology for inter-sectoral and inter-regional risk is as computed for vulnerability (Section 2.3.1). The classification legend for inter-regional risk is presented in

2.4.2. CRAT – Climate Risk Assessment Tool

The findings of the study have been integrated into a dynamic visualisation tool.

A basic algorithm was developed to guide the back- and front-end engineering of the tool (Figure 14).

Figure 14: Algorithm for the web-based interactive tool (CRAT)



S

In this study, CRAT was developed using four major components: Angular, GeoServer, Django (Python), and PostgreSQL database. Angular is used for building the front end, Django (Python) served as the back-end framework, GeoServer handled geospatial data, and PostgreSQL acted as the database. Together, they enabled the development of a web application that visualises geospatial data on maps using Leaflet.

Back-end engineering

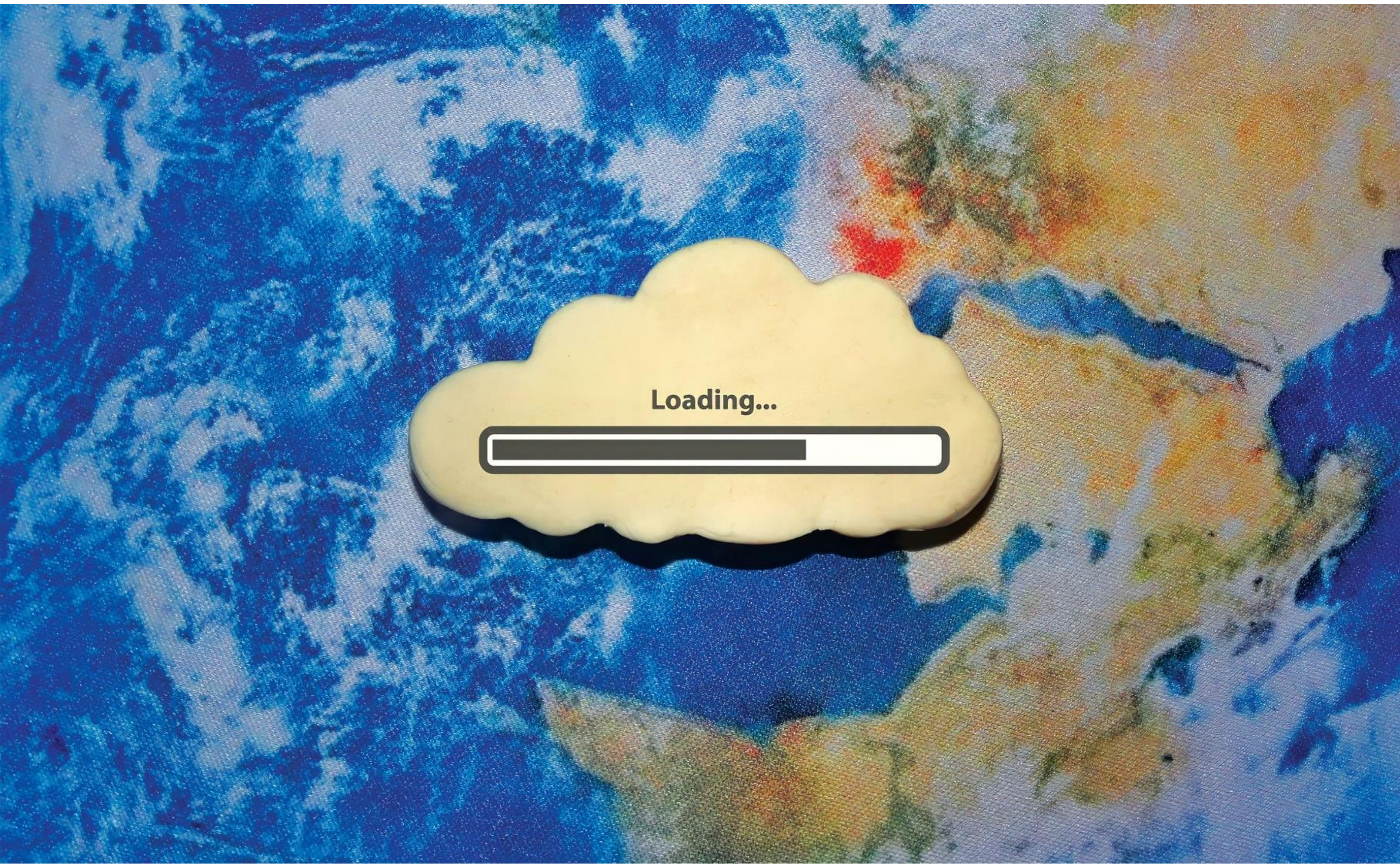
Django (Python) serves as the back-end framework in this architecture, leveraging its Django REST Framework (DRF) to create RESTful application programming interfaces (APIs). These APIs handle data requests from the Angular front end and manage interactions with the PostgreSQL database, ensuring smooth data flow between the database and the front end.

PostgreSQL is used for data storage. Django communicates with PostgreSQL to manage data retrieval and storage, ensuring the data is properly formatted and ready for the process and to serve to the front end.

Front-end engineering

Angular serves as the front-end framework, enabling the creation of dynamic applications. Angular interacts with GeoServer to fetch geospatial data, such as polygons, points, and lines, and visualises this data on maps using Leaflet, a lightweight JavaScript library for interactive maps. This set-up allows users to interact with geospatial data in a seamless and responsive environment.

GeoServer plays a crucial role in managing and processing geospatial data. It acts as an intermediary between the geospatial data and the Angular front end. GeoServer outputs are processed data in formats compatible with Leaflet, enabling Angular to display complex spatial datasets on the web application.



3. Results

3.1. Hazard

The probability of occurrence, which is classified as 'high', 'medium', and 'low', is colour-coded as shown below.

	High probability of occurrence
	Medium probability of occurrence
	Low probability of occurrence

3.1.1. Drought

Probability of occurrence

The average 9-month SPI index indicated that all four regions of the UT experienced moderate drought during the current time period (1993–2022). Similarly, they are projected to experience moderate drought in the future under the RCP-4.5 scenario. The number of drought events, in the current and future time periods, are presented in Table 8.

Table 8: Current and future drought events

	Number of drought event	
Region	**Current (1993–2022)**	**Future (2041–2070)**
Puducherry	36	41
Karaikal	27	36
Yanam	36	21
Mahe	20	28

The probability of occurrence of moderate drought in the four regions is represented in Table 9. It is evident that the Puducherry and Yanam regions in the UT have witnessed the highest number of moderate droughts in the past, with a high probability of a moderate drought occurring every year. In the future, Puducherry and Karaikal both have a high probability of occurrence of a moderate drought, while Yanam and Mahe have low probability of occurrence of a moderate drought.

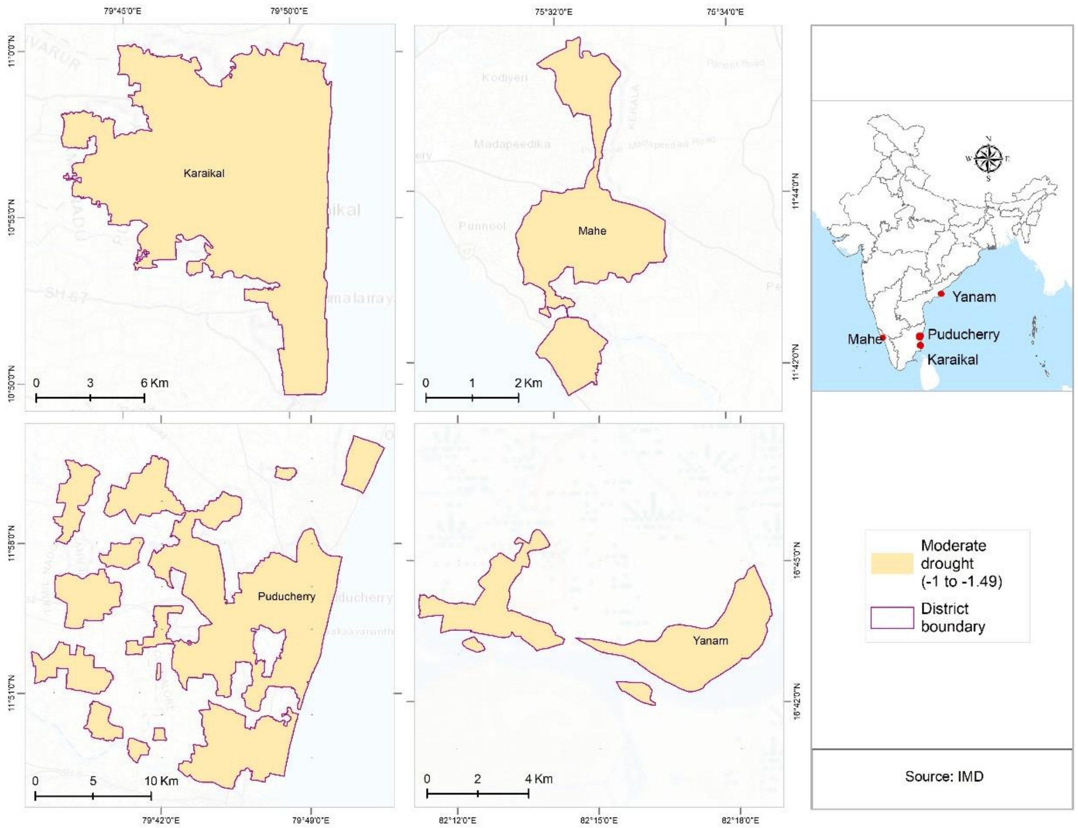
Table 9: Region-wise probability of occurrence of moderate drought for current and future time periods

Region	Current (1993–2022)	Future (RCP 4.5, 2041–2070)
Puducherry		
Karaikal		
Yanam		
Mahe		

Spatial extent

All four regions experienced moderate drought conditions under both current and future (RCP 4.5) time periods. As the resolution of the rainfall data used to assess drought was low and the size of the four regions of Puducherry UT is small, the spatial extent of moderate drought covers all four regions. Figure 15 depicts droughts in the current and future time periods.

Figure 15: Spatial extent of droughts in the current (1993–2022) and future (RCP 4.5, 2041–2070) time periods



3.1.2. Heatwave

Probability of occurrence

The probability of occurrence of at least one heatwave event is presented in Table 11, while Table 10 summarises the number of years with single heatwave events in Puducherry UT.

Puducherry, Karaikal, and Yanam have the highest probability of occurrence of one heatwave event per year in the current time period. In the future, Karaikal and Yanam continue to have high probability of heatwave occurrence, and Puducherry and Mahe have a low probability.

Table 10: Number of years with one heatwave event per year in Puducherry UT for the current and future time periods

Region	Current (1993–2022)	Future (RCP 4.5; 2041–2070)
Puducherry	16	2
Karaikal	14	15
Yanam	14	19
Mahe	0	6

Table 11: Region-wise probability of occurrence of heatwave for current and future time periods

Region	Current (1993–2022)	Future (RCP 4.5, 2041–2070)
Puducherry		
Karaikal		
Yanam		
Mahe		

Spatial extent

The analysis of daily maximum temperatures revealed that the maximum heatwave events occurred in Karaikal (45), followed by Yanam (44) and Puducherry (39) during the current (1993–2022) time period. Mahe did not experience any heatwave events during the current time period (Figure 16). In the future, a similar trend is projected for heatwave events for the four regions under the RCP-4.5 scenario. Puducherry is projected to experience 87 heatwave events, followed by Karaikal (54), Yanam (42), and Mahe 6; (Figure 17).

Figure 16: Spatial extent of heatwaves in the current (1993–2022) time period

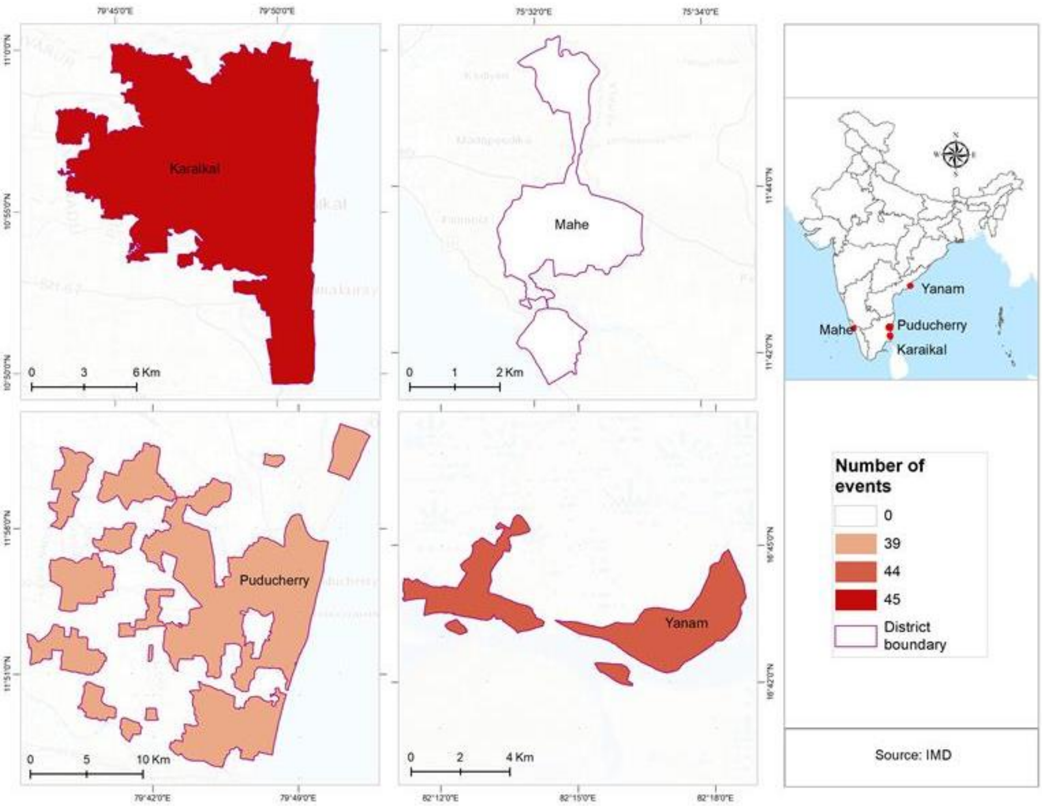
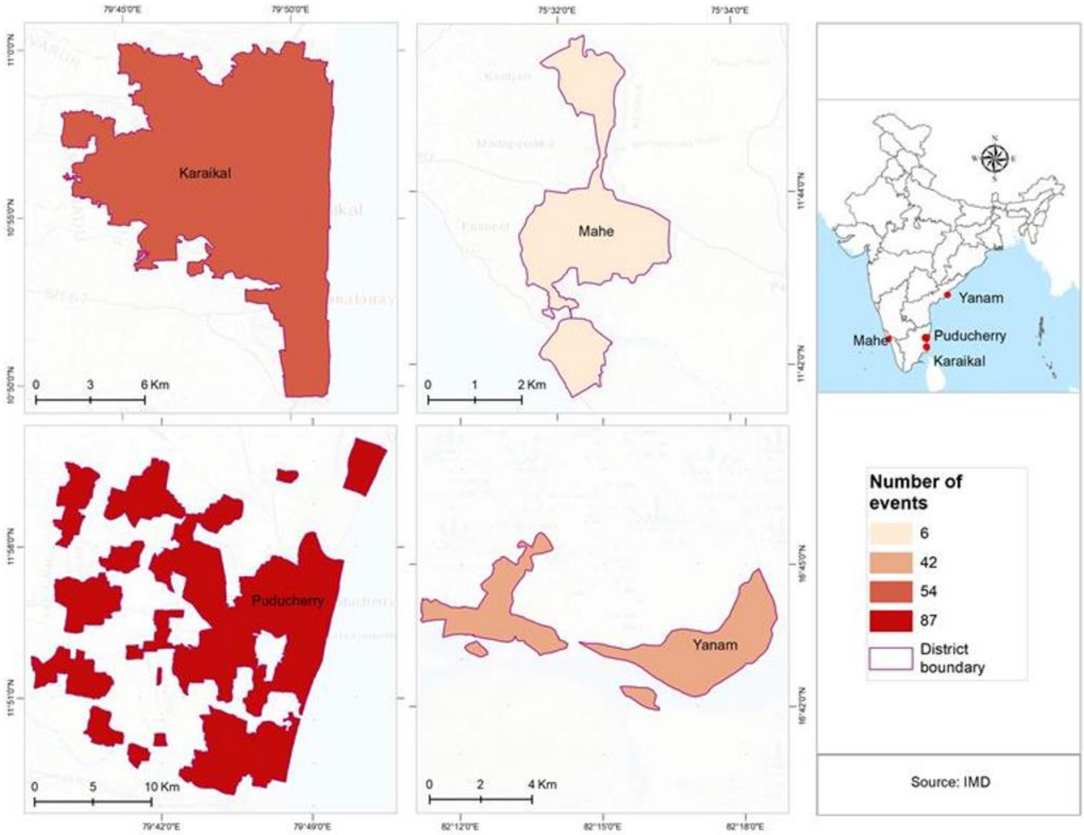


Figure 17: Spatial extent of heatwaves in the future (RCP 4.5, 2041–2070) time period



3.1.3. SLR

Probability of occurrence

Table 12 is a summary of the number of years where SLR crosses the threshold[11] in the current and future time periods.

Table 12: Region-wise tally of years where SLR exceeded the threshold

Region	Tide gauge station	Threshold[12] sea level (cm)	No. of years the SLR crossed the threshold
Karaikal	Chennai	0.69	7
Puducherry			
Mahe	Kochi	2.12	2
Yanam	Visakhapatnam	2.38	9

The probability of occurrence of SLR exceedance for current and future (SSP2-4.5) time periods is presented in Table 13. As data for Puducherry and Karaikal are from the Chennai tide gauge station, the results are the same. In the current time period, Yanam has the highest exceedance probability of SLR, Mahe has the least, and Puducherry and Karaikal have medium exceedance probability. In the future, for all years, SLR is higher than the threshold, which is a 100% probability of occurrence.

[11] The threshold is the maximum sea level of the observed periods from the respective tide gauge stations (Table A 5).

Table 13: Region-wise exceedance probability of SLR for the current and future time periods

Region	Current (1972–2021)	Future (SSP2-4.5, 2041–2070)
Puducherry		
Karaikal		
Yanam		
Mahe		

Spatial extent

The assessment of spatial extent of SLR revealed that the river mouths and intertidal zones in the Puducherry region were affected during the current time period (Figure 18). Future projections indicate that all regions, except Mahe, will experience inundation (Figure 19). In both time periods, inundation primarily affects intertidal zones and newly formed coastal landforms such as sandbars, beaches, and river mouths. These findings are corroborated by previous studies (Murray, et al., 2022; Ramesh, et al., 2011).

Figure 18: Spatial extent of SLR in the current (1972–2021) time period

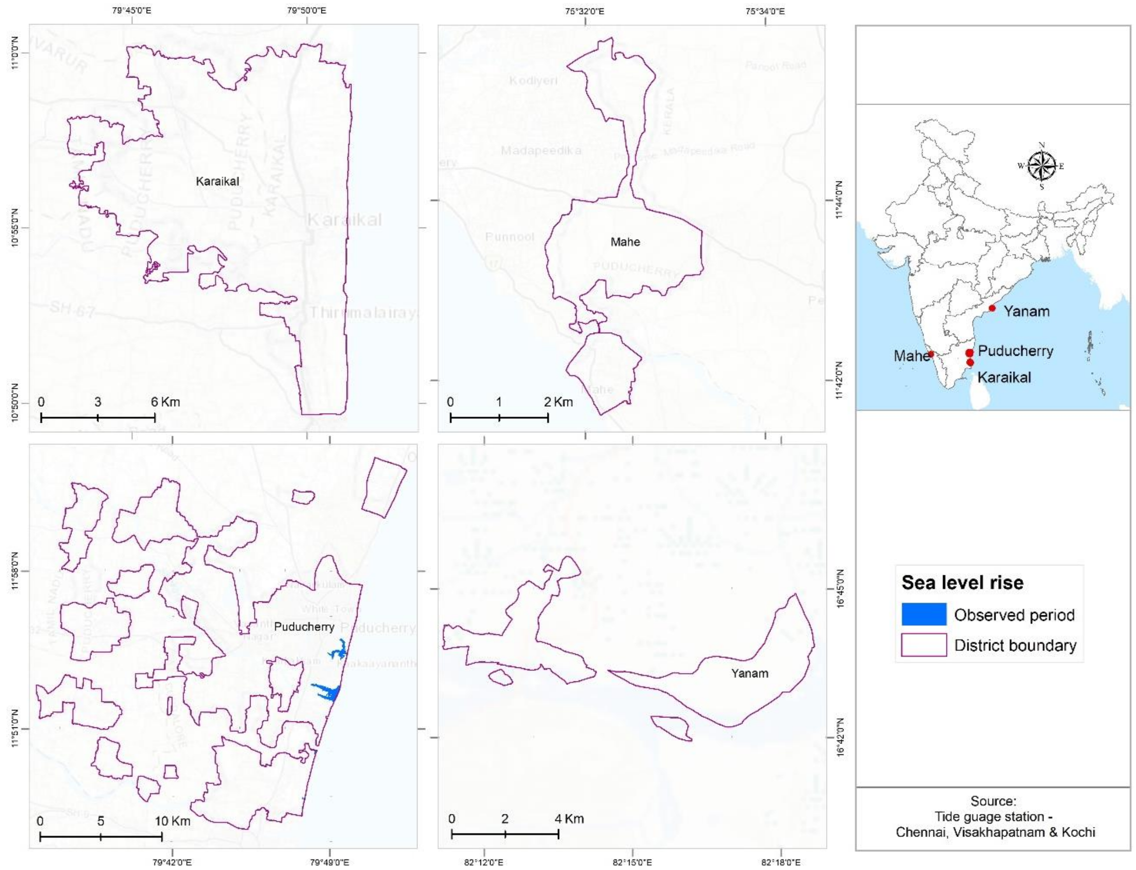
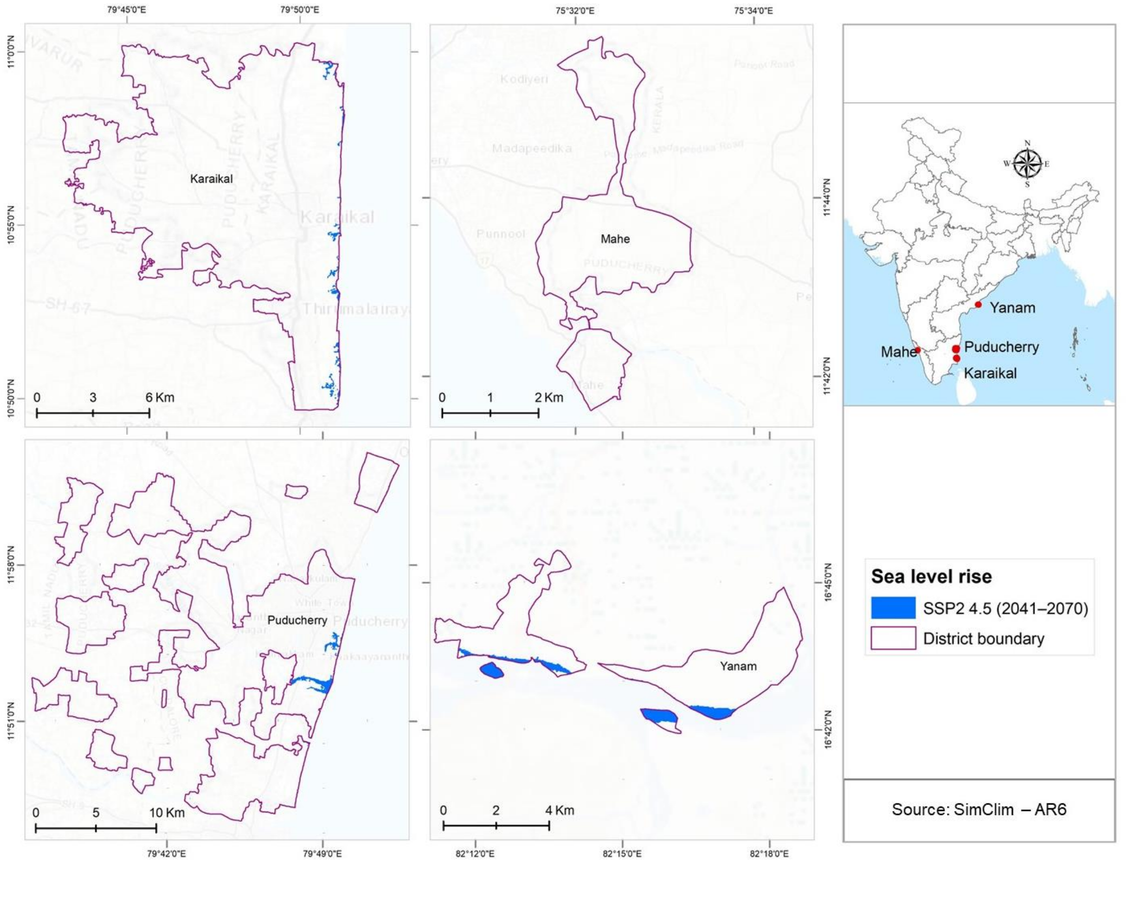


Figure 19: Spatial extent of SLR in the future (SSP2-4.5, 2041–2070) time period



3.1.4. Flood

Probability of occurrence

The probability of occurrence of flood is derived from its return periods (Equation 2) and remains the same for all regions in the current and future (RCP 4.5) time periods.

Table 14: Probability of occurrence of floods in the current and future time periods

Return period (year)	Probability of occurrence (%)	
	Current (1993–2023)	Future[13] (2041–2070)
2	50	50
5	20	20
10	10	10
50	2	2
100	1	1

[13] The scenario for the future time period does not matter, and the probability of occurrence will remain the same.

Spatial extent

The spatial extent of flooding, derived from the HEC–RAS 2D hydraulic model for the current (1993–2023) and future (2041–2070) time periods under the RCP-4.5 scenario are presented below.

Flood-affected areas in the current time period (1993–2023)

Puducherry consistently exhibits the largest flood-affected area across all return periods (Figure 21 and Figure 22), showing the highest area under inundation with a 100-year return-period flood event. Karaikal and Yanam show minimal flood-affected areas while Mahe remains unaffected.

Flood-affected areas in the future time period (2041–2070)

Puducherry's flood-affected areas are projected to increase significantly, particularly with a 100-year return-period flood event. Karaikal and Yanam are expected to experience a moderate increase in flood-affected areas, suggesting a growing risk. Mahe remains largely unaffected, with negligible changes in flood-affected areas (Figure 20).

Figure 20: Flood inundation area for current (1993–2023) and future (RCP 4.5, 2041–2070) time periods

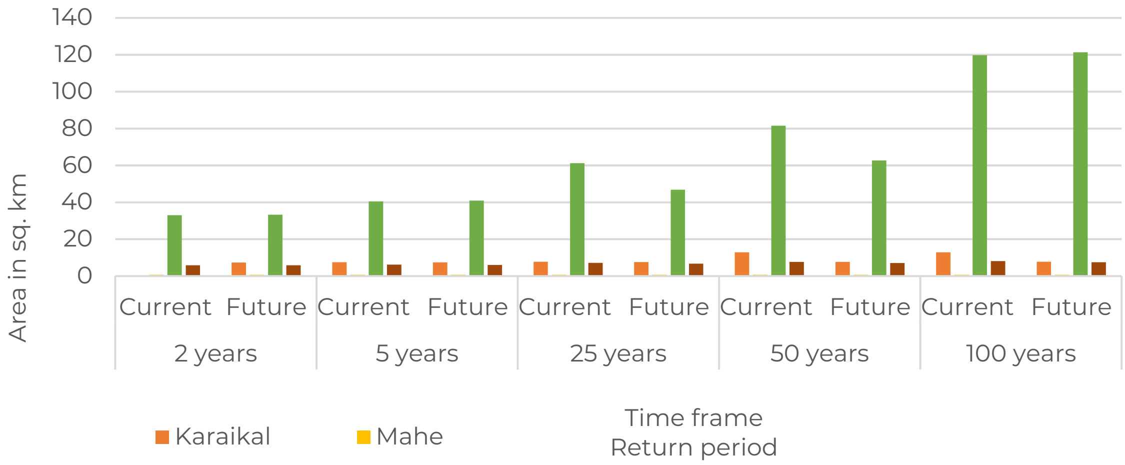


Figure 21: Spatial extent of flood in the current (1993–2023) time period

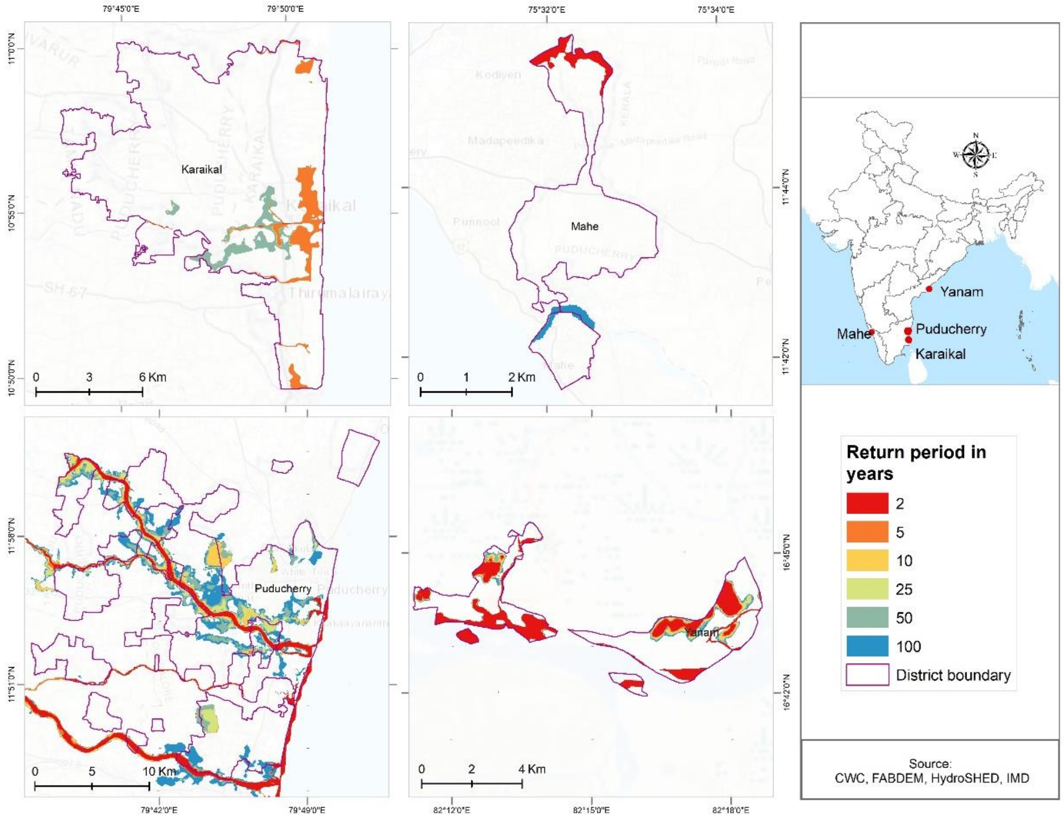
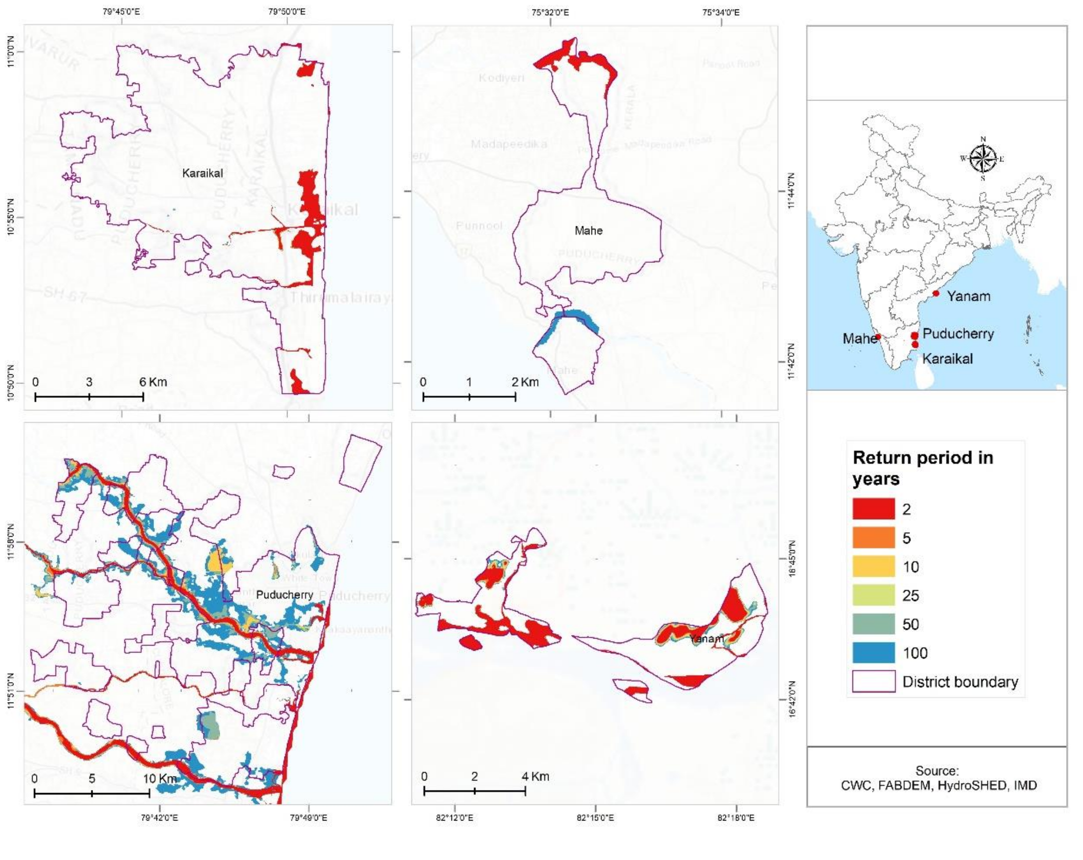


Figure 22: Spatial extent of flood in the future (RCP 4.5, 2041–2070) time period



3.2. Exposure

This section visualises the exposure of sectors to floods in the current and future (RCP 4.5) time periods and quantifies the percentage of exposure for each indicator within each sector. As seen in Figure 15, Figure 16, and Figure 17 the spatial variation of droughts and heatwaves within all regions of the UT are uniform. It is therefore considered that all indicators, across all sectors, are uniformly exposed to drought and heatwave hazards in the current and future time periods. Therefore, exposure maps and percentage of exposure tables for these two hazards are not presented. Further, SLR maps were not created due to the limited extent of its impact, which is confined to the coastal line and riverine mouths. Nevertheless, users can visualise the exposure of all sectors to SLR on CRAT.

3.2.1. Spatial exposure maps

The following points offer an overview and guidance on reading the maps presented in Figure 23 and Figure 24 The figures include four maps, representing each region of the UT.

- On the top right is an inset map of India, highlighting all the regions of the UT. The legend, on the bottom right, displays the flood return period, wherein each sector is displayed using a unique colour.
- The colour grading for each sector represents the magnitude of the flood. Darker colours, correspond to higher return periods, implying greater flood severity.
- The rectangular boxes refer to polygons, which represent assets such as sown area. Lines represent roads and railways, and triangles represent points with assets such as livestock shelters.
- One can visualise each region and identify the colours and their respective shading to understand if a certain sector is exposed to a flood of a certain magnitude.
- The map does not specify which particular indicator of the sector is exposed to the hazard. For example, in the agriculture sector, areas with green shades could be any of the exposure indicators (Table 16) that are exposed to flood.

Figure 23: Region-wise sectoral exposure to floods in the current (1993–2023) time period

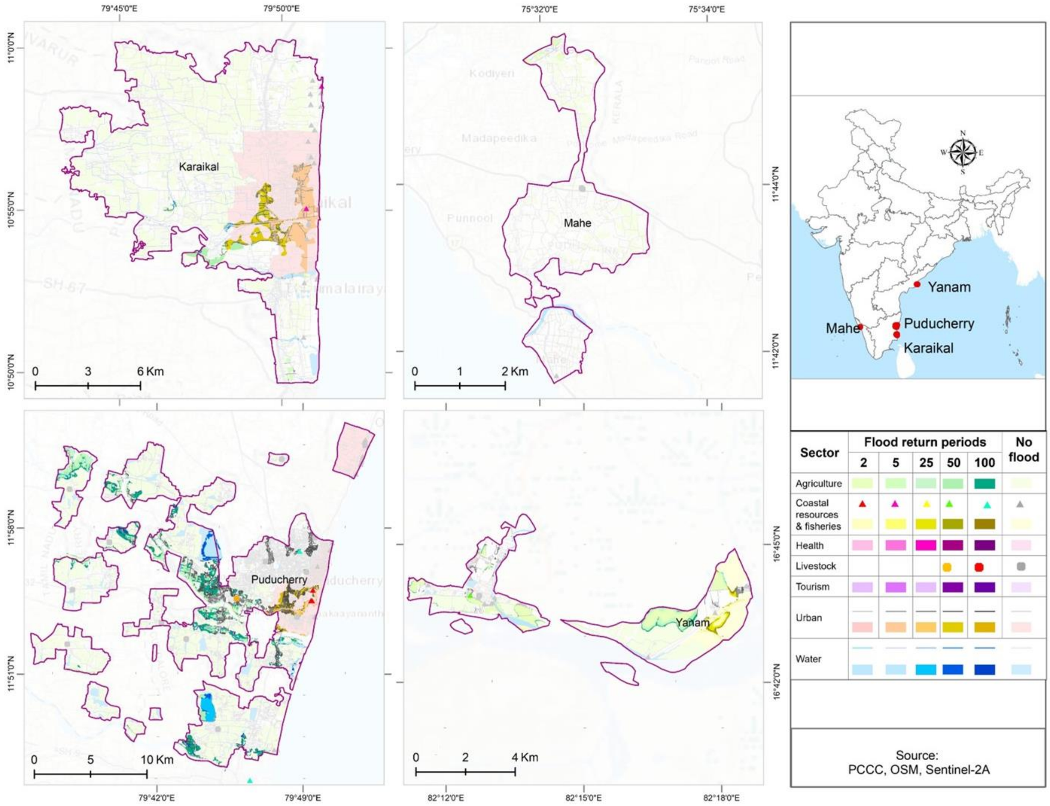
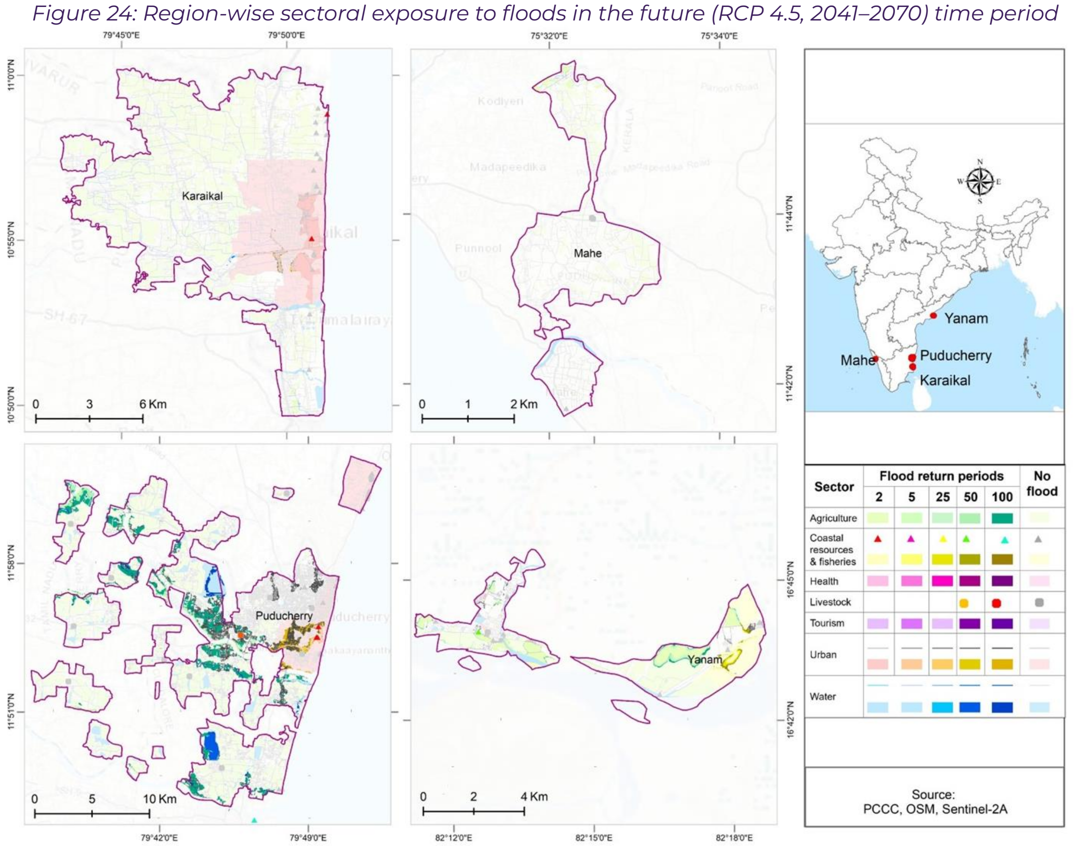


Figure 24: Region-wise sectoral exposure to floods in the future (RCP 4.5, 2041–2070) time period



3.2.2. Percentage of exposure

Table 15 to Table 21 present the exposure of the agriculture, livestock, fisheries, water, urban, tourism, and health sectors to SLR and flood in the current and future time periods. Droughts and heatwaves were excluded from these tables as all indicators across all sectors are uniformly exposed to droughts and heatwaves.

Table 15: Percentage of exposure of the agriculture sector to flood and SLR in the current and future time periods

Indicator	Region	Total area (sq. km)	Current SLR (1972–2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
					2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Agriculture market	Karaikal	5,641.50	-	-	-	-	-	-	30.75	30.76	-	-	-	-	-	-
	Puducherry	12,197.00	-	-	-	-	-	-	0.89	0.89	-	-	-	-	-	0.89
	Yanam	3,383.10	-	-	3.42	6.91	13.67	25.42	33.97	49.88	3.37	5.11	8.61	22.72	22.72	28.87
Food processing unit	Karaikal	8,624.80	-	-	-	1.66	1.66	4.26	11.63	11.63	1.66	1.66	1.66	1.98	1.98	4.86
	Mahe	6,314.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Puducherry	6,766.40	-	-	-	-	-	-	0.78	9.96	-	-	-	-	-	10.64
Net sown area	Karaikal	5,96,72,320.30	-	0	0.01	1.07	1.09	1.11	3.55	3.56	1.03	1.05	1.07	1.14	1.14	1.11
	Mahe	14,48,346.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Puducherry	13,82,07,323.00	0.13	0.13	1.48	2.13	3.1	5.78	10.36	18.42	1.51	2.19	3.25	6.01	6.01	18.73
	Yanam	79,43,186.40	-	0.01	23.75	25.98	28.16	31.22	33.81	35.93	23.52	24.94	26.54	30.73	30.73	32.85
Storage godown	Mahe	14,920.10	-	-	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21
	Puducherry	35,371.10	-	-	-	-	0.41	1.65	4.68	9.71	-	-	0.41	1.64	1.64	9.15

’-‘indicates that the indicator is not exposed to the hazard.

Table 16: Percentage of exposure of the fisheries sector to flood and SLR in the current and future time periods

Indicator	Sub-indicator	Region	Geometry	Total point (count), polygon area (sq. km)	Current SLR (1972–2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
							2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Essential infrastructure	Cold storage	Karaikal	Point	1	-	-	-	100	100	100	100	100	100	100	100	100	100	100
		Puducherry		5	-	-	-	-	-	-	-	60	-	-	-	-	-	20
	Community hall	Yanam		11	-	-	-	-	-	9.09	9.09	9.09	-	-	-	9.09	9.09	9.09
	Diesel bunk	Puducherry		1	-	100	100	100	100	100	100	100	100	100	100	100	100	100
	Fish curing yard	Puducherry		2	-	-	-	-	-	-	-	50	-	-	-	-	-	50
	Fish drying platform	Puducherry		5	-	20	40	40	40	40	40	40	40	40	40	40	40	40
	Work shelter	Karaikal		10	-	30	-	10	10	10	10	10	10	10	10	10	10	10
		Puducherry		13	-	20	-	-	-	-	-	-	-	-	-	-	-	-
Mangrove	-	Karaikal	Polygon	2,10,535.81	-	9.05	-	79.58	79.63	79.70	79.83	79.83	79.51	79.53	79.56	79.64	79.64	79.70
		Puducherry		7,19,530.53	28.20	21.92	30.08	30.32	31.98	40.23	51.15	63.40	30.04	30.32	32.30	41.37	41.37	64.18
		Yanam		52,23,218	-	0.66	8.26	9.22	10.35	12.60	14.54	16.09	8.10	8.77	9.53	12.23	12.23	13.80

Table 17: Percentage of exposure of the health sector to flood in the current and future time periods

Indicator	Sub-indicator	Region	Total area (sq. km)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
				2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Anganwadi	-	Karaikal	6,421.46	-	4.83	4.83	4.83	5.76	5.76	4.83	4.83	4.83	4.83	4.83	4.83
	-	Puducherry	10,631.58	-	-	-	1.88	2.04	6.63	-	-	-	1.88	1.88	6.35
Medical facility	Government hospital	Puducherry	47,203.96	-	-	-	0.27	1.28	1.30	-	-	-	0.69	0.69	1.34
	Private hospital	Karaikal	6,429.02	-	2.88	2.88	2.88	30.71	30.80	2.88	2.88	2.88	2.88	2.88	2.88
	Private hospital	Puducherry	33,435.76	-	-	0.14	0.99	0.99	3.52	-	0.12	0.12	0.99	0.99	3.43
Old age home	-	Karaikal	1,040.81	-	53.09	53.09	53.09	53.09	53.09	53.09	53.09	53.09	53.09	53.09	53.09
	-	Puducherry	3,061.14	0.40	0.40	0.41	0.43	0.58	0.88	0.40	0.40	0.40	0.44	0.44	0.93

Note: None of the indicators are exposed to SLR.

Table 18: Percentage of exposure of the livestock sector to flood and SLR in the current and future time periods

Indicator	Sub-indicator	Region	Geometry	Total point (count), polygon area (sq. km)	Current SLR (1972–2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
							2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Cattle	-	Mahe	Polygon	90,15,609.60	-	-	6.22	6.22	6.22	6.22	6.22	6.22	6.22	6.22	6.22	6.22	6.22	6.22
	-	Yanam		3,94,48,084.00	-	-	31.44	32.75	34.19	36.53	38.87	40.76	31.21	32.15	33.16	36.15	36.15	38
Dairy booth	-	Puducherry		1,292.26	-	-	-	-	-	-	-	20.58	-	-	-	-	-	20.58
Dairy farm	-	Karaikal		779.25	-	-	-	15.03	15.03	15.03	15.03	15.03	15.03	15.03	15.03	15.03	15.03	15.03
	-	Puducherry		1,635.15	-	-	-	-	-	-	5.72	24.53	-	-	-	-	-	26.25
Livestock population	Cattle	Karaikal		11,770,2236.7	-	-	0.08	0.75	0.81	0.91	4.93	4.94	0.67	0.72	0.76	0.86	0.86	0.92
	Cattle	Puducherry		28,321,3021.6	-	-	4.16	5.39	6.42	9.65	14.17	21.81	4.19	5.46	6.55	10.01	10.01	22.06
	Chicken	Karaikal		11,840,0539.1	-	-	0.08	0.78	0.83	0.94	4.95	4.96	0.7	0.75	0.79	0.88	0.88	0.95
	Chicken	Puducherry		28,321,3021.4	-	-	4.16	5.39	6.42	9.65	14.17	21.81	4.19	5.46	6.55	10.01	10.01	22.06
	Sheep	Puducherry		28,321,3021.4	-	-	4.16	5.39	6.42	9.65	14.17	21.81	4.19	5.46	6.55	10.01	10.01	22.06
Poultry farm	-	Yanam		309.19	-	-	100	100	100	100	100	100	100	100	100	100	100	100
Slaughter house	-	Karaikal		1,810.07	-	-	-	27.34	27.34	27.34	27.34	27.34	27.34	27.34	27.34	27.34	27.34	27.34
	-	Puducherry		952.30	-	-	-	-	-	-	-	6.38	-	-	-	-	-	8.56

Indicator	Sub-indicator	Region	Geometry	Total point (count), polygon area (sq. km)	Current SLR (1972–2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
							2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Veterinary dispensary	-	Puducherry	Point	13.00	-	-	-	-	-	-	7.69	7.69	-	-	-	-	-	7.69

Table 19: Percentage of exposure of the tourism sector to flood and SLR in the current and future time periods

Indicator	Region	Total polygon area (sq. km)	Current SLR (1972–2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
					2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Bus stand	Puducherry	7,453.26	-	-	-	0.49	0.53	0.53	0.53	0.53	-	0.53	0.53	0.53	0.53	0.53
	Yanam	702.89	-	-	16.44	16.44	16.44	16.44	16.44	16.50	16.44	16.44	16.44	16.44	16.44	16.44
Church	Karaikal	13,019.79	-	-	-	10.29	10.29	10.29	10.29	10.29	10.29	10.29	10.29	10.29	10.29	10.29
	Puducherry	36,030.90	-	-	-	-	0.49	0.57	2.53	17.08	-	-	0.39	0.57	0.57	17.53
	Yanam	2,341.89	-	-	15.59	15.59	15.59	15.59	15.59	15.59	15.59	15.59	15.59	15.59	15.59	15.59
Guest house	Karaikal	7,664.65	-	-	-	0.45	0.46	0.48	0.59	0.59	0.43	0.44	0.45	0.47	0.47	0.48
	Puducherry	5,555.77	-	-	-	-	-	-	-	4.61	-	-	-	-	-	4.87
Hotel, lodge, and restaurant	Karaikal	28,738.65	-	-	-	3.10	3.68	3.79	9.65	9.65	2.05	2.22	3.16	3.75	3.75	3.83
	Mahe	3,786.57	-	-	58.61	58.61	58.61	58.61	58.61	58.61	58.61	58.61	58.61	58.61	58.61	58.61
	Puducherry	1,24,483.09	0.15	0.50	-	-	0.21	0.77	1.27	3.84	-	0	0.21	0.80	0.80	4.18
Monument	Yanam	2,491.67	-	-	89.32	89.32	89.32	89.32	89.32	89.32	89.32	89.32	89.32	89.32	89.32	89.32
Mosque	Karaikal	17,027.95	-	-	-	1.83	1.83	1.83	2.35	2.36	1.83	1.83	1.83	1.83	1.83	1.83
	Puducherry	11,009.29	-	-	-	-	1	1	1	4.95	-	-	1	1	1	4.95

Indicator	Region	Total polygon area (sq. km)	Current SLR (1972–2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
					2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
	Yanam	350.18	-	-	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26
Temple	Karaikal	1,13,509.24	-	-	-	0.33	0.33	0.33	0.59	0.60	0.33	0.33	0.33	0.33	0.33	0.33
	Puducherry	1,91,750.51	-	0.01	0.08	0.19	0.30	1.85	4.83	9.67	0.08	0.23	0.37	2.05	2.05	9.75
	Yanam	4,027.97	-	-	11.30	11.33	11.38	16.86	20.07	21	11.30	11.32	11.36	16.07	16.07	17.92
Tourist facility centre	Puducherry	2,109.65	-	-	-	-	-	-	-	36.96	-	-	-	-	-	46.18

Table 20: Percentage of exposure of the urban sector to flood and SLR in the current and future time periods

Indicator	Region	Geometry	Total polyline (m), polygon area (sq. km)	Current SLR (1972–2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
						2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Green space	Puducherry	Polygon	1,35,821.51	-	-	-	-	1	0.01	0.03	0.37	-	-	01	0.02	0.02	0.37
	Yanam		66,108.30	-	-	23.92	23.92	23.92	23.93	24.34	25.84	23.92	23.92	23.92	23.92	23.92	24.10
Municipal urban area	Karaikal		10,09,39,409.00	-	0.94	0.09	15.76	15.97	16.24	25.10	25.13	15.36	15.59	15.76	16.12	16.12	16.27
	Puducherry		3,33,92,898.34	2.32	2.91	3.38	3.48	4.04	5.70	9.97	17.86	3.38	3.50	4.11	5.88	5.88	18.22
Railway line	Karaikal	Polyline	14,759.99	-	-	-	8.43	8.64	8.88	12.65	12.64	8.06	8.27	8.44	8.79	8.79	8.89
	Puducherry		13,187.85	-	-	1.42	1.51	1.53	1.56	4.11	10.64	1.43	1.51	1.53	1.54	1.56	10.70
Road network	Karaikal		8,74,245.19	-	0.23	0.03	3.70	3.81	3.92	7.47	7.47	3.51	3.62	3.69	3.88	3.88	3.95
	Mahe		94,007.00	-	-	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43
	Puducherry		23,24,706.46	0.06	0.14	0.87	1.32	2.01	4.43	8.73	16.82	0.89	1.44	2.09	4.78	4.78	16.91
	Yanam		1,46,261.45	-	0.02	15.84	16.53	17.69	20.71	22.88	24.95	15.66	16.22	16.79	20.10	20.10	22.02

Table 21: Percentage of exposure of the water sector to flood and SLR in the current and future time periods

Indicator	Region	Geometry	Total polyline (m), polygon area (sq. km)	Current SLR (1972-2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
						2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Check dam	Puducherry	Polyline	5,531.16	-	0.94	51.08	56.43	58.92	65.95	79.36	84.06	51.27	56.70	59.16	66.71	66.71	84.30
Drainage network	Puducherry	Polygon	1,59,579.56	9.25	8.27	13.14	13.92	15.54	18.75	24.19	35.19	13.16	14.06	15.7	19.1	19.1	35.84
	Karaikal		82,77,116.76	-	-	-	0.03	0.03	0.03	0.12	0.12	0.03	0.03	0.03	0.03	0.03	0.03
River	Karaikal		3.93	-	4.07	2.42	38.20	38.82	40.42	49.19	49.20	37.41	37.87	38.21	38.81	39.51	40.55
	Mahe		0.16	-	0.00	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28
	Puducherry		10.41	16.15	19.29	82.83	84.43	85.40	86.81	88.99	91.83	82.92	84.53	85.48	85.47	86.97	92.05
	Yanam		1.06	-	24.59	71.36	71.55	71.72	72.02	72.28	72.56	71.40	71.65	71.91	72.32	72.70	73.07
Water pumping station	Karaikal		4,330.51	-	-	-	-	-	-	5.43	5.43	-	-	-	-	-	-
	Mahe		159.09	-	-	39.87	39.87	39.87	39.87	39.87	39.87	39.87	39.87	39.87	39.87	39.87	39.87
	Puducherry		20,542.38	-	-	0.13	0.98	2.28	4.35	8.65	17.36	0.13	0.50	2.28	4.35	4.35	15.59
	Yanam		1,194.68	-	-	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Water treatment plant	Puducherry		5,454.12	-	-	0.64	0.64	0.64	1.08	3.11	14.65	0.64	0.64	0.64	1.17	1.17	12.22

Indicator	Region	Geometry	Total polyline (m), polygon area (sq. km)	Current SLR (1972-2021)	Future SLR (SSP2-4.5, 2041–2070)	Current flood (1993–2023)						Future flood (RCP 4.5, 2041–2070)					
						2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Waterbody	Karaikal		38,84,554.04	0	5.83	0.52	30.43	30.77	31.53	33.99	33.99	29.95	30.24	30.43	31.17	31.17	31.57
	Mahe		665.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Puducherry		2,02,98,960.25	0	0.01	0.21	11.08	11.67	22.12	28.83	33.01	0.24	11.16	11.77	23.44	23.44	33.14
	Yanam		1,36,661.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-

3.3. Inter-sectoral vulnerability assessment

This section presents the sectoral vulnerability ranking of each region on a three-point scale of high, moderate, and low vulnerability (Table 22). In Puducherry, the tourism sector is highly vulnerable while all other sectors are moderately vulnerable. In Karaikal, the fisheries sector is highly vulnerable, with other sectors being moderately vulnerable. In Yanam, the livestock and water sectors are highly vulnerable while the remaining sectors are moderately vulnerable. The fisheries sector is highly vulnerable in Mahe while the tourism sector is at low vulnerability.

Table 22: Sector-wise vulnerability analysis

Region	Agriculture	Livestock	Fisheries	Water	Urban	Tourism	Health
Puducherry							
Karaikal							
Yanam							
Mahe							

	High vulnerability		Medium vulnerability		Low vulnerability

3.4. Inter-regional vulnerability assessment

This section presents the inter-regional vulnerability assessment. The purpose of this visualisation is to prioritise regions for adaptation within each sector. It is to be noted that VI values have no standalone significance and that vulnerability is a relative measure, indicating how much more vulnerable a particular region is in comparison with other regions in Puducherry UT. This also means that all regions are vulnerable; however, some are less vulnerable than others due to multiple factors. This section also presents the drivers of vulnerability for each sector or in other words, the factors contributing to a region's vulnerability.

3.4.1. Agriculture

According to our analysis, Yanam and Mahe are highly vulnerable while Puducherry and Karaikal are at low vulnerability.

Table 23: Inter-regional agricultural vulnerability

Region	Vulnerability
Puducherry	
Karaikal	
Yanam	
Mahe	

Drivers of agricultural vulnerability

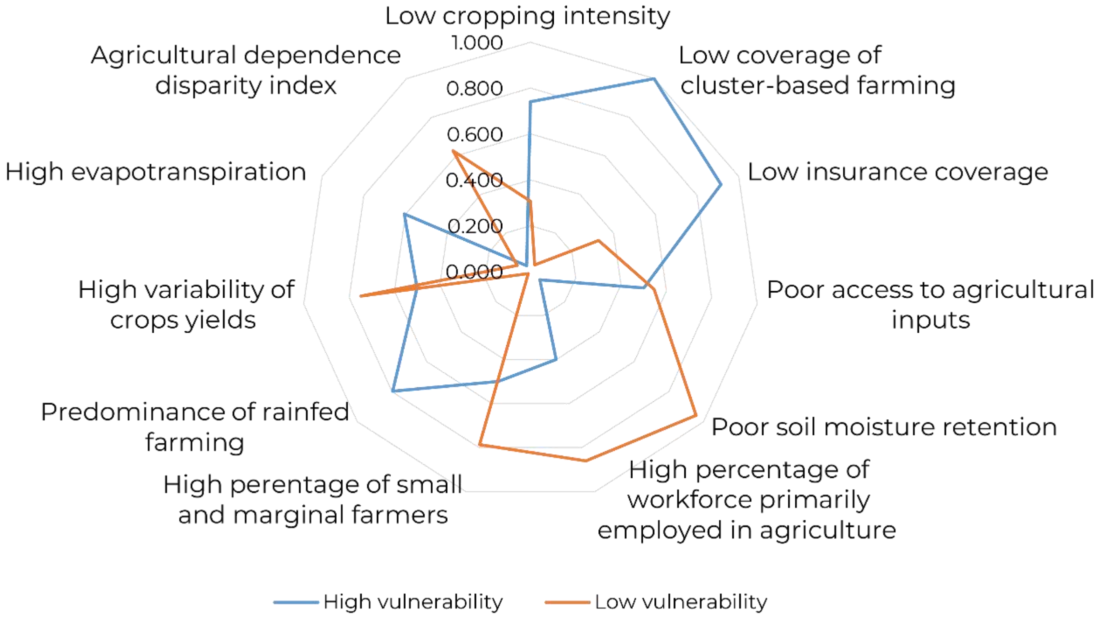
The drivers of agricultural vulnerability for Yanam and Mahe are presented in Figure 25. The indicators that drive agricultural vulnerability are the following:

1. *Low cropping intensity*: A low cropping intensity could be due to multiple inter-related issues, such as low input usage, inefficient farming practices, or poor soil and rainfall conditions.

2. *Low coverage of cluster-based farming*: Lower cluster-based farming reduces knowledge transfer between farmers and market access, apart from increasing input costs.
3. *Low insurance coverage*: Insurance provides a safety-net for farmers during times of agrarian distress. A loss of insurance further entrenches farmers in debt traps, leading to greater vulnerability.
4. *Predominance of rainfed farming*: The agricultural yield and productivity from rainfed farming are lower than that from irrigated agriculture, leading to lower incomes.

The drivers for regions classified as having low vulnerability, along with potential solutions, are provided in Table 30.

Figure 25: Drivers of the agriculture sector vulnerability in Puducherry UT



3.4.2. Livestock

The livestock sector of Yanam is the most vulnerable among all livestock sectors. Puducherry and Karaikal are at moderate vulnerability while Mahe is the least vulnerable as seen in Table 24.

Table 24: Inter-regional livestock vulnerability

Region	Vulnerability
Puducherry	
Karaikal	
Yanam	
Mahe	

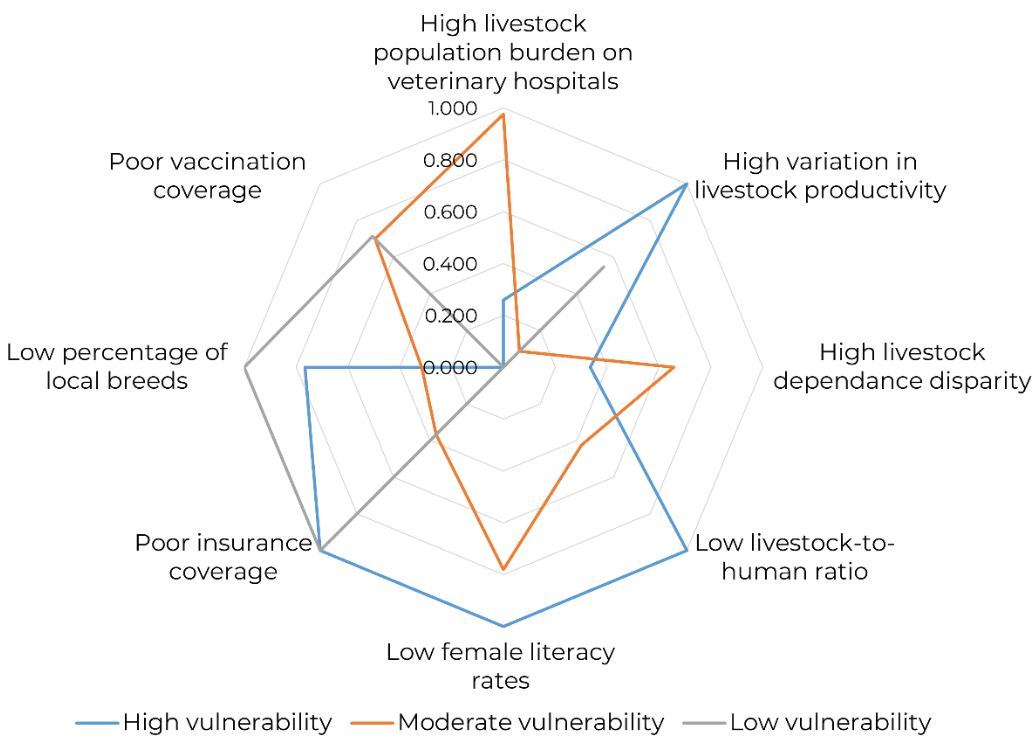
Drivers of livestock sector vulnerability

The drivers of vulnerability for Yanam is due to the following factors:

1. *High variation in livestock productivity*: Variable livestock productivity implies that incomes from livestock are unstable, which can cause significant rural distress.
2. *Low livestock-to-human ratio*: A low livestock-to-human ratio implies that many farmers in Puducherry do not rear livestock as a supplementary livelihood. It has been shown that livestock rearing can help farmers tide over lean agricultural seasons.
3. *Low female literacy*: Low female literacy rates impact the welfare and upkeep of livestock, which rural women predominantly manage. Poor literacy among women can significantly hinder their capacity for effective livestock management.
4. *Low insurance coverage of livestock*: Livestock are expensive assets and, therefore, would benefit from being insured from diseases and climate extremities.
5. *Low percentage of local breeds*: Local breeds are known to be hardier and resilient compared with cross-bred livestock. However, their numbers are small in Yanam.
6. *High livestock population burden on veterinary hospitals*: A higher burden of livestock on veterinary hospitals implies a burden on the existing healthcare infrastructure, which can compromise the healthcare given to livestock.

Potential recommendations to address the drivers of vulnerability are provided in Table 30.

Figure 26: Drivers of the livestock sector vulnerability in Puducherry UT



3.4.3. Fisheries

Karaikal and Mahe are ranked as having high vulnerability with respect to the fisheries sector. They are followed by Puducherry, which is moderately vulnerable, and Yanam, which is ranked as having low vulnerability (Table 25).

Table 25: Inter-regional fisheries vulnerability

Region	Vulnerability
Puducherry	
Karaikal	
Yanam	
Mahe	

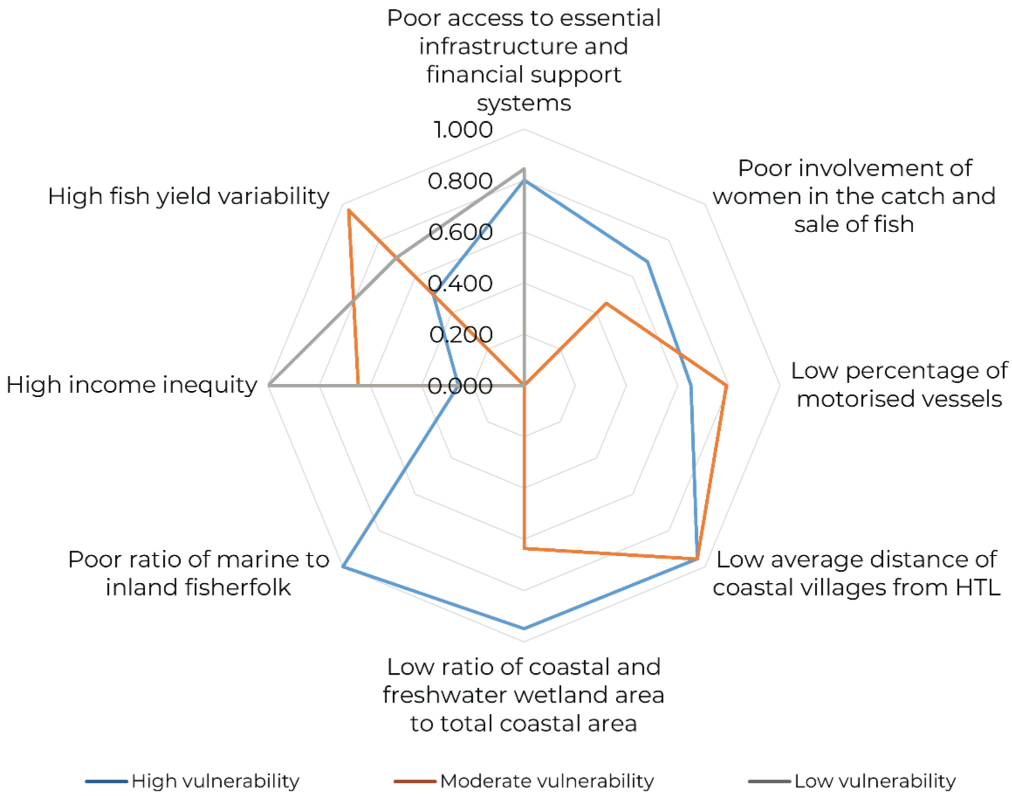
Drivers of fisheries sector vulnerability

In Karaikal and Mahe, the following issues drive the vulnerability of the fisheries sector (Figure 26).

1. *Poor ratio of marine to inland fisherfolk*: The dependence on marine fisheries is 14 times greater than the dependence on inland fisheries in Karaikal. There are no inland fisherfolk in Mahe or Yanam. This highlights a predisposition to be impacted by marine and coastal hazards.
2. *Low average distance of coastal villages from the high tide line (HTL)*: The average distance of fishing villages in Puducherry and Karaikal is 123 and 148 m, respectively, to the HTL of the Bay of Bengal. This is significantly closer to the sea than the fishing villages of Yanam, which are all well beyond 500 m from the HTL but are on average 645 m from the banks of the Godavari river. This proximity to the HTL significantly enhances the susceptibility of the fishing villages in Puducherry and Karaikal to coastal hazards such as storm surges and cyclonic winds.
3. *Low ratio of coastal and freshwater wetland area to total coastal area*: Mahe has the least area under coastal and freshwater wetlands, followed closely by Karaikal. Wetlands are essential as they protect and improve water quality, provide fish and wildlife habitats, and store floodwaters.
4. *Poor access to essential infrastructure and financial support systems*: Essential infrastructure for the fisheries sector considered in this study include cold storage, community halls, fish auction halls, fish curing yards, net mending sheds, work shelters, fish drying platforms, diesel bunks, fish landing points, and fish harbours. Financial support systems are represented by co-operative societies. Fisherfolk in Mahe have the least access to such infrastructure or co-operative societies, followed by Karaikal, highlighting their lack of adaptive capacity.
5. *Poor involvement of women in the catch and sale of fish*: A low involvement of the female population in the fisheries sector can mean a stagnant female workforce. Higher involvement of females can socially and financially empower women and bring in larger revenues to the fisheries sector.

The drivers for regions classified as having moderate and low vulnerability, along with potential solutions, are provided in Table 30.

Figure 27: Drivers of the fisheries sector vulnerability in Puducherry UT



3.4.4. Water

Yanam is the only region that is at high vulnerability in the water sector. All other regions are at low vulnerability (Table 26).

Table 26: Inter-regional water vulnerability

Region	Vulnerability
Puducherry	
Karaikal	
Yanam	
Mahe	

Drivers of water sector vulnerability

The following indicators drive the vulnerability of the water sector in Yanam (Figure 27):

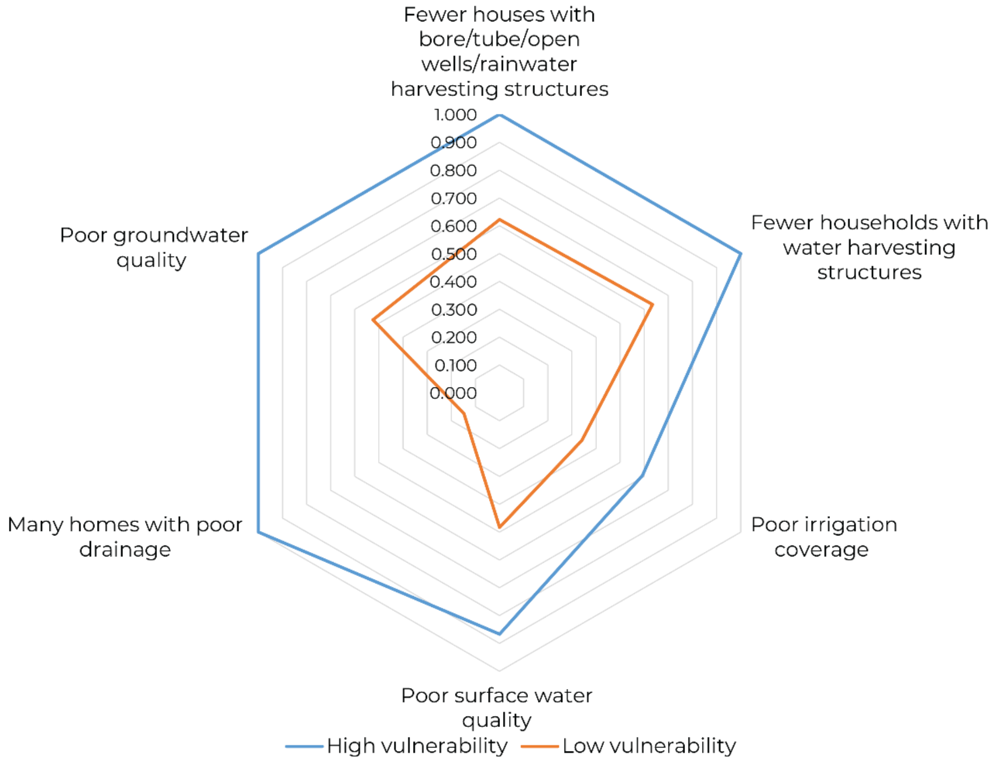
1. *Poor groundwater quality*: The groundwater in Yanam is saline and as such this entire resource becomes unsuitable for drinking, irrigation, and most industrial purposes without expensive desalination or treatment processes. Groundwater of high salinity can also negatively impact Yanam's surface water resources, which is used for drinking and irrigation.
2. *Fewer houses with bore/tube/open wells/rainwater harvesting structures*: While there is no scope for groundwater use in Yanam due to salinity, the lack of private rainwater harvesting structures in the region is a significant driver of vulnerability. Given the dependence on rainwater or surface water for domestic use, the region needs to invest

in or promote such critical infrastructure. Puducherry has the least number of houses with access to groundwater or rainwater harvesting structures.

3. *Homes with poor drainage*: Yanam has the highest number of homes with either no drainage or open drains. This can lead to significant pollution of land and water resources, consequently leading to the spread of vector- and water-borne diseases, impacting human health.
4. *Poor surface water quality*: Poor surface water quality can indirectly affect groundwater quality. Furthermore, surface water–dependant sectors such as fisheries can be significantly hampered by poor water quality, affecting marine life, and subsequently, fisherfolk income.

The drivers for regions classified as having low vulnerability, along with potential solutions, are provided in Table 30.

Figure 28: Drivers of the water sector vulnerability in Puducherry UT



3.4.5. Health

Puducherry and Karaikal are ranked as having high vulnerability while Yanam and Mahe have low vulnerability (Table 27).

Table 27: Inter-regional health vulnerability

Region	Vulnerability
Puducherry	
Karaikal	
Yanam	
Mahe	

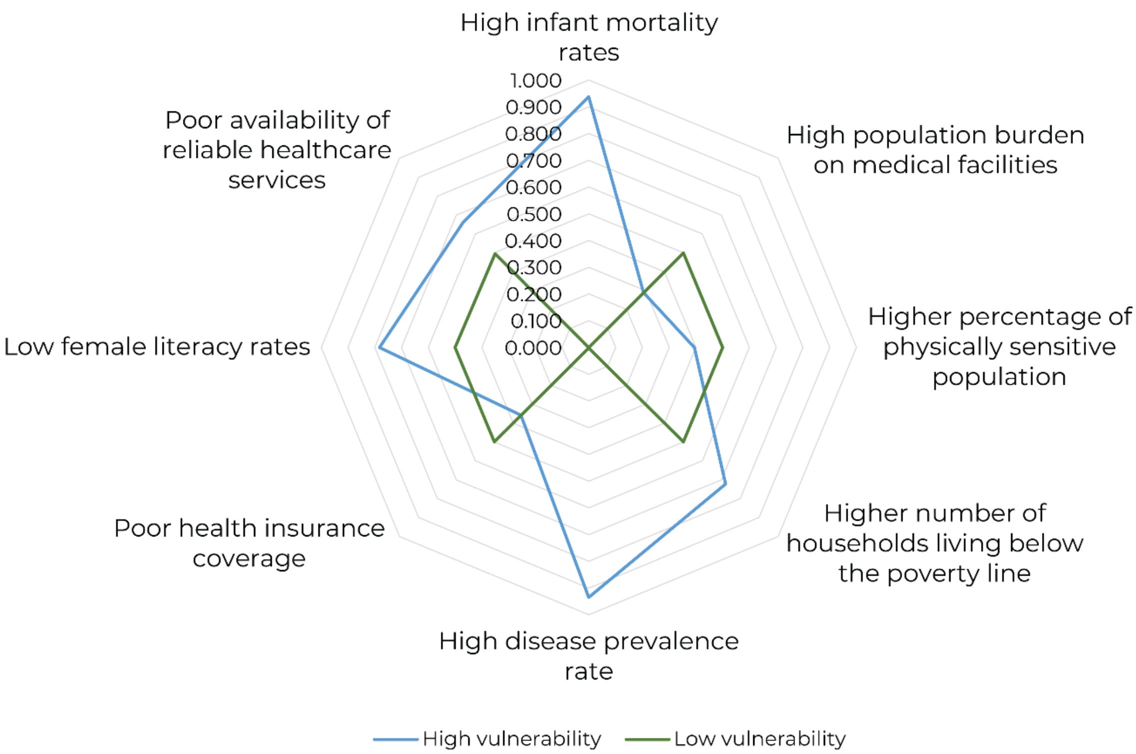
Drivers of health sector vulnerability

The following indicators contribute to high vulnerability in Puducherry and Karaikal (Figure 28):

1. *High infant mortality rates*: High mortality rates are a serious concern in any society and are a combination of many factors. However, high infant mortality rates strongly imply poor healthcare infrastructure, especially with regard to early childcare and child health.
2. *High number of households living below the poverty line:* Widespread poverty in India leads to poor health, low education, economic stagnation, and deepening inequality. Further, it strains public resources and worsens living conditions.
3. *High disease prevalence rate*: Regions such as Puducherry receive a heavy in-flow of tourists, which can be sources for new diseases. Furthermore, the presence of leading medical institutions such as the Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER) can possibly be skewing the data towards showing higher disease prevalence.
4. *Low female literacy rate*: Low female literacy rates restricts employment opportunities for women. Moreover, low literacy affects the awareness of pre-, and post-natal care, which leads to higher maternal and infant mortality rates.
5. *Poor availability of reliable healthcare services*: Poor availability of healthcare services reduces the overall quality of life and increases the financial burden, especially for the marginalised populations.

The drivers for regions classified as having low vulnerability, along with potential solutions, are provided in Table 30.

Figure 29: Drivers of the health sector vulnerability in Puducherry UT



3.4.6. Urban

Yanam and Mahe are ranked as highly vulnerable while Puducherry and Karaikal have low vulnerability (Table 28).

Table 28: Inter-regional urban vulnerability

Region	Vulnerability
Puducherry	
Karaikal	
Yanam	
Mahe	

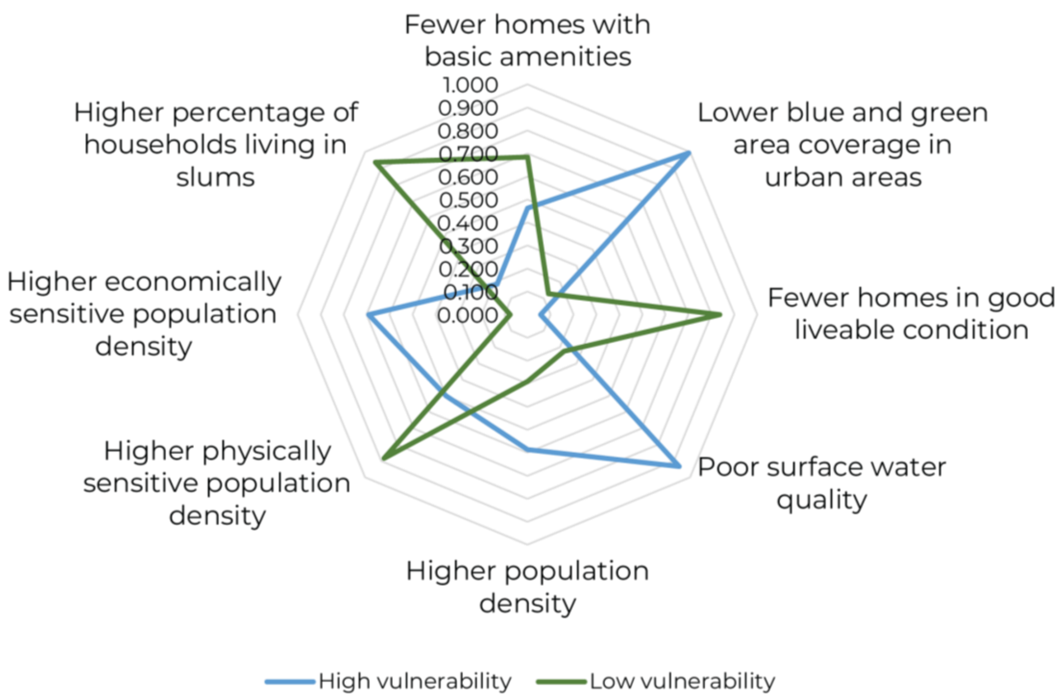
Drivers of urban sector vulnerability

The following indicators drive high vulnerability in Yanam and Mahe (Figure 29):

1. *Lower blue and green area coverage in urban areas*: Green and blue spaces host multiple ecosystem functions and services such as groundwater recharge and flood run-off control. They also reduce the urban heat island effect and provide much-needed aesthetic and mental well-being benefits. Such ecosystem services are crucial to the functioning of a city. Lower green–blue areas lead to lower ecosystem services, which heightens the vulnerability of a region.
2. *Poor surface water quality*: While surface water is not directly used for potable uses, poor water quality can be a breeding ground for diseases. Furthermore, surface water recharges the aquifers through sub-surface infiltration. The poorer the quality of the surface water, the poorer the groundwater.
3. *Higher economically sensitive population density*: Puducherry has a high density of economically vulnerable population, leading to financial instability, poor living conditions, and limited access to healthcare, education, and social security. It increases dependence on government aid, fuels unemployment, and slows economic growth, while also making communities more susceptible to exploitation and crises such as inflation or natural disasters.

The drivers for regions classified as having low vulnerability, along with potential solutions, are provided in Table 30.

Figure 30: Drivers of the urban sector vulnerability in Puducherry UT



3.4.7. Tourism

Puducherry and Karaikal are highly vulnerable. Yanam is moderately vulnerable, while Mahe is at low vulnerability for the tourism sector (Table 29).

Table 29: Inter-regional tourism vulnerability

Region	Vulnerability
Puducherry	
Karaikal	
Yanam	
Mahe	

Drivers of tourism sector vulnerability

The following indicators drive tourism vulnerability in Karaikal and Puducherry (Figure 30):

1. *Poor groundwater quality*: Groundwater is used for drinking and irrigation in Puducherry. Poor groundwater quality can lead to gastrointestinal diseases that can disincentivise tourists from visiting Puducherry.
2. *Poor surface water quality*: Refer to 3.4.4.
3. *High variation in tourists*: High variation in tourists do not provide a stable, predictable, and dependable income for the hospitability sector, thus making them vulnerable. Variation in tourists is also a disincentive for other potential businesses to enter the hospitality industry.
4. *High tourist burden on hotels*: This implies that hotel demand is greater that its supply during high tourist seasons, placing a strain on the existing infrastructure. High tourist burden also leads to inflated prices, which crowds out local tourists.

5. *Fewer police stations per 1,000 tourists*: The presence of police stations and police personnel provides a sense of safety, especially among foreign tourists. A lower number of police stations may disincentivise tourists from visiting Puducherry.
6. *Low road density*: Low road density in Puducherry's tourism sector leads to traffic congestion, longer travel times, and limited accessibility to key tourist attractions, reducing visitor satisfaction. It also hampers the growth of tourism-related businesses by restricting the movement of goods, services, and workforce needed to support the industry.

The drivers for regions classified as having low vulnerability, along with potential solutions, are provided in Table 30.

Figure 31: Drivers of the tourism sector vulnerability in Puducherry UT

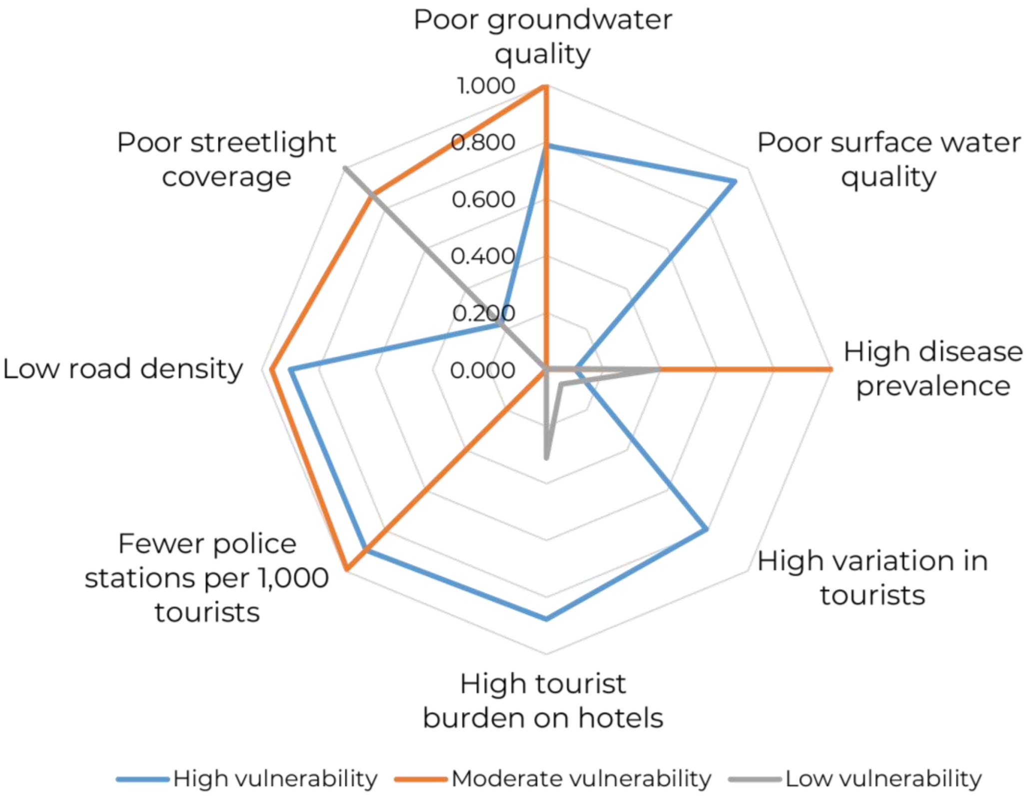


Table 30 presents a comprehensive discussion on solutions that can address vulnerability across all sectors, disaggregated by region.

Table 30: Sector-wise drivers of vulnerability for regions and potential solutions

Sector	Vulnerability class	Region	Driver	Solution
Agriculture	High	Yanam and Mahe	Low coverage of cluster-based farming	Civil society organisations (CSOs) and non-governmental organisations (NGOs) can work with farmers to incentivise collectivisation. They can aid in knowledge transfer and access to funds and certifications that can increase the credibility of cluster-based farmers. The government can disseminate knowledge on the advantages of cluster-based farming across all the regions.
			Low insurance coverage	Improved dissemination of and awareness creation on insurance schemes must be done by the UT, CSOs, and NGOs. These should target farmers, particularly in Yanam and Mahe.
			Predominance of rainfed farming	Prioritisation of rainfed farmers for receiving adequate crop loss insurance. Schemes such as Mahatma Gandhi Rural Employment Scheme (MGNREGS) should prioritise water and soil conservation works in Yanam and Mahe to increase agricultural resilience. If feasible, the government must improve canal-based irrigation to rainfed areas. Rainfed farmers, who are likely to be economically vulnerable, must be given the financial resources to construct open or bore wells. However, this must be done sensitively to ensure that groundwater is not over-exploited.
			Low cropping intensity	Increase water-use efficiency through the use of drip and sprinkler irrigation. Improve the adoption of high-yielding varieties that are suited to the agro-ecology of Yanam and Mahe. Enhance soil fertility through the use of compost, green manure, crop residue, and zero-tillage practices.

Sector	Vulnerability class	Region	Driver	Solution
			High percentage of workforce employed in agriculture	Refer to the points mentioned under 'high percentage of small and marginal farmers'.
			Poor access to agricultural inputs	Subsidise access to mechanisation, organic fertilisers, and pesticides. Invest in increasing the density of agricultural input stores across Karaikal.
	Low	Puducherry and Karaikal	Poor soil moisture retention	Promote plantation activities for soil moisture retention. However, this must be done in an ecologically sensitive manner. Adopt watershed management techniques such as contour bunds and bench terracing, where applicable. Integrate mulching, a technique where straw, leaves, or even plastic sheets are used to cover cropping land, especially during non-cropping seasons.
			High percentage of workforce employed in agriculture	Increase the number of skill-based training institutes through vocational programmes and polytechnic courses. Incentivise supplementary livelihoods such as fisheries and livestock, which can provide higher incomes. Incentivise greater private sector activity in rural areas, especially through micro, small, and medium enterprises (MSMEs).
			High crop yield variability	Some of the crop variability can be reduced with a cluster-based farming system. Moreover, the following solutions can be adopted: Facilitate the provision of accurate weather and climate forecasts to farmers to enable the planning of agriculture operations, including sowing. Provide assured inputs at reasonable costs to farmers.

Sector	Vulnerability class	Region	Driver	Solution
				Disseminate knowledge on best practices in agriculture through a collaborative effort between the UT, CSOs, and NGOs. However, this must be a periodic process.
			High percentage of small and marginal farmers	Encourage the consolidation of fragmented land holdings through voluntary cooperative/collective farming models. Improve access to credit and other financial sources. Promote supplementary livelihoods such as fisheries and livestock to tide over lean cropping seasons. Expand social safety net programmes such as MGNREGS that can help farmers earn supplementary incomes.
Livestock	High	Yanam	High variation in livestock productivity	Ensure a greater density of veterinary hospitals, clinics, and doctors to treat livestock diseases, thereby ensuring their productivities. Further, A balanced and nutrient-rich diet must be supplied to cattle. Where this is not possible, the use of vitamin and mineral supplements can be encouraged. Provide adequate shelter for livestock to protect them from climatic extremities.
			Low livestock-to-human ratio	The UT can provide loans at low or nil interest, subsidies, and/or subsidised insurance to help farmers purchase livestock. Expand the Kisan Credit Card scheme to allow for livestock purchases. Strengthen the role of co-operative societies to help farmers pool in capital to purchase and maintain livestock.
			Low female literacy	The government must raise awareness about education for women, especially among families with female children.

Sector	Vulnerability class	Region	Driver	Solution
				Ensure girl children do not drop out from school, at least till the secondary level. For adult females, the government can work with CSOs and NGOs and conduct trainings on livestock management, which can improve general education levels while also assuring better livestock care.
			Low livestock insurance coverage	Awareness building, led by the government and supported by CSOs and NGOs, to avail insurance coverage for livestock.
			Low percentage of local breeds	Local breeds are inherently more resilient to climate change. The government can host field workshops and trainings to educate farmers on the advantages of shifting to local breeds. It must be made clear that while the short-term gains may be unattractive, the long-term gains would be higher with local breeds than with cross-breeds, in the light of climate change.
	Moderate	Puducherry and Karaikal	High livestock burden on veterinary hospitals	Construct additional veterinary hospitals to ease the current demands. Increase the supply of veterinary clinics that can address minor health issues. Train local para-veterinarians to administer first-aid assistance for livestock.
			Low female literacy rates	Refer to the points mentioned under 'high' vulnerability.
			Poor vaccination coverage	Increase the coverage of mobile veterinary units to reach remote areas. Conduct mass immunisation campaigns with the assistance of panchayats and self-help groups. Train local para-veterinarians to administer vaccinations.

Sector	Vulnerability class	Region	Driver	Solution
	Low	Mahe	Poor insurance coverage Low percentage of local breeds Poor vaccination coverage	All drivers mentioned have been addressed under the 'high' and 'moderate' vulnerability classes.
Fisheries	High	Karaikal and Mahe	Poor ratio of marine to inland fisherfolk	Higher government incentives towards inland fisheries. Targeted training to women fisherfolk to undertake inland fisheries.
			Low average distance of coastal villages from HTL	Draft rehabilitation plans for vulnerable homes along the coast.
			Low ratio of coastal and freshwater wetland area to total coastal area	Stringent restrictions to conserve existing wetlands. Invest in constructed wetlands. Such spaces can also act as sites for groundwater recharge and sewage treatment.
			Poor access to essential infrastructure and financial support systems	Develop a cold storage supply chain. Incentivise private sector to enter this market. At the same time, the creation of inclusive fisherfolk societies is paramount. Such societies have greater bargaining power and will be able to vocalise the needs of the fisherfolk through a unified front, which can help the government better provision for their needs.
			Poor involvement of women in the catch and sale of fish	Educate fisherfolk co-operatives and societies on the benefits of the involvement of women in the catch and sale of fish. Provide transport subsidies to allow the safe travel of women to their worksites. Skill-based educational programmes specifically targeted for women to help them integrate into the fishery livelihood.
	Moderate	Puducherry	Low percentage of motorised vessels	Subsidies to purchase motors that can be retrofitted to traditional boats.

Sector	Vulnerability class	Region	Driver	Solution
				The UT can seek aid from international donor agencies that focus on the blue economy.
			Low average distance of coastal villages from HTL	In Puducherry, the challenge of relocation would be more complex, given that the region comprises of *pucca* homes and other establishments. The government can conduct awareness building activities among residents and businesses along the coast to inform them about the imminent threat of SLR and coastal flooding. Sea walls and barricades along the coast must be strengthened along with the uptake of nature-based solutions (NbS).
	Low	Yanam	Poor access to essential infrastructure and financial support systems	Refer to the points mentioned under 'poor access to essential infrastructure and financial support systems' for Karaikal and Mahe.
			High income inequity	Incentivise the private sector to enter the fisheries sector, especially with regard to setting up a cold supply chain. Establish direct market linkages between the fisherfolk and the buyer. This can help fisherfolk gain a better price for their produce. Implement comprehensive insurance schemes to protect fisherfolk from loss of catch due to the effects of climate change.
			High fish yield variability	Given that there are already many regulations with regard to fishing seasons, catch limits, and protected zones, the government can: Promote aquaculture. Ponds can be constructed through state fishing schemes and MGNREGS. Improve supply chain management, especially with regard to cold storage of fish produce. This can help farmers avoid a supply glut.
Water	High	Yanam	Poor groundwater quality	In cases where poor groundwater quality is due to geogenic factors, there are two options:

Sector	Vulnerability class	Region	Driver	Solution
				Invest in water treatment facilities that can bring the groundwater to potable standards. Provide homes with water from a surface water source. In other areas, it is recommended that: Groundwater recharge zones are maintained hygienically. If groundwater is sourced from hand pumps, it must be ensured that cattle do not stray next to these sources to avoid contamination.
			Fewer houses with bore/tube/open wells/rainwater harvesting structures	Schemes such as MGNREGS can be used to create climate-resilient infrastructure to harvest and conserve water. In more urban areas such as Puducherry, a groundwater sharing mechanism can be adopted. In such a system, water from a single borewell can be used by multiple houses. Such a task would require the intervention of multiple CSOs and NGOs.
			Many homes with poor drainage	Ensure that all open drains are covered, which can be done with simple concrete slabs. In the rural villages of Yanam, decentralised waste water treatment solutions such as waste stabilisation ponds, activated sludge processes, and constructed wetlands can be initiated.
Health	High	Puducherry and Karaikal	Low female literacy rates	Refer to the points mentioned for the same indicator under 'livestock'. The point regarding women in livestock management is not relevant for this sector. Moreover, women healthcare workers can provide basic healthcare information and training to women in both rural and urban areas.
			High number of households living below the poverty line	Invest in vocational training, entrepreneurship programmes, and MSME support to create sustainable employment opportunities. Improve access to quality education, scholarships, and digital literacy programmes to break the cycle of poverty for future generations.

Sector	Vulnerability class	Region	Driver	Solution
				Strengthen social safety nets, provide affordable housing, and expand access to microfinance and self-help groups for economic stability. Leverage Puducherry's tourism sector by promoting eco-tourism, handicrafts, and local businesses to generate income for low-income families.
			High disease prevalence rate	Improve public healthcare facilities, increase the number of medical professionals, and ensure access to affordable medicines and diagnostics. Established institutes such as JIMPER can increase its presence through mobile health vans, community health works, and regular medical camps. Conduct awareness campaigns on hygiene, nutrition, vaccination, and lifestyle diseases to prevent common health issues. Implement nutrition programmes and strengthen mid-day meals and maternal health services to combat malnutrition and improve overall community health. Increase the number of community health workers that can respond to acute healthcare needs and can also increase awareness, especially in distant rural communities.
			Poor availability of reliable healthcare services	Establish more primary health centres (PHCs) and recruit more community health workers in both urban and rural areas. Invest in building more hospitals, clinics, and specialty care centres to increase the capacity of the healthcare system. Hospitals such as JIPMER can expand to rural areas with satellite clinics. Expand the reach of schemes such as the *Ayushman Bharat*, especially to the underprivileged. Expand telemedicine services to provide remote consultations and follow-up care, reducing the need for in-person visits.

Sector	Vulnerability class	Region	Driver	Solution
				Promote immunisation drives, especially in rural areas. Deploy a greater number of community health workers such as Accredited Social Health Activist (ASHA) and *anganwadi* workers.
			High infant mortality rates	In addition to all the points mentioned above, Strengthen the *anganwadi* programme to ensure adequate maternal health coverage. Improve access to fortified foods, vitamins, and minerals for both mothers and infants. Increase access to Special Newborn Care Units (SNCUs) to treat premature and low-birth-weight babies.
Urban	High	Yanam and Mahe	Low blue and green area coverage in urban areas	Identify and convert vacant lots, abandoned areas, and underutilised spaces into parks, gardens, and recreational green spaces. Plant trees along streets, sidewalks, and medians to create green corridors and improve air quality. Develop and restore urban waterbodies such as lakes, ponds, and rivers to enhance blue spaces.
			Poor surface water quality	Enforce strict regulations on industrial discharges to ensure that effluents are treated before being released into waterbodies. Implement decentralised wastewater treatment systems in areas not connected to central sewage systems. Promote reforestation and afforestation projects to enhance watershed health and reduce erosion.
			High economically sensitive population density	Provide vocational training and upskilling initiatives to enhance employability and income stability. Expand access to microfinance, self-help groups, and government welfare schemes to improve financial security for vulnerable populations.

Sector	Vulnerability class	Region	Driver	Solution
				Promote small businesses, traditional crafts, and tourism-related enterprises to create sustainable livelihoods. Implement stronger labour laws, ensure fair wages, and expand social safety nets such as MGNREGS.
	Low	Puducherry and Karaikal	Fewer homes with basic amenities	Government initiatives such as the *Swacch Bharat* Mission can move into its next phase and ensure that the constructed toilets receive adequate water and is being used by all members of the household. Ensure that houses in slums in Puducherry are provided with adequate cooling through fans or air-conditioners.
			Fewer homes in good liveable condition	Ensure that homes built under the *Pradan Mantri Awas Yojna* are ecologically constructed, with adequate ventilation. Provide low-interest loans to allow lower-income citizens refurbish their homes.
			High percentage of households living in slums	Improve the living standards of current slums through improvements in sanitation, water, waste management, and thermal comfort. Engage slum inhabitants in the planning and redevelopment of the existing slums. Increase employment especially through the MSME sector, which can help slum inhabitants move to better housing facilities.
			High physically sensitive population density	Expand pensions, disability benefits, and child welfare schemes to provide financial stability for vulnerable populations. Strengthen healthcare services, including free medical check-ups, nutrition programmes for young children, and specialised care for senior citizens and disabled individuals.

Sector	Vulnerability class	Region	Driver	Solution
				Improve public spaces, transport, and facilities with ramps, special seating, and age-friendly services to ensure mobility and independence. Increase day-care centres, senior citizen homes, and caregiver support programmes to provide necessary assistance and social inclusion.
Tourism	High	Puducherry, Karaikal	Poor groundwater quality	Refer to the points mentioned under 'poor ground water quality' under the 'water' sector.
			Fewer police stations per 1,000 tourists	The UT can increase police presence in Puducherry, Karaikal, and Yanam.
			Poor surface water quality	Refer to the points mentioned under 'poor surface water quality' under the 'water' sector.
			High variation in tourists	Offer discounts, special events, and unique experiences during the off-season to attract visitors year-round. Develop eco-tourism, wellness retreats, cultural festivals, and adventure tourism to appeal to a broader audience beyond peak seasons. Enhance road networks, transport options, and digital promotions to make Puducherry more accessible throughout the year. Attract business conferences, workshops, and student exchange programmes to ensure a steady flow of visitors outside peak tourist months.
			High tourist population burden on hotels	Promote alternative accommodations such as homestays, guesthouses, and eco-lodges to distribute tourists more evenly. Encourage the development of serviced apartments and vacation rentals to reduce pressure on traditional hotels.

Sector	Vulnerability class	Region	Driver	Solution
				Develop seasonal and event-based tourism strategies to balance visitor flow and prevent peak-time overcrowding.
			Low road density	Expand and upgrade existing road networks by developing new arterial and connector roads to improve accessibility. Integrate smart traffic management and alternative transport routes to optimise existing road usage while planning new developments.
	Moderate	Yanam	Poor groundwater quality	Refer to the points mentioned under 'poor ground water quality' under the 'water' sector.
			High disease prevalence	Refer to the points mentioned under 'high disease prevalence' under the 'health' sector.
			Fewer police stations per 1,000 tourists	Refer to the points mentioned under 'high' for the same driver.
			Low road density	
			Poor street light coverage	Increase street light coverage, with preferably solar street lights as it also leads to lower greenhouse gas emissions.
	Low	Mahe	Poor street light coverage	Refer to the points mentioned under 'moderate' for the same driver.

3.5. Inter-regional climate risk

This section presents the risk for each sector, segregated on the basis of the hazard. The analysis is presented to allow users to prioritise regions that require attention for specific sectors.

3.5.1. Agriculture

Puducherry is at high risk for drought in the current and future time periods. For heatwaves, Karaikal and Yanam are at high risk across the current and future time periods. Puducherry remains high at risk to SLR across both current and future time periods. With respect to flooding, Yanam remains high at risk in the current and future time periods (Table 31).

Table 31: Risk to the agriculture sector across current and future time periods

Current									
Region	**Drought**	**Heatwave**	**SLR**	**Flood return period (year)**					
				2	***5***	***10***	***25***	***50***	***100***
Puducherry									
Karaikal									
Yanam									
Mahe									
Future									
Puducherry									
Karaikal									
Yanam									
Mahe									

3.5.2. Livestock

Table 32 is a summary of the risk to the livestock sector across the selected hazards.

In both time periods, Mahe remains at low risk to droughts and heatwaves. Puducherry, while being at high risk to heatwaves in the current time period, will exhibit low risk in the future.

None of the livestock assets are exposed to SLR, thereby having no risk.

For flood risk, across both time periods, most regions follow similar trends with Puducherry and Mahe being at low risk, Karaikal at medium risk, and Yanam at high risk. For the 100-year return period flood, Puducherry and Karaikal are at medium risk, Yanam at high risk, and Mahe at low risk across both time periods.

Table 32: Risk to the livestock sector across current and future time periods

Region	Drought	Heatwave	SLR	Flood return period (year)					
				2	5	10	25	50	100
Current									
Puducherry			Not exposed						
Karaikal									
Yanam									
Mahe									
Future									
Puducherry			Not exposed						
Karaikal									
Yanam									
Mahe									

3.5.3. Fisheries

Puducherry is at high risk to SLR under the current and future time periods. All the remaining regions display mixed trends across different return and time periods for flooding.

Table 33 summarises the risk to the fisheries sector across the chosen hazards.

In the current and future time periods, Karaikal and Puducherry exhibit high drought risk while Yanam is at low drought risk. Mahe is at low drought risk in the current time period, but exhibits high risk in the future.

When heatwaves are considered, all regions except Mahe exhibit high risk in the current time period. In the future, Karaikal and Yanam will be at high risk, Puducherry at low risk, and Mahe at medium risk.

In the current and future time periods, none of the fishery-related infrastructural assets in Mahe are exposed to SLR, giving them a low risk score. Puducherry is at high risk to SLR under the current time period. In the future time period, all regions are at low risk.

Puducherry is at high risk to SLR under the current and future time periods. All the remaining regions display mixed trends across different return and time periods for flooding.

Table 33: Risk to the fisheries sector across current and future time periods

Region	Drought	Heatwave	SLR	Flood return period (years)					
				2	5	10	25	50	100
Current									
Puducherry									
Karaikal									
Yanam									
Mahe									
Future									
Puducherry									

Karaikal									
Yanam									
Mahe									

3.5.4. Urban

Table 34 is a summary of the risk to the urban sector across the selected hazards.

The urban sector of Yanam and Puducherry is the most at risk while that of Mahe is the least at risk to drought in the current time period. In the future time period, under the RCP 4.5 scenario, the urban sector of Yanam is the least at risk to drought while Puducherry and Karaikal are at high risk, and Mahe is at medium risk.

Mahe has low heatwave risk in the current time period, whereas the remaining regions exhibit a high heatwave risk. In the future time period, under the RCP 4.5 scenario, Puducherry is the least at risk to heatwaves, Karaikal and Yanam remain the highest at risk, and Mahe is at medium risk.

In the current time period, Karaikal, Mahe, and Yanam are the least at risk, whereas Puducherry's SLR risk is classified as high. In the future time period, under the SSP2-4.5 scenario, the urban sector in Yanam is deemed to be at high risk while Mahe is at low risk and Puducherry and Karaikal are at medium risk.

Flood poses a high risk to the urban sector in Yanam across all return and time periods. Puducherry is at low risk across both time periods and for all return periods.

Table 34: Risk to the urban sector across current and future time periods

Current									
Region	**Drought**	**Heatwave**	**SLR**	**Flood return period (year)**					
				2	***5***	***10***	***25***	***50***	***100***
Puducherry									
Karaikal									
Yanam									
Mahe									
Future									
Puducherry									
Karaikal									
Yanam									
Mahe									

3.5.5. Water

Table 35 summarises the risk to the water sector across the chosen hazards.

Across both time periods, Yanam and Mahe are at high and low risk to drought, respectively. Puducherry, which is at medium risk in the current time period, is at high risk for future drought.

In the current time period, the water sector of Karaikal, Puducherry, and Yanam are at high heatwave risk while Mahe is the least at risk. In the future time period, under the RCP 4.5 scenario, Puducherry and Mahe are the least at risk, Yanam is at high risk and Karaikal is at medium risk.

In the current time period, Puducherry exhibits the highest SLR risk while all other regions are at low risk. In the future time period, under the SSP2-4.5 scenario, Puducherry and Yanam are at high risk, Yanam at medium risk, and Mahe at low risk.

Flood risk exhibits mixed trends across all regions in current and future time periods.

Table 35: Risk to the water sector across current and future time periods

Current									
Region	**Drought**	**Heatwave**	**SLR**	**Flood return periods (years)**					
				2	***5***	***10***	***25***	***50***	***100***
Puducherry									
Karaikal									
Yanam									
Mahe									
Future									
Puducherry									
Karaikal									
Yanam									
Mahe									

3.5.6. Tourism

Table 36 is a summary of the risk to the tourism sector across the selected hazards.

Mahe's tourism sector is at low risk to drought in the current and future time periods while that in Karaikal and Puducherry have a high risk. Yanam, while being at high risk to drought in the current time period, is at low risk in the future.

Mahe's tourism sector is the least at risk to heatwave in the current and future time periods, while Karaikal, Puducherry, and Yanam are at a high risk in the current time period. Puducherry, while being at high risk to heatwaves in the current time period, is at low risk in the future.

The tourism sector of Puducherry, on the other hand, is at high risk to SLR, while all other regions are at low risk across both time periods.

Yanam exhibits high flood risk across all return periods in the current and future time periods. The other regions exhibit mixed trends.

Table 36: Risk to the tourism sector across current and future time periods

Current									
Region	**Drought**	**Heatwave**	**SLR**	**Flood return period (year)**					
				2	***5***	***10***	***25***	***50***	***100***
Puducherry									
Karaikal									
Yanam									
Mahe									
Future									
Puducherry									

Karaikal									
Yanam									
Mahe									

3.5.7. Health

Table 37 presents the risk to the health sector across the chosen hazards.

In the current time period, the health sector of Mahe is the least at risk to drought, Yanam is deemed to be at medium risk, and Karaikal and Puducherry are the highest at risk. In the future time period, Karaikal and Puducherry remain high at risk while the health sector of Yanam and Mahe is low at risk to droughts.

In the current time period, Mahe remains at low risk to heatwaves while Puducherry, Karaikal, and Yanam are high at risk. In the future, under the RCP 4.5 scenario, Puducherry and Mahe both have low risk while Karaikal and Yanam remain at high risk.

Under current and future time periods, SLR does not pose a threat to the health sector in Puducherry UT as none of the assets are exposed.

Mahe and Yanam are at low flood risk across all return periods and both time periods. Karaikal is seen to be at a relatively higher risk in the current and future time periods, barring the 2-year return period in the current time period.

Table 37: Risk to the health sector across current and future time periods

Current									
Region	**Drought**	**Heatwave**	**SLR**	**Flood return period (year)**					
				2	***5***	***10***	***25***	***50***	***100***
Puducherry			Not exposed						
Karaikal									
Yanam									
Mahe									
Future									
Puducherry			Not exposed						
Karaikal									
Yanam									
Mahe									

3.5.8. Drivers of risk

The drivers of risk for each region and hazard are determined by assessing the highest value among hazard, exposure, and vulnerability.

For both drought and heatwave risk, all regions across all sectors are driven by exposure. This is because drought and heatwave uniformly affect all the regions in the UT, thereby causing the exposure to be 100% for all sectors.

In the case of SLR, given that the probability of occurrence of future SLR is 100%, the hazard is the main driver of risk for future SLR across all regions and sectors. For the current SLR, in most cases, vulnerability drives risk.

In the case of floods, the drivers vary depending on the return period. However, for the 2-year return period flood event, in many cases, vulnerability and hazard share equal responsibility of being the main drivers. For the remaining return periods, vulnerability is the main driver for most sectors and regions.

3.6. Inter-sectoral climate risk

This section presents risk to be visualised across all regions, for each hazard. The visualisation aids users assess which sector is the most at risk to a given hazard.

Legends for all tables in this sub-section are colour-coded as shown below.

High risk	
Medium risk	
Low risk	

3.6.1. Drought

In the current time period, most regions lie between moderate and low risk. In Puducherry all sectors are moderately affected by drought across both time periods. In Karaikal, the agriculture and water sectors are at low risk to drought while the rest remain at moderate risk. Aside from fisheries, all sectors are moderately affected by drought. In Mahe, aside from fisheries, all sectors are at low risk.

For the future time period, all sectors in Puducherry and Karaikal are moderately at risk to drought. Yanam and Mahe display mixed trends.

Table 38: Current and future drought risk to all sectors

Region	Time period	Agriculture	Livestock	Fisheries	Water	Urban	Tourism	Health
Puducherry	Current							
	Future							
Karaikal	Current							
	Future							
Yanam	Current							
	Future							
Mahe	Current							
	Future							

3.6.2. Heatwave

In Puducherry, the tourism and health sectors are at high risk to heatwaves in the current time period while the remaining sectors are moderately at risk (Table 39). In Karaikal, the fisheries, health, and tourism sectors are at high risk while the rest are moderately at risk. The livestock and water sectors are at high risk in Yanam, and all sectors in Mahe are at low risk.

In the future time period, aside from the tourism and health sectors, all other sectors are at low risk in Puducherry. In Karaikal, the health, fisheries, and tourism sectors are at high risk, and the remaining are moderately at risk to heatwaves. In Yanam, aside from the fisheries and health sector, all others are at high heatwave risk. In Mahe, all sectors are moderately at risk.

Table 39: Current and future heatwave risk to all sectors

Region	Time period	Agriculture	Livestock	Fisheries	Water	Urban	Tourism	Health
Puducherry	Current							
	Future							
Karaikal	Current							
	Future							
Yanam	Current							
	Future							
Mahe	Current							
	Future							

3.6.3. SLR

Regarding SLR risk in the current time period, all sectors are uniformly at low risk for all regions (Table 40).

In the future time period, in Puducherry, the urban sector is moderately at risk to SLR while the remaining sectors are at low risk. In Yanam, the water sector is moderately at risk while the remaining sectors are at low risk. In Mahe, all sectors are equally at low risk to SLR. The health sector is exempted as it is not exposed to SLR across all regions.

Table 40: Current and future SLR risk to all sectors

Region	Time period	Agriculture	Livestock	Fisheries	Water	Urban	Tourism	Health
Puducherry	Current							
	Future							
Karaikal	Current							
	Future		Not exposed					Not exposed
Yanam	Current							
	Future							
Mahe	Current							
	Future							

3.6.4. Flood

2-Year return period

As seen in Table 41, all sectors are uniformly at low flood risk in Karaikal in the current time period. In Puducherry, the fisheries and water sector are at moderate risk while all other sectors are at low risk. In Yanam, the agriculture, fisheries, and health sectors are at low risk while the remaining sectors are moderately at risk. In Mahe, the water sector is moderately at risk while all other sectors are at low risk.

For the future time period, in Puducherry, the fisheries and water sector are moderately at risk to flooding while all other sectors are at low risk. In Karaikal, the fisheries sector is moderately at risk while all others remain at low risk. In contrast, in Yanam, the fisheries, agriculture, and health sectors are at low risk while all other sectors are moderately at risk. In Mahe, the water sector is moderately at risk while all other sectors are at low risk.

Table 41: Current and future flood risk to all sectors under the 2-year return period

Region	Time period	Agriculture	Livestock	Fisheries	Water	Urban	Tourism	Health
Puducherry	Current							
	Future							
Karaikal	Current							
	Future							
Yanam	Current							
	Future							
Mahe	Current							
	Future							

5-Year return period

As seen in Table 42, aside from the fisheries sector in Karaikal, the livestock sector in Yanam, and the water sector in Mahe, all regions exhibit low flood risk in the current time period.

Under the future time period, the agriculture sector in Puducherry and Karaikal, as well as the fisheries sector in Karaikal, the livestock sector in Karaikal, and the water sector in Mahe, are moderately at risk. The remaining regions remain low at risk across all sectors.

Table 42: Current and future flood risk to all sectors under the 5-year return period

Region	Time period	Agriculture	Livestock	Fisheries	Water	Urban	Tourism	Health
Puducherry	Current							
	Future							
Karaikal	Current							
	Future							
Yanam	Current							
	Future							
Mahe	Current							
	Future							

For the current and future flood risk under the 10-, 25-, 50-, and 100-year return periods, all regions across all sectors are uniformly at low risk to flooding.

1.1. CRAT – Puducherry

CRAT is available as a web-based interactive tool. Users can use the tool to visualise the probability of occurrence and spatial extent of a hazard, the exposure of assets, the vulnerability of sectors, and the overall climate risk.

Figure 32: Spatial extent of a 100-year return-period flood event

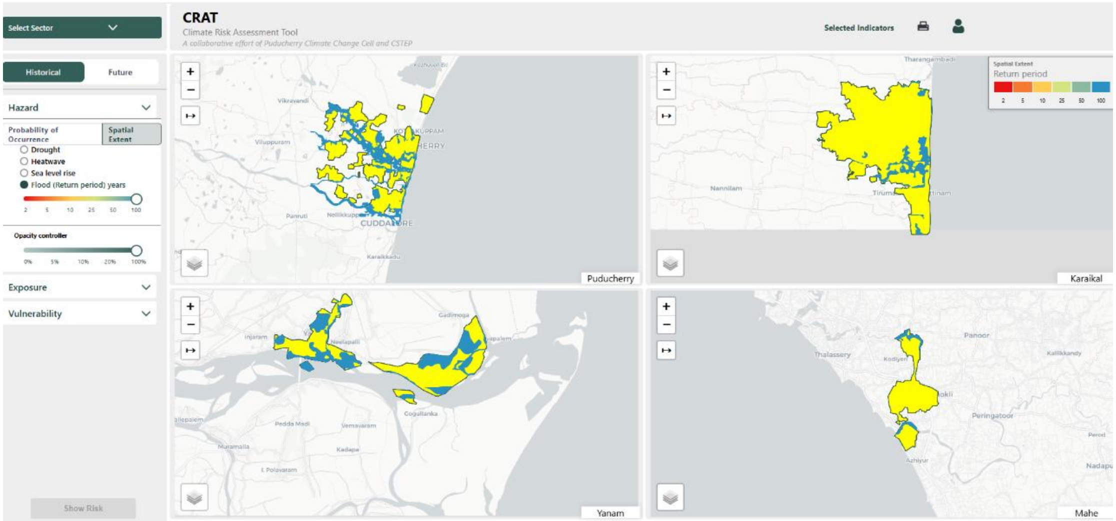


Figure 33: Exposure of tourism-related assets to a 100-year return-period flood event

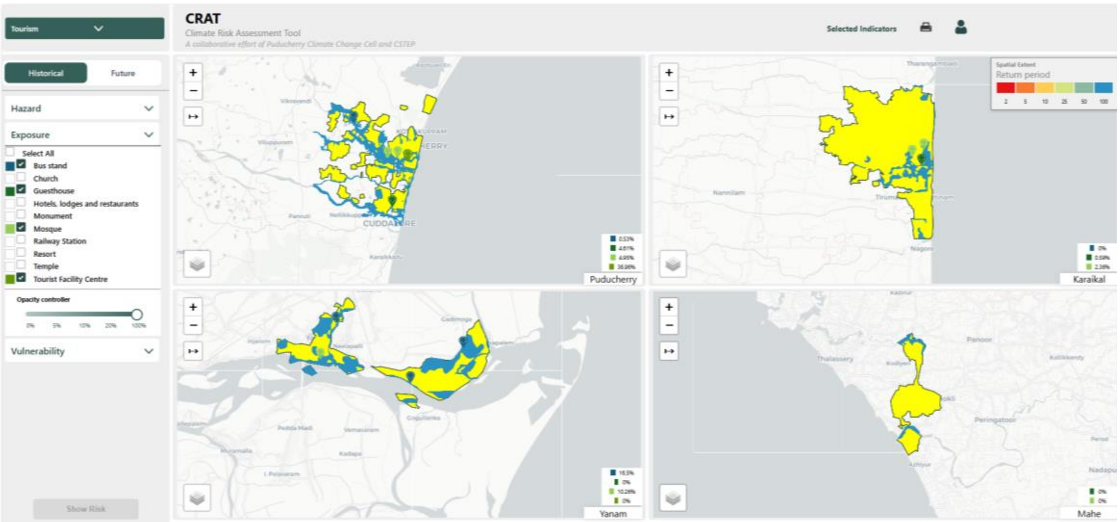
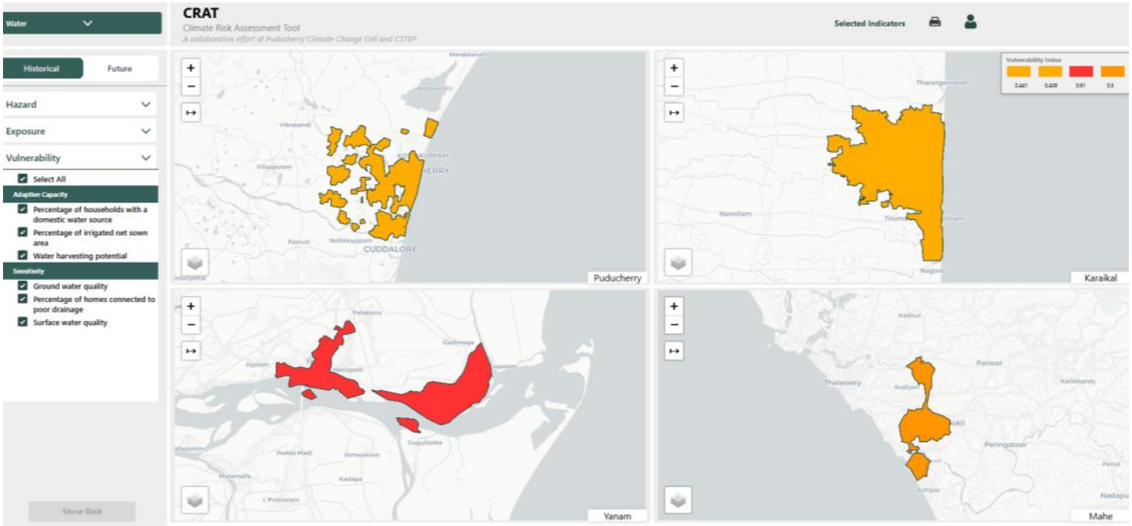


Figure 34: Vulnerability of the urban sector



4. Conclusion

Comprehensive regional information on current and future climate risks is crucial for developing effective adaptation plans and is, therefore, one of the priorities of the National Mission on Strategic Knowledge for Climate Change (NMSKCC). A climate risk assessment is vital to fostering resilience, safeguarding assets in all sectors, and ensuring sustainable development in a world increasingly affected by climate change.

It is necessary to develop and customise tools and methodologies for adaptation planning interventions from the global models to suit regional requirements. It allows stakeholders to manage uncertainty and make plans for a more climate-resilient future. In this context, an extensive climate risk assessment for the UT of Puducherry, utilising the IPCC AR5 framework, was conducted, and the results of the assessment are presented in this report. This assessment encompassed the evaluation of the probability of occurrence of climate hazards—drought, heatwave, SLR, and flood—under both current (historical) and future scenarios using the best possible datasets, methods, and tools. The exposure of sectors—agriculture, livestock, fisheries, tourism, urban, and water—to these hazards were analysed and geospatially mapped. Moreover, an indicator-based vulnerability assessment was performed, incorporating biophysical, socio-economic, institutional, and governance indicators to provide a comprehensive understanding of sector-specific risks.

The findings of this assessment facilitated the development of CRAT, which offers a visual and interactive interface for users to explore overall risks across different sectors due to selected hazards. This first-of-kind user-friendly interactive tool is aimed at helping officials/stakeholders to understand climate risk components and visualise its extent in the region. Moreover, this tool could guide policy decisions and resource allocation for climate adaptation and mitigation activities in the UT. Moving forward, it is imperative to develop and implement targeted adaptation and mitigation strategies for the high-risk sectors, leveraging visual insights from the CRAT. This tool can be updated with new datasets to recalculate the risk after a few years after implementation of targeted adaptation and resilience measures in Puducherry UT.

To enhance the accuracy of future studies, there is a critical need for improved data, which will enable more refined and high-resolution assessments. In the hazard assessment, 0.25° × 0.25° gridded data were used, yet further high-resolution data will be beneficial for small regions such as Puducherry UT. Moreover, for vulnerability assessments, the availability of more recent datasets beyond the 2011 census data will provide more information on current vulnerabilities and risks.

Future research would benefit significantly from a more localised and context-specific approach, such as zone-level studies, which would offer nuanced insights and support the development of tailored risk management strategies for Puducherry UT. Finally, expanding the development of CRAT to other multi-hazard-prone areas of India will provide valuable visual representations and information on risks across states/regions/sectors, thereby supporting more effective climate risk management nationwide.

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6. Appendices

Appendix 1: Exposure indicators

Table A 1: Exposure indicators for Karaikal

Sector	Indicator	Sub-indicator	Geometry	Total (polygon; sq. m, polyline; m, point; count)
Agriculture	Agriculture market	-	Polygon	5,641.45
	Food processing unit	-	Polygon	8,624.84
	Net sown area	-	Polygon	5,96,72,320.34
Fisheries	Essential infrastructure	Cold storage	Point	1
		Community hall	Point	10
		Diesel bunk	Point	1
		Fish drying platform	Point	2
		Work shelter	Point	10
	Mangrove	-	Polygon	2,10,535.81
Health	Anganwadi	-	Polygon	6,421.46
	Medical facility	Diagnostic centre	Polygon	72.43
		Government hospital	Polygon	43,807.63
		Pharmacy	Polygon	515.75
		Private hospital	Polygon	6,429.02
	Old age home	-	Polygon	1,040.81
Livestock	Dairy booth	-	Polygon	76.22
	Dairy farm	-	Polygon	779.25
	Livestock population	Cattle	Polygon	11,77,02,236.74
		Chicken	Polygon	11,84,00,539.12
	Medical facility	Government hospital	Polygon	122.13
	Slaughter house	-	Polygon	1,810.07
Tourism	Bus stand	-	Polygon	3,168.01
	Church	-	Polygon	13,019.79
	Guesthouse	-	Polygon	7,664.66
	Hotel, lodge, and restaurant	-	Polygon	28,738.66
	Mosque	-	Polygon	17,027.95
	Railway station	-	Polygon	3,906.36
	Resort	-	Polygon	4,688.77
	Temple	-	Polygon	1,13,509.24
Urban	Municipal urban area	-	Polygon	10,09,39,409.04
	Railway line	-	Polyline	14,759.99
	Railway station	-	Polygon	3,906.36
	Road network	-	Polyline	8,74,245.19

Sector	Indicator	Sub-indicator	Geometry	Total (polygon; sq. m, polyline; m, point; count)
Water	Drainage network	-	Polyline	82,77,116.76
	Water pumping station	-	Polygon	4,330.51
	Water treatment plant	-	Polygon	80.58
	Waterbody	-	Polygon	38,84,554.04

Table A 2: Exposure indicators for Mahe

Sector	Indicator	Sub-indicator	Geometry	Total (polygon; sq. m, polyline; m, point; count)
Agriculture	Food processing unit	-	Polygon	6,314.31
	Net sown area	-	Polygon	14,48,346.21
	Storage godown	-	Polygon	14,920.12
Fisheries	Essential infrastructure	Cold storage	Point	1
	Mangrove	-	Polygon	155.66
Health	Anganwadi	-	Polygon	456.18
	Medical facility	Government hospital	Polygon	5,180.38
		Pharmacy	Polygon	2,870.49
		Private hospital	Polygon	353.69
Livestock	Cattle	-	Polygon	90,15,609.56
	Poultry farm	-	Polygon	1
	Veterinary dispensary	-	Point	1
Tourism	Church	-	Polygon	1,090.68
	Guesthouse	-	Polygon	347.60
	Hotel, lodge, and restaurant	-	Polygon	3,786.58
	Mosque	-	Polygon	5,223.69
	Temple	-	Polygon	8,589.24
Urban	Road network	-	Polyline	94,007
Water	Canal	-	Polygon	785.21
	River	-	Polygon	1,92,586.78
	Water pumping station	-	Polygon	159.09
	Waterbody	-	Polygon	665.11

Table A 3: Exposure indicators for Puducherry

Sector	Indicator	Sub-indicator	Geometry	Total (polygon; sq. m, polyline; m, point; count)
Agriculture	Agriculture market	-	Polygon	12,197.04
	Food processing unit	-	Polygon	6,766.44
	Net sown area	-	Polygon	13,82,07,322.86
	Storage godown	-	Polygon	35,371.06
Fisheries	Essential infrastructure	Cold storage	Point	5
		Diesel bunk	Point	1
		Fish auction hall	Point	2
		Fish curing yard	Point	2
		Fish drying platform	Point	5
		Net mending shed	Point	6
		Work shelter	Point	13
	Mangrove	-	Polygon	7,19,530.53
Health	Anganwadi	-	Polygon	10,631.58
	Medical facility	Diagnostic centre	Polygon	408.42
		Government hospital	Polygon	47,203.96
		Nursing home	Polygon	1,363.01
		Pharmacy	Polygon	7,464.68
		Private hospital	Polygon	33,435.76
	Old age home	-	Polygon	3,061.14
Livestock	Dairy booth	-	Polygon	1,292.26
	Dairy farm	-	Polygon	1,635.15
	Key village unit	-	Point	1
	Livestock population	Cattle	Polygon	28,32,13,021.57
		Chicken	Polygon	28,32,13,021.39
		Sheep	Polygon	28,32,13,021.39
	Poultry farm	-	Polygon	478.93
	Slaughter house	-	Polygon	952.30
	Veterinary dispensary	-	Point	13
Tourism	Bus stand	-	Polygon	7,453.27
	Church	-	Polygon	36,030.90
	Guesthouse	-	Polygon	5,555.78
	Hotel, lodge, and restaurant	-	Polygon	1,24,483.09

Sector	Indicator	Sub-indicator	Geometry	Total (polygon; sq. m, polyline; m, point; count)
	Monument	-	Polygon	986.54
	Mosque	-	Polygon	11,009.30
	Railway station	-	Polygon	3,704.75
	Resort	-	Polygon	28,935.46
	Temple	-	Polygon	1,91,750.51
	Tourist facility centre	-	Polygon	2,109.65
Urban	Green space	-	Polygon	1,35,821.51
	Municipal urban area	-	Polygon	3,33,92,898.34
	Railway line	-	Polyline	13,187.85
	Railway station	-	Polygon	3,704.75
	Road network	-	Polyline	23,24,706.46
Water	Check dam	-	Polyline	5,531.16
	Drainage network	-	Polygon	8,277,116
	Sewage treatment plant	-	Polygon	2,736.14
	Water pumping station	-	Polygon	20,542.38
	Water treatment plant	-	Polygon	5,454.12
	Waterbody	-	Polygon	2,02,98,960.25

Table A 4: Exposure indicators for Yanam

Sector	Indicator	Sub-indicator	Geometry	Total (polygon; sq. m, polyline; m, point; count)
Agriculture	Food processing unit	-	Polygon	8,805.70
	Agriculture market	-	Polygon	10,766.31
	Net sown area	-	Polygon	3,54,56,212.79
Livestock	Cattle population	-	Polygon	21,20,12,970.3
	Dairy booth	-	Polygon	154.52
	Dairy farm	-	Polygon	0.21
	Poultry farm	-	Polygon	4,019.44
	Veterinary dispensary	-	Point	1
Fisheries	Mangrove	-	Polygon	1,09,18,415.8
	Essential infrastructure	Cold storage	Point	1
		Diesel bunk	Point	1
		Community hall	Point	17
Tourism	Bus stand	-	Polygon	2,089.76
	Church	-	Polygon	6,456.54
	Guesthouse	-	Polygon	910.71
	Hotel, lodge, and restaurant	-	Polygon	3,512.10
	Monument	-	Polygon	29,198.10
	Mosque	-	Polygon	781.27
	Temple	-	Polygon	10,763.24
	Tourist facility centre	-	Polygon	79.89
Urban	Green space	-	Polygon	2,57,559.59
	Road network	-	Polyline	4,52,604.49
Water	Drainage network	-	Polyline	1,04,94,509.97
	Sewage treatment plant	-	Polygon	1,034.46
	Water pumping station	-	Polygon	1,517.87
	Waterbody	-	Polygon	1,36,661.67
Health	Anganwadi	-	Polygon	515.18
	Old age home	-	Polygon	887.78
	Medical facility	Diagnostic centre	Polygon	148.69
		Government hospital	Polygon	1,839.32
		Nursing home	Polygon	104.76
		Private hospital	Polygon	196.74
		Pharmacy	Polygon	823.77

Appendix 2: Tide gauge station–derived sea level data

Table A 5: Sea level data for Chennai, Kochi, and Vishakhapatnam tide gauge stations accessed from PSMSL portal

Year	Tide gauge station		
	Chennai (cm)	Kochi (cm)	Vishakhapatnam (cm)
1968	696.6	-	-
1969	697.7	-	-
1971	699.3	-	-
1972	694	-	701.7
1973	700.7	-	710.9
1974	700.8	-	710.7
1975	697.5	-	710.4
1976	695.2	-	705.8
1977	-	710.1	706
1978	699.1	705.5	710.8
1979	-	707.8	708.3
1980	700.4	708.9	710.4
1981	704.4	710.6	-
1982	692.6	706	703.2
1983	697.1	703.2	706.8
1984	-	702.8	714.9
1985	-	-	709.7
1986	-	703.9	705.7
1987	699.7	704.9	-
1988	-	706.1	714.1
1989	-	708	710.7
1990	-	706.8	
1991	-	-	705.2
1992	698	708.7	-
1993	-	705.5	707.9
1994	-	706.5	703.1
1995	700.4	-	709.1
1997	-	713.5	-
1999	700.4	-	-
2000	703.1	-	715.3
2001	705.5	-	-

Year	Tide gauge station		
	Chennai (cm)	Kochi (cm)	Vishakhapatnam (cm)
2002	698.7	-	-
2003	700	-	-
2004	698.9	-	-
2005	699.9	-	712.2
2006	696	-	-
2007	699.4	-	-
2008	703.7	710.5	-
2009	703.1	709.4	709.2
2010	706.7	711.1	-
2011	705.4	713.2	712.5
2012	701.6	710.8	-
2013	-	712	717.2
2015	-	720.5	-
2016	-	714.4	-
2017	-	713.6	718.1
2018	-	714.7	719.1
2019	-	715.1	708.5
2020	-	717.9	719.7
2021	-	720.2	729

Appendix 3: Rationale for selection of vulnerability indicators

Table A 6: Rationale for selection of vulnerability indicators

Sector	Indicator	Rationale
Agriculture	Cropping intensity	Cropping intensity can provide an estimate of the efficiency of agricultural land use
	Cluster-based farming area	Cluster-based farming is a practice that employs organic farming through resource pooling. Given that organic farming is crucial for human and planet health, it is important to measure this indicator.
	Insured gross cropped area	Agricultural insurance is an important tool to help farmers tide over losses brought about by climate impacts.
	Access to agricultural inputs	A higher number of agricultural inputs improves farm productivity and, hence, reduces vulnerability.
	Agricultural workforce	Agricultural labourers are acutely vulnerable to the effects of climate change.
	Small and marginal farmers	These farmers are socially and economically deprived, making them vulnerable to the impacts of climate change.
	Rainfed net sown area	Rainfed agricultural lands are at risk to variations in climatic patterns, which in turn affects agricultural output.
	Yield variability	Yield variability implies unstable farm incomes, thereby increasing vulnerability.
	Agricultural Dependence Disparity Index	This index highlights the disparity between the agriculture sector's contribution to employment and its economic output within a district. A high disparity indicates an unproductive and sluggish agriculture sector.
	Soil moisture	Higher soil moisture indicates better soil health, making agriculture more productive.
	Average evapotranspiration	This measurement is critical for assessing water availability and agricultural productivity.
Livestock	Veterinary hospital burden	Higher the burden, greater is the strain placed on veterinary services by the livestock population, affecting the hospital's ability to provide adequate care and treatment.
	Variation in livestock productivity	This indicator reflects how productivity has increased, decreased, or fluctuated due to factors such as breeding practices, feed quality, disease management, and environmental conditions.
	Livestock Dependence Disparity Index	This index highlights the disparity between the livestock sector's contribution to employment and its economic output within a district. A high disparity is indication of an unproductive and sluggish livestock sector.

Sector	Indicator	Rationale
	Livestock-to-human ratio	A higher livestock-to-human ratio implies higher income generating capacities, which can reduce vulnerabilities.
	Female literacy rate	As females predominantly tend to livestock in Puducherry, it is important to gauge their literacy rate so that future adaptation actions and plans can be adequately tailored to their needs.
	Insured cattle (%)	This indicator reflects the extent to which livestock owners have opted for financial protection to mitigate potential losses, which is a measure of their preparedness for climate-related impacts.
	Local breeds to total cattle population (%)	Traditional varieties of livestock are more resilient to the effects of climate change.
	Livestock vaccinated (%)	This indicator measures the extent to which livestock owners have implemented preventive healthcare measures to protect their animals from contagious diseases and improve overall herd health, thereby making livestock less vulnerable to the effects of climate change.
Fisheries	Access to essential infrastructure and financial support systems	Higher the access to essential infrastructure and financial support systems, lower is the vulnerability of fisherfolk.
	Involvement of female fisherfolk	This indicator highlights the role and contribution of females in the fisheries sector, providing insights into gender distribution.
	Vessel motorisation	A higher proportion of motorised vessels can provide better economic outcomes and improved livelihoods for fisherfolk.
	Distance of coastal villages from HTL	Average distance of coastal fishing villages from HTL represents the proximity of these villages to the sea, increasing their susceptibility to coastal erosion, storm surges, and other impacts.
	Wetland density	Wetlands play a crucial role in microclimate regulation and protection from storm surges, which reduces the vulnerability of coastal settlements to the impacts of climate change.
	Ratio of marine to inland fisherfolk	Marine fisherfolk incur risk by venturing into the sea. This makes them prone to disasters such as cyclones, floods, and storms, thereby increasing their vulnerability.
	Fisheries Dependence Disparity Index	This index highlights the disparity between the fishery sector's contribution to employment and its economic output within a district. A high disparity indicates an unproductive and sluggish fishery sector.
	Fish yield variability	High yield variabilities imply a high variation in incomes, which causes greater vulnerability among fisherfolk.

Sector	Indicator	Rationale
Water	Domestic water source	A proximate domestic water source reduces the drudgery women face to collect water, thereby reducing their vulnerability.
	Water harvesting potential	The indicator reflects the capacity and utilisation of water harvesting infrastructure within each district.
	Irrigation potential	This metric reflects the extent and utilisation of irrigation infrastructure in agricultural practices.
	Surface water quality	The health of the surface water determines the health of groundwater, which impacts agricultural and human health.
	Households with poor drainage	Poor drainage can lead to a host of chronic (such as stunting) and acute (such as diarrhoea) diseases.
	Groundwater quality index	This indicator determines the health of groundwater for a variety of uses.
Urban	Households with basic amenities	This metric represents the standard of living for individuals residing in an area.
	Green/blue area density	These areas are a proxy to measure the quantum of ecosystem services provided by natural resources.
	Percentage of homes in good liveable condition	Pucca homes with structurally sound roofs and walls have been considered for this indicator, which provides a higher degree of safety during storms, cyclones, and rainfall torrents.
	Surface water quality	The health of the surface water determines the health of groundwater, which impacts agricultural and human health.
	Population density	A higher density indicates greater concentration of people in an area, influencing resource distribution and the overall liveability of the area.
	Physically sensitive population	A higher degree of physically and economically sensitive populations increases the vulnerability of the region.
	Economically vulnerable population	
	Urban slum households (%)	Urban slums often house some of the most marginalised and vulnerable populations, making them vulnerable to the effects of climate change.
Tourism	Groundwater quality index	This indicator determines the health of groundwater for a variety of uses.
	Disease prevalence rate	This metric indicates the frequency and prevalence of diseases within a population, which can negatively affect tourism in those regions.
	Variation in tourists	A higher variation of tourists translates into a greater degree of income variation, which can negatively impact the tourism industry.
	Tourist burden on hotels	A high tourist burden on hotels implies a lack of infrastructure, which can affect tourism incomes, making the sector more vulnerable.

Sector	Indicator	Rationale
	Tourist burden on police stations	A high tourist burden on police stations implies a lack of safety infrastructure, which can increase the vulnerability of the tourism industry.
	Road density	This metric reflects the extent of road infrastructure within a given area, influencing transportation accessibility and connectivity.
	Street light density	This indicator reflects the level of street illumination and infrastructure in a particular area, contributing to safety, visibility, and urban planning.
	Surface water quality	The health of the surface water determines the health of groundwater, which impacts agricultural and human health.
Health	Infant mortality rate	A high degree of infant mortality indicates inadequate healthcare and early childcare infrastructure.
	Access to healthcare	This indicator reflects the demand for medical services relative to the capacity of healthcare infrastructure.
	Physically sensitive population	A higher degree of physically sensitive population increases the vulnerability of the region.
	Percentage of BPL households	Such households are economically and socially deprived, making them acutely vulnerable.
	Disease prevalence rate	This metric indicates the frequency and prevalence of diseases within a population, which can negatively affect tourism in those regions.
	Population with health insurance coverage (%)	This metric reflects the extent to which individuals in a given area are protected against medical costs and have access to medical services through insurance coverage.
	Female literacy rates	Female literacy rates are correlated with higher literacy of the overall family, reducing household vulnerability.
	Availability of reliable healthcare services	Reliable healthcare services aid in improving the overall health outcomes of a region, thereby decreasing vulnerability.

Appendix 4: Legends

Hazard

Table A 7: Probability of occurrence of droughts in the current time period

Probability of occurrence	Upper limit	Lower limit
High	0.101	0.087
Medium	0.086	0.072
Low	0.071	0.056

Table A 8: Probability of occurrence of droughts in the future time period

Probability of occurrence	Upper limit	Lower limit
High	0.115	0.098
Medium	0.097	0.079
Low	0.078	0.059

Table A 9: Probability of occurrence of heatwaves in the current time period

Probability of occurrence	Upper limit	Lower limit
High	0.533	0.357
Medium	0.356	0.179
Low	0.178	0.000

Table A 10: Probability of occurrence of heatwaves in the future time period

Probability of occurrence	Upper limit	Lower limit
High	0.633	0.445
Medium	0.444	0.257
Low	0.256	0.067

Table A 11: Probability of occurrence of SLR in the current time period

Probability of occurrence	Upper limit	Lower limit
High	0.430	0.354
Medium	0.353	0.278
Low	0.277	0.200

Inter-regional vulnerability

Table A 12: Inter-regional vulnerability classification

Vulnerability	Agriculture		Livestock		Fisheries		Urban		Water		Tourism		Health	
	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
High	0.553	0.528	0.670	0.583	0.714	0.599	0.562	0.536	0.892	0.741	0.729	0.561	0.663	0.568
Medium	0.527	0.502	0.582	0.496	0.598	0.482	0.535	0.509	0.740	0.589	0.560	0.392	0.567	0.472
Low	0.501	0.475	0.495	0.408	0.481	0.364	0.508	0.481	0.588	0.436	0.391	0.223	0.471	0.375

Risk

Agriculture

Table A 13: Risk of drought to the agriculture sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
	Upper limit	**Lower limit**	**Upper limit**	**Lower limit**
High	0.383	0.361	0.380	0.361
Medium	0.360	0.337	0.360	0.341
Low	0.336	0.313	0.340	0.320

Table A 14: Risk of heatwave to the agriculture sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	**Upper limit**	**Lower limit**	**Upper limit**	**Lower limit**
	0.637	0.427	0.705	0.576
Medium	0.426	0.216	0.575	0.447
Low	0.215	0.004	0.446	0.316

Table A 15: Risk of SLR to the agriculture sector in the current and future time periods

Risk	Current time period		Future time period (SSP2-4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.037	0.026	0.049	0.034
Medium	0.025	0.013	0.033	0.017
Low	0.012	-	0.016	0.000

Table A 16: Risk of flood to the agriculture sector in the current time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.293	0.203	0.230	0.181	0.197	0.157	0.161	0.131	0.136	0.109	0.117	0.093
Medium	0.202	0.112	0.180	0.131	0.157	0.117	0.130	0.100	0.108	0.082	0.092	0.068
Low	0.111	0.020	0.130	0.080	0.116	0.075	0.099	0.067	0.081	0.053	0.067	0.042

Table A 17: Risk of flood to the agriculture sector in the future time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.292	0.228	0.223	0.176	0.186	0.151	0.158	0.126	0.125	0.100	0.104	0.085
Medium	0.227	0.162	0.175	0.129	0.150	0.114	0.125	0.093	0.099	0.074	0.084	0.064
Low	0.161	0.096	0.128	0.080	0.113	0.076	0.092	0.058	0.073	0.046	0.063	0.042

Livestock

Table A 18: Risk of drought to the livestock sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.408	0.368	0.389	0.366
Medium	0.367	0.327	0.365	0.343
Low	0.326	0.284	0.342	0.318

Table A 19: Risk of heatwave to the livestock sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.679	0.453	0.751	0.609
Medium	0.452	0.227	0.608	0.466
Low	0.226	-	0.465	0.321

Table A 20: Risk of SLR to the livestock sector in the current and future time periods

Risk	Current time period		Future time period (SSP2-4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	-	0.001	-	0.001
Medium	-	0.001	-	0.001
Low	-	-	-	0.000

Table A 21: Risk of flood to the livestock sector in the current time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower imit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.479	0.335	0.354	0.277	0.282	0.221	0.209	0.164	0.167	0.131	0.133	0.104
Medium	0.334	0.189	0.276	0.199	0.220	0.158	0.163	0.117	0.130	0.094	0.103	0.075
Low	0.188	0.043	0.198	0.119	0.157	0.095	0.116	0.070	0.093	0.055	0.074	0.044

Table A 22: Risk of flood to the livestock sector in the future time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower imit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.479	0.371	0.354	0.277	0.281	0.220	0.209	0.164	0.166	0.130	0.132	0.104
Medium	0.370	0.262	0.276	0.198	0.219	0.158	0.163	0.117	0.129	0.093	0.103	0.074
Low	0.261	0.151	0.197	0.119	0.157	0.095	0.116	0.070	0.092	0.055	0.073	0.044

Fisheries

Table A 23: Risk of drought to the fisheries sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.384	0.368	0.414	0.370
Medium	0.367	0.351	0.369	0.324
Low	0.350	0.333	0.323	0.278

Table A 24: Risk of heatwave to the fisheries sector in the current and future time period

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.688	0.461	0.705	0.582
Medium	0.460	0.233	0.581	0.458
Low	0.232	0.004	0.457	0.334

Table A 25: Risk of SLR to the fisheries sector in the current and future time periods

Risk	Current time period		Future time period (SSP2-4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.187	0.126	-	0.001
Medium	0.125	0.063	-	0.001
Low	0.062	-	-	0.000

Table A 26: Risk of flood to the fisheries sector in the current time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower imit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.390	0.261	0.354	0.237	0.281	0.188	0.207	0.139	0.164	0.110	0.130	0.088
Medium	0.260	0.131	0.236	0.119	0.187	0.095	0.138	0.070	0.109	0.056	0.087	0.044
Low	0.130	0.000	0.118	0.000	0.094	-	0.069	0.000	0.055	0.000	0.043	0.000

Table A 27: Risk of flood to the fisheries sector in the future time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower imit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower imit	Upper limit	Lower limit
	0.480	0.321	0.354	0.237	0.281	0.188	0.207	0.139	0.164	0.110	0.130	0.088
Medium	0.320	0.161	0.236	0.119	0.187	0.095	0.138	0.070	0.109	0.056	0.087	0.044
Low	0.160	0.000	0.118	0.000	0.094	-	0.069	0.000	0.055	0.000	0.043	0.000

Urban

Table A 28: Risk of drought to the fisheries sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.380	0.360	0.382	0.361
Medium	0.359	0.339	0.360	0.340
Low	0.338	0.316	0.339	0.317

Table A 29: Risk of heatwave to the fisheries sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.636	0.426	0.699	0.573
Medium	0.425	0.215	0.572	0.446
Low	0.214	0.004	0.445	0.318

Table A 30: Risk of SLR to the fisheries sector in the current and future time periods

Risk	Current time period		Future time period (SSP2-4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.178	0.120	0.460	0.308
Medium	0.119	0.060	0.307	0.154
Low	0.059	-	0.153	0.000

Table A 31: Risk of flood to the fisheries sector in the current time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower imit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower imit	Upper limit	Lower limit
	0.392	0.277	0.292	0.231	0.235	0.189	0.177	0.145	0.144	0.122	0.117	0.100
Medium	0.276	0.160	0.230	0.169	0.188	0.142	0.144	0.111	0.121	0.100	0.099	0.082
Low	0.159	0.043	0.168	0.107	0.141	0.094	0.110	0.077	0.099	0.076	0.081	0.062

Table A 32: Risk of flood to the fisheries sector in the future time period

Risk	Upper limit		Lower limit		Upper limit		Lower imit		Upper limit		Lower limit	
High	Upper limit	Lower limit	Upper limit	Lower imit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.391	0.309	0.291	0.231	0.233	0.186	0.175	0.144	0.140	0.115	0.113	0.097
Medium	0.308	0.225	0.230	0.170	0.185	0.139	0.143	0.111	0.114	0.089	0.096	0.080
Low	0.224	0.140	0.169	0.107	0.138	0.091	0.110	0.078	0.088	0.062	0.079	0.062

Tourism

Table A 33: Risk of drought to the tourism sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.420	0.358	0.438	0.380
Medium	0.357	0.296	0.379	0.320
Low	0.295	0.232	0.319	0.260

Table A 34: Risk of heatwave to the tourism sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.730	0.489	0.702	0.587
Medium	0.488	0.246	0.586	0.471
Low	0.245	0.003	0.470	0.354

Table A 35: Risk of SLR to the tourism sector in the current and future time periods

Risk	Current time period		Future time period (SSP2-4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.033	0.023	0.072	0.049
Medium	0.022	0.012	0.048	0.025
Low	0.011	-	0.024	0.000

Table A 36: Risk of flood to the tourism sector in the current time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.365	0.245	0.269	0.196	0.214	0.162	0.159	0.125	0.127	0.104	0.101	0.088
Medium	0.244	0.123	0.195	0.122	0.161	0.110	0.124	0.089	0.103	0.079	0.087	0.073
Low	0.122	0.000	0.121	0.046	0.109	0.057	0.088	0.052	0.078	0.053	0.072	0.058

Table A 37: Risk of flood to the tourism sector in the future time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.365	0.255	0.269	0.196	0.214	0.162	0.159	0.125	0.126	0.099	0.101	0.085
Medium	0.254	0.143	0.195	0.123	0.161	0.110	0.124	0.089	0.098	0.071	0.084	0.069
Low	0.142	0.031	0.122	0.048	0.109	0.057	0.088	0.052	0.070	0.042	0.068	0.051

Health

Table A 38: Risk of drought to the health sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.395	0.356	0.412	0.370
Medium	0.355	0.317	0.369	0.326
Low	0.316	0.276	0.325	0.281

Table A 39: Risk of heatwave to the health sector in the current and future time periods

Risk	Current time period		Future time period (RCP 4.5)	
High	Upper limit	Lower limit	Upper limit	Lower limit
	0.687	0.460	0.692	0.577
Medium	0.459	0.232	0.576	0.461
Low	0.231	0.003	0.460	0.343

Table A 40: Risk of flood to the health sector in the current time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.056	0.038	0.238	0.159	0.189	0.127	0.139	0.094	0.126	0.085	0.100	0.067
Medium	0.037	0.020	0.158	0.080	0.126	0.064	0.093	0.047	0.084	0.043	0.066	0.034
Low	0.019	0.000	0.079	0.000	0.063	-	0.046	0.000	0.042	0.000	0.033	0.000

Table A 41: Risk of flood to the health sector in the future time period

Risk	2 year		5 year		10 year		25 year		50 year		100 year	
High	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
	0.323	0.216	0.238	0.159	0.189	0.127	0.139	0.094	0.110	0.075	0.088	0.059
Medium	0.215	0.109	0.158	0.080	0.126	0.064	0.093	0.047	0.074	0.038	0.058	0.030
Low	0.108	0.000	0.079	0.000	0.063	-	0.046	0.000	0.037	0.000	0.029	0.000

Appendix 5: List of participants from the stakeholder consultations with PCCC

Table A 42: Stakeholder participant list

Department name	Nodal officer name	Designation
District Rural Development Agency	Thiru N Balasubramanian	Executive Engineer
Directorate of Forest and Wildlife	Thiru S Kumaravelu	Deputy Director
Public Works Department	1. Thiru A Selvarasu	Assistant Engineer
	2. Thiru K Mohanraj	Assistant Engineer (Planning)
Directorate of School Education	Thiru S Rajkumar	Lecturer, STC
Tourism Department	Thiru M Poubalane	Manager
Renewable Energy Agency	Thiru J ArunPrakash	Technical Assistant – Civil
Electricity Department	Thiru V Madhavan	Assistant Engineer/ MMC
Department of Agriculture and Farmers Welfare	Thiru H Jakir Hussain	Joint Director
Department of Animal Husbandry and Animal Welfare	Dr S Anbukkarasu	Joint Director
Department of Fisheries and Fishermen Welfare	Thiru P Meera Saheb	Project Officer
Department of Health and Family Welfare Services	Dr K Vivekandanda	State Surveillance Officer
Labour Department	1. Smt. P Ragini	Deputy Labour Commissioner
	2. P Murugaiyan	Joint Chief Inspector of Factories and Boilers
Local Administration Department	Thiru R Yuvaraj	Assistant Engineer, Pondicherry Municipality
Department of Revenue and Disaster Management	Thiru Bhaskara Rao Mulam	Sr Consultant
Department of Social Welfare	Thiru S Saravanan	Welfare Officer
Department of Town and Country Planning	Thiru A Elango	Junior Town Planner
Adi Dravidar Welfare and Scheduled Tribes Welfare Department	Thiru V Vinayagamourthi	Superintendent
Planning and Research Department	1. J Devidasan	Deputy Director
	2. A Swaminaden	Planning Assistant

Directorate of Economics and Statistics	Smt. G Indra	Deputy Director
Puducherry Ground Water Authority	Thiru U Prabagaran	Deputy Director
Department of Science, Technology and Environment, Puducherry.	Thiru Yasam Lakshmi Narayana Reddy	Director, DSTE
	Dr Sagaya Alfred	Senior Scientific Officer, DSTE
	Thiru N Ramesh	Senior Environmental Engineer, DSTE
	Thiru K Kalamegam	Environmental Engineer, DSTE
	Thiru Vipin Babu	Scientist, PCCC
	Smt. Rukmani	Scientist, DSTE
	Smt. Sumathi	Scientist, DSTE
	Thiru Devaanandh	Assistant Environmental Engineer, PCCC
	Thiru Prabhu	Junior Engineer, DSTE
	Thiru Poogajendy	Junior Engineer, DSTE
	Thiru Balaji T	Senior Project Associate, PCCC
	Smt. S Santhalakshmy	Senior Project Associate, Climate Change Cell
	Smt. R Thenmozhi	Senior Project Associate, PCCC
	Smt. K Deeba	Project Assistant, PCCC
	Smt. Jayabarathi	Project Assistant, PCCC
CSTEP	Dr Indu K Murthy	Sector Head, Climate, Environment and Sustainability
	Dr Anushiya J	Group Head, Adaptation and Risk Analysis
	Ms Tashina Madappa Cheranda	Senior Associate, Adaptation and Risk Analysis
	Ms Srilakshmi Jayasankar Menon	Senior Analyst, Adaptation and Risk Analysis
	Mr Sahil Mathew	Analyst, Adaptation and Risk Analysis

Appendix 6: Stakeholder consultation meeting

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